DEVELOPMENT OF AN STS-BASED LEARNING UNIT ON BIOCONTROL FOR SECONDARY SCHOOL STUDENTS

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ABSTRACT

This report discusses a study employing the STS approach for developing a learning unit on biocontrol for secondary students to enhance their understanding of the impact of pesticides, their knowledge of biocontrol, their science process skills, and their attitude toward the environment. This study focused on the collaboration between students, school teachers, and local sages in supporting authentic learning of students by using a biocontrol experiment as the case study. The students not only learned about the plant diseases, insect pests, and other natural enemies of plants in the vegetable plantation; they also learned from the laboratory and local experts. The students learned basic techniques in controlling plant pathogens and insect pests by biological agents, both from school and from visiting local farms, and through conversation with local experts. Teachers then encouraged them to design and conduct their own projects to solve problems on plants, fruits, and vegetable diseases in their own area. Teachers supported them with certain laboratory materials and equipment as well as the necessary textbooks and journals**.** Seven instruments were used to assess the students' achievements in terms of knowledge, science process skills, attitude, teacher, and students' perception: pre-test and post-test, concept mapping, questionnaire, semi-structured interview, students' reflection, teachers' reflection, and classroom observation. The results showed a significant enhancement in students' knowledge and understanding of pesticides, plant diseases, insect pests and enemies of plants, biocontrol, and also a significant improvement in scientific process skills. They were able to apply and integrate the scientific knowledge learned both in classroom and field studies to help solve agricultural problems in their own communities. Students also became more aware of and friendly toward the environment and were able to connect science in the classroom to local problems in their community.

KEY WORDS: BIOCONTROL/ ENVIRONMENTAL PROBLEMS/ PESTICIDES/ PROJECT-BASED SCIENCE/ SCIENCE, TECHNOLOGY, AND SOCIETY (STS APPROACH)

166 pages

การพัฒนาหน่วยการเรียนรู้ตามแนวคิดวิทยาศาสตร์ เทคโนโลยี และสังคม (STS APPROACH) เรื่องการควบคุมโดยชีววิธี สำหรับนักเรียนชั้นมัธยมศึกษาตอนต้น

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บทคัดย่อ

งานวิจัยครั้งนี้ได้นำแนวคิดการจัดการเรียนรู้ตามแนวคิดวิทยาศาสตร์ เทคโนโลยี และสังคม (STS approach) มาพัฒนาหน่วยการเรียนรู้เรื่อง การควบคุมโดยชีววิธี สำหรับนักเรียนชั้นมัธยมศึกษาตอนต้น มีวัตถุประสงค์เพื่อส่งเสริมให้นักเรียนมีความรู้ความเข้าใจเกี่ยวกับการควบคุมโดยชีววิธี และผลกระทบของสารเคมีในการเกษตรต่อมนุษย์และสิ่งแวดล้อม พัฒนาทักษะกระบวนการทางวิทยาศาสตร์ และสร้างทัศนคติที่ดีต่อสิ่งแวดล้อมในชุมชน การพัฒนาหน่วยการเรียนรู้นี้ได้รับความร่วมมือจากครูผู้สอนสาระการเรียนรู้วิทยาศาสตร์จาก 5 โรงเรียน ปราชญ์ชาวบ้าน (ที่มีความเชี่ยวชาญเกี่ยวกับการควบคุมแมลงและโรคพืชโดยชีววิธี และการใช้จุลินทรีย์ในการเกษตร) เกษตรกร ผู้ปกครองนักเรียน ศึกษานิเทศก์ นักวิทยาศาสตร์ศึกษา และนักวิทยาศาสตร์ จากนั้นครูผู้สอนสาระการเรียนรู้วิทยาศาสตร์จาก 5 โรงเรียน ได้นำหน่วยการเรียนรู้ดังกล่าวไปใช้จัดการเรียนรู้กับนักเรียนชั้นมัธยมศึกษาตอนต้น จำนวน 357 คน โดยเน้นให้นักเรียนได้ศึกษาปัญหาจริงที่พบในชุมชน ฝึกวิเคราะห์ปัญหาในชุมชนร่วมกับเพื่อน ครู และเกษตรกร จากนั้นเรียนรู้การแก้ปัญหาโดยใช้องค์ความรู้ทางวิทยาศาสตร์ผสมผสานกับวิธีชาวบ้านเพื่อแก้ปัญหา ของชุมชน และนำความรู้ที่ได้จากการศึกษาถ่ายทอดสู่ชุมชนของตนเอง ในรูปแบบของแนวคิดและการปฏิบัติโดยเชื่อมโยงระหว่างโรงเรียนและชุมชน

ในการศึกษานี้ได้ประเมินประสิทธิภาพของหน่วยการเรียนรู้โดยการผสมผสานระหว่างการวิจัยเชิงปริมาณและเชิงคุณภาพ เครื่องมือในการประเมินเชิงปริมาณ ได้แก่ แบบทดสอบวัดความรู้ความเข้าใจเรื่องการควบคุมโดยชีววิธี แบบทดสอบวัดทักษะการทดลอง แผนผังมโนทัศน์ แบบสอบถามทัศนคติต่อสิ่งแวดล้อม แบบสอบถามความพึงพอใจต่อการเรียนรู้ของนักเรียน และแบบสอบถามความพึงพอใจต่อหน่วยการเรียนรู้ของครู ส่วนวิธีการในการประเมินเชิงคุณภาพ ได้แก่ การสัมภาษณ์ ผลงานของนักเรียน และการสังเกตการณ์ในห้องเรียน

ผลการประเมินประสิทธิภาพของหน่วยการเรียนรู้ พบว่า นักเรียนมีความรู้ความเข้าใจเรื่องการควบคุมโดยชีววิธี มีทักษะกระบวนการทางวิทยาศาสตร์ มีทัศนคติที่ดีต่อสิ่งแวดล้อมในชุมชน และมีความพึงพอใจต่อการเรียนจากหน่วยการเรียนรู้เรื่องการควบคุมโดยชีววิธี สำหรับครูมีทัศนคติที่ดีต่อหน่วยการเรียนรู้เรื่องการควบคุมโดยชีววิธี และหน่วยการเรียนรู้นี้มีความเหมาะสมสำหรับนำไปใช้ในการจัดการเรียนการสอนในเนื้อหาความรู้วิทยาศาสตร์และสิ่งแวดล้อม

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CHAPTER I

INTRODUCTION

Overview

This chapter introduces the significance of the research study on the development of instructional units based on an STS approach on biocontrol for secondary school students. The rationale of the study is described. The objectives and research questions of this instructional unit and the definitions of the terms are presented here.

1.1 Significance of the Study

Plant diseases and insect pests are one of the problems in the agriculture, because they damage and reduce crop quality (Xia et al., 2006). A large number of farmers have now relied on the use of chemical pesticides and herbicides to fight plant diseases, insects, and other pests because they aimed only at increasing agricultural yields. Other reasons are the increase in speed of production and reduction in the amount of labor (Kunstadter et al., 2001). Farmers lack knowledge concerning the dangers of pesticides that most pesticides also affect non-target organisms, agricultural products, as well as contaminating soil surface, ground waters (Margri, Rossier, Crettaz, & Jollit, 2002; Stuetz, Prapamontal, Erhardt, & Classen, 2001), and polluting the air (Van Eerd, Hougland, & Hall, 2003). Moreover, the contamination by pesticides also has resulted in an environment with fewer natural insect habitats, earthworms, micro-organisms, and cover crops. Pesticide residues in agricultural products not only affect the health of consumers, but cause the rejection of exported goods, leading to economic damage to the country (Health System Research Institute, 2005).

The impact of pesticides on environment is an important problem, especially the children who live in/near the agriculture lands. Many agriculturists attempted to find alterative methods to replace the agrichemical substances and found that biocontrol method seemed to be appropriate one. Biocontrol, the use of living agents to control pests or plant pathogens, is an attractive alternative for modern agriculture. This approach is non-dangerous to humans, animals, and the environment. It can reduce chemical pesticide contamination in foods, vegetables, and environment (Trigiano, Windham, & Windham, 2004).

Several research works on using biocontrol agents to control plant diseases have been reported. For example, Chanchaichaovivat, Ruenwongsa, and Panijpan (2007, 2008) employed the yeasts isolated from Thai fruits in protecting antracnose diseases in chili fruits. In addition, Nantawanit, Chanchaichaovivat, Panijpan, and Ruenwongsa (2010) investigated the mechanism of action of the yeast in inducing resistance against the anthracnose disease in chili fruit. They found that this yeast induced the accumulation of phytoalexin and increase the ability of the defense-related enzyme and thus suppresses the growth of fungal pathogen responsible for anthracnose disease. This scientific knowledge on biocontrol was integrated with the experiential learning process to be a laboratory experiments for high school students (Chanchaichaovivat, Panijpan, & Ruenwongsa, 2008). In another learning unit, a laboratory exercise on induction of resistance to anthracnose disease was integrated with Kolb learning cycle to enable science students to develop both conceptual understanding and experimental skills (Nantawanit, Panijpan, & Ruenwongsa, in press). In addition, a learning unit based on guided-inquiry approach was integrated with laboratory experiment on plants capable of defending themselves for promoting students knowledge and attitude on plants (Nantawanit, Panijpan, & Ruenwongsa, in press). These learning units, however, aimed at promoting students' knowledge and skills but did not encourage students to link science in classroom to society. The knowledge on biocontrol in schools had not been transferred to the community.

Moreover, the biocontrol issue has not been incorporated into science curriculum. Students do not realize the harms caused by pesticides or chemical agents, and have little or no knowledge on the advantages of biocontrol. Thus, there is a need for an effective learning unit. Such a learning-teaching approach should be able to develop students' knowledge, skills, and attitude in protecting the environment. We deemed it appropriate to design teaching strategies for students to exploit their knowledge on biocontrol to tackle the environmental problems. Many educators suggest that the science, technology and society or STS approach can provide links between the scientific knowledge from classroom with the society (Lee & Erdogan, 2007; Mbajiorgu & Ali, 2003). Therefore, an STS approach, a learning process in human's experience context (National Science Teachers Association [NSTA], 2007), was employed in this study.

The STS focuses on connections between science and technology as well as science that is related to personal, social, and national issues (Akcay & Yager, 2010). The STS approach would provide the opportunity for students to identify the local problems and use local resources in solving them. STS pedagogy contributes chance to bring the knowledge into community and develop investigation and analysis skill (Caseau & Norman, 1997). Moreover, the STS approach enables students to understand the relationship between science and technology in society, allows the students to "feel and act like scientists" (Dass & Deal, 2007), and encourages them to exploit scientific inquiry in their problem solving (Wong, Kwan, Hodson, & Yung, 2009).

1.2 Rationale of the Study

There is a need for the learning process that encourages students to identify problems that are relevant to their needs and have impact in their local area (Dass & Deal, 2007; Lazarowitz & Bloch, 2005; Yager, Lim, & Yager, 2006). The teaching should not be based on solely on dry knowledge, but employ societal issues in open discussions (Lazarowitz & Bloch, 2005). Many educators suggest that teachers should design activities that concern with students' life, and provide the learning processes based on the students life experiences (Caseau & Norman, 1997).

This study aimed to enhance students' understanding in biocontrol and increase environmental awareness by providing them with real-world connections between the classroom and society (Amirshokoohi, 2010). The science, technology and society (STS) instructional approach was used to construct the novel lesson plan on biocontrol for secondary students by using local materials from school vicinity and/or student's farm. The students had the opportunity to learn outside the classroom by themselves, and share experiences with knowledgeable experts in their local community. The teachers' role will be changed from lecturer to facilitator who provides resources for learning. This learning unit is expected to enhance secondary students' conceptual understanding in biocontrol, improve science process skills, and raise attitude of issues in their local environment. In addition, the students were expected to transfer the knowledge learned to their community.

1.3 Objectives and Research Questions

The objectives of the research study are to develop the learning unit on biocontrol based on science, technology and society (STS) approach. The four objectives of this study are:

1. To develop a learning unit on biocontrol based on the STS approach.
2. To enhance students' conceptual understanding in biocontrol.
3. To improve students' science process skills.
4. To raise students' attitudes toward the natural environment.

Three research questions help frame this study:

1. To what extent a learning unit on biocontrol based on an STS approach enhance students' conceptual understanding in biocontrol?
2. To what extent a learning unit on biocontrol based on an STS approach improve students' science process skills?
3. Do the students have more awareness of the natural environment after participating in the learning unit?

1.4 Definition of Terms

STS-based learning unit on biocontrol means the learning unit about biocntrol of the environment that employs the STS approach as a teaching-learning process. This unit content is identification of the local problems, biocontrol of plant diseases, biocontrol of insect pests, students' science projects, and bringing scientific knowledge into community.

Students' understanding in biocontrol concept means students construct their fundamental understanding in biocontrol which comprised three concepts: biocontrol concept, impact of pesticides, and environmental conservation.

Students' science process skills means students are able to pose question, design, conduct, and conclude their experiments in laboratory activities and science projects. Science process skills involved observation, prediction, formulate hypothesis, identify variables, experimentation, classification, measurement, communication and conclusion.

Students' attitudes toward the natural environment means students have positive attitude toward the natural environment. The students realize and would like to resolve the problems in their community. Attitudes to the Natural Environment consisted of the impacts of pesticides on human and environment, the impacts of biocontrol concept on human and environment, and the conservation of the natural environment.

1.5 Organization of the Thesis

The thesis is presented in six chapters.

The first chapter provides the significance of the study, states the research questions which informs the study and specifies the objectives of the study including describing the definition of terms.

Chapter Two provides a literature review relevant to the topic of this study and consists of four major parts. The first part is literature relevant to the importance of the local problems and real-life situation. The second part reviews the philosophy of constructivism, and the theory of an STS approach. The third part is the impacts of pesticides, and the fourth part reviews the importance of biocontrol.

Chapter Three describes the detail of theoretical basic, a description of the participants and population, and the development of the instructional units on biocontrol. The descriptions of methodology approach, research design, research instruments, and data analysis are included in this chapter.

Chapter Four describes the results on implementation of an STS-based learning unit on biocontrol to secondary students. These results included students' understanding on biocontrol concepts, students' experimental skills, and students' attitude toward natural environment.

Chapter Five offers a discussion of the findings of the study. The effectiveness of the STS-based learning unit on students' outcome is discussed. How the learning unit enhances students' conceptual understanding and experimental skills are discussed.

Finally, chapter six describes conclusions of this study. Limitations of the study and suggestions for further study and further development are included in this chapter.

1.6 Summary of the Chapter

This chapter outlines the details of the significance of this study and rationale for investigation. The aims of the research study, the research questions, the definitions of terms, and the organization of the thesis are also presented.

The next chapter, on literature review, describes the theoretical framework of this study and the necessary literatures as background of the study.

CHAPTER II
LITERATURE REVIEW

Overview

This chapter reviews the literatures in seven main topics, beginning with the learning in the authentic context. The second and third topics concern with the theory of constructivism, and science, technology and society or STS approach. The fourth to the sixth topics present the project-based science, scientific literacy, and science process skills. Finally, the sixth and seventh topics review the impacts of pesticides on human, and environment and the importance of biocontrol.

2.1 Learning in Authentic Context

The education grounded in the local community helps students see the relevance of what they are learning, which, in turn, increased their engagement in the learning process (Powers, 2004). Learning becomes meaningful as the learner is engaged in issue related to both human and environmental systems that directly affect them and other members of their community. The “real world” problem provides student opportunities to investigate the school and community issues in which they are interested (Wanich, 2006). It is the responsibilities of the teacher to facilitate this process and link the problems and the various activities to the conventional school subjects. Like culture and nature studies, the real-world problem-solving approach is in part a form of outdoor education because students often learn and work outside their classrooms. Real-world problem-solving can impart to students a sense of their own agency and collective capacity to alter their neighborhoods or communities for the better (Smith, 2007). As mentioned above, the study of science to societal problems is one way of engaging students.

Many researchers encouraged students to learn by using the problems that related to everyday life. For example, Mutonyi, Nielsen, and Nashon (2007) used the problem about HIV/AIDS to promote students' understanding of that issue, and found that the students could make connections between "school" and "home" knowledge. Cheong, Treagust, Kyeleve, and Oh (2010) have shown an enhancement of students' conceptual understanding about Malaria. Fortus and co-workers (2005) examined whether the enactment of a design-based science (DBS) unit supported students' efforts to construct and transfer new science knowledge and designerly problem-solving skills to the solution of a new problem in a real-world setting. They found that the knowledge constructed during the unit enactment supported the solution of the transfer task. Bouillion and Gomez (2001) explored a form of "connected science," in which real-world problems and school-community partnerships were used as contextual scaffolds for bridging students' community-based knowledge and school-based knowledge. This is to provide all students opportunities for meaningful and intellectually challenging science learning. The potential of the "connected science" was examined through a case study in which a team of fifth-grade teachers used the student-identified problem of pollution along a nearby river as an interdisciplinary anchor for teaching science, math, language arts, and civics. The analysis results made visible how diverse forms of knowledge were able to support project activities, examined the consequences for student learning, and identified the features of real-world problems and school-community partnerships that created these bridging opportunities.

2.2 Constructivism

Constructivism refers to the experiences that the learners construct knowledge for themselves. Settlage and Southerland (2007) described two major traditions in explaining the process of learning science based on Piaget's and Vygotsky's works namely individual and social constructivism.

The individual constructivism philosophy associated with Jean Piaget claims that a learner independently builds understandings of his or her world. Individual constructivism refers to a theory of learning as the construction of new knowledge by the individual learner (Brown, 2006). Settlage and Southerland (2007) noted that individual constructivism focuses on the learning by each separate child and all learning takes place within the individual mind. In individual constructivism philisophy, learning occurs through the lens of previous knowledge, thus individual learners are thought to use and reconstruct their preexisting mental models to make sense of new experiences (Settlage & Southerland, 2007). Teaching approaches in science based on this perspective focus on providing children with physical experiences that induce cognitive conflict and hence encourage learners to develop new knowledge schemes that are better adapted to experience (Driver, Asoko, Leach, Mortimer, & Scott, 1994).

The social constructivist philosophy typically associated with Lev Vygotsky emphasizes the importance of students' communication as essential to making students' experiences (Settlage & Southerland, 2007). Social constructivism refers to a theory of learning that the students construct their new experiences through the participation in a community (Brown, 2006). Social constructivism is influenced by interactions with social groups. In a social constructivist would claim that learning first occurs within a group setting as thoughts are exchanged and then become incorporated into individual minds (Settlage & Southerland, 2007). This perspective knowledge and understandings, including scientific understandings, are constructed when individuals engage socially in talk and activity about shared problems or tasks (Driver et al., 1994).

In addition to the individual and social constructivism, the socio-cultural views of learning emphasize the social and culture (Dixon-Kraussm, 1996). Socio-cultural views of learning endorse the view that knowledge is socially constructed and context dependent, and that human mental process are situated within their historical, cultural and institutional setting (Wertsch, 1991). Social-cultural views of science learning promote the community aspect of the classroom and the role of peers. This would provide students with alternative models of scientific phenomena and to introduce criteria as well as evidence to help learners to distinguish among scientific models.

2.3 Science, Technology, and Society (STS approach)

A Science, Technology, and Society (STS) approach first emerged in 1971 when Jim Gallagher used it in his research: A Broader Base for Science Teaching (Aikenhead, 1998, as cited in Mbajiorgu & Ali, 2003). He noted that the citizens in the future must understand the interrelationships between science, technology, and society (Gallagher, 1971). Many educators and researchers have employed this approach to develop the curricula (Mbajiorgu & Ali, 2003). Yager and Roy (1993) stated that STS is banner of a new interdisciplinary epistemology aiming to integrate science, technology, and culture into the traditional learning of society that directed service by universities. STS is based upon the constructivist learning model. Constructivism has been described as both a learning theory and an epistemology in which the learner has autonomy concerning the learning.

STS approach connects between science, technology, and society. National Science Teachers Association (NSTA) defined STS as the study of teaching and learning science and technology in the context of human experience (NSTA, 1993). Yager (1993) said that STS approach begins with student' perspective, their investigations and their own lives, and focuses on real-world problem. STS activities advocate them involvement in science for everyday life. STS means focusing upon current issues and attempts at their resolution as the best way of preparing students for current and future citizenship roles. This means identify local, regional, national, and international problems with students, planning for individual and group activities which address them, and moving to actions designed to resolve the issues investigated. The emphasis is on responsible decision-making in the real world of the students (Akcay, 2007).

2.3.1 Fundamentals of an STS education

Fundamentally, STS teaching employs a student-oriented approach that gives students the central position in the curriculum. As Yager and Roy (1993) pointed out that STS is an idea for identifying goals, curriculum modules, instructional strategies, and evaluating methods.

Aikenhead (1994) uses a figure (Figure 2-1) to explain the essence of STS education. He articulates the role of the three components in STS education as follows: the study of the natural world is science, the study of the artificially constructed world is technology, and the society is the social milieu. In the figure, Aikenhead uses solid arrows to link students with each of the natural, technological, and social environments. In addition, broken arrows, which are superimposed among science, technology, and society, describe the pedagogical structure that harmonizes with the environments. Aikenhead defines STS teaching as follows:

"STS science teaching conveys the image of socially constructed knowledge. Its student-oriented approach emphasizes the basic facts, skills, and concepts of traditional science...but does so by integrating that science content into social and technological contexts meaningful to students, (p. 59)."

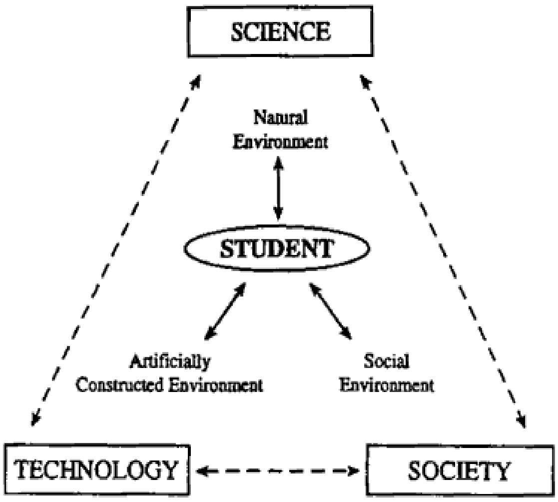

Figure 2-1 The essence of STS education (Aikenhead, 1994)

In general, the overarching purpose of the STS approach is to increase students' interest in science by placing science content in a social context. STS instruction is best organized in a sequence indicated by the arrow in Figure 2-2 (Aikenhead, 1994).

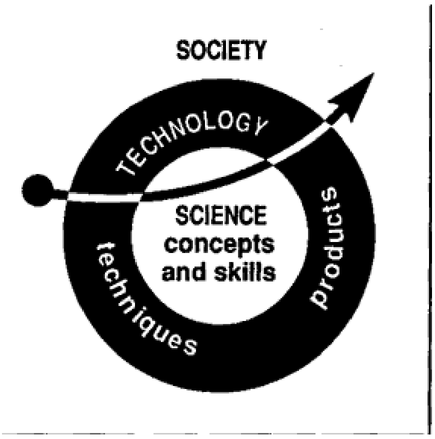

Figure 2-2 A sequence for STS science teaching (Aikenhead, 1994)

The teaching begins in the realm of society by posing a key question; for instance: "Should we be concerned about high voltage power lines in our community?", "How can we explain the conflicting scientific testimony in a newspaper article?" or "For what purposes are we using different kinds of light sources?", A societal question or problem then creates the need to examine some technology, even at a superficial level. Social issues are almost always connected to technology, because technology is primarily concerned with developing knowledge and designing processes in response to human needs (Aikenhead, 1994). Moreover, students are affected far more by technological world than by the scientific world (Aikenhead, 1994). Subsequently, both the societal and technological aspects of an issue require some knowledge of science content. In essence, science knowledge helps students 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. At this time, more complex technologies can be introduced. Finally, the STS instruction ends in the domain of society, where students address the original social problem and then make a decision. Students make thoughtful decisions informed by (1) an in-depth understanding of the underlying science, (2) a grasp of the relevant technology, and (3) an awareness of the guiding values (Aikenhead, 1994).

2.3.2 Characteristic of an STS approach

An STS approach emphasizes on social problems and local community issues, including the cooperative work on real problems. STS pedagogy contributes chance to bring the knowledge into community and develop investigation and analysis skill (Caseau & Norman, 1997). Lutz (1996) claimed that STS teaching provides an appropriate strategy. An STS teaching strategy focuses on process, not product.

Aikenhead (1986) referred that the STS approach is a beneficial approach used to connect science, technology, society, and problem solving. The STS approach pointed to the real-world questions by using science and technology knowledge and methods (Yager, 1993). Moreover, Kumar and Berlin (1998) claimed that

> *"STS education provides a meaningful and relevant context for students that focus on personal, social, global, technology, and society. Students can apply science knowledge and processes to solve real problems, weigh social issues, understand the role of government and private sectors, and make and evaluate decisions."*

National Science Teachers Association (NSTA, 2007) described the eleven essential features characterizing STS that include: 1) Student identification of problems with local interest and impact; 2) The use of local resources (human and material) to locate information that can be used in problem resolution; 3) The active involvement of students in seeking information that can be applied to solve real- life problems; 4) The extension of learning beyond the class period, the classroom, the school; 5) A focus upon the impact of science and technology on each individual student; 6) A view that science content is not something that exists merely for students to master on tests; 7) A de-emphasis upon process skills per se just because they represent glamorized skills used by practicing scientists; 8) An emphasis upon career awareness especially careers related to science and technology; 9) Opportunities for students to perform in citizenship roles as they attempt to resolve issues they have identified; 10) Identification of ways that science and technology are likely to impact the future; and 11) Some autonomy in the learning process as individual issues are identified and used to frame instruction. Aikenhead (1994) claimed that students in an

STS approach are capable applying the science concepts to new situations, more positive towards science classes, and achieve science process skills.

2.3.3 Models of an STS approach

Carin (1993) suggested that the content of STS approach should be concerned with the environment in human life such as communication, transportation, medicine, farming, manufacturing, space exploration, warfare, and politics. Aikenhead (1986) showed the content used for teaching with STS approach including (i) interior theme of society related with science, for example history, scientific society, etc. (ii) exterior theme of society, for example water pollution, narcotic drugs, etc., and (iii) science subjects such as biology, physics, chemistry, and earth science. In addition, Mbajiorgu and Ali (2003) said that the STS content is instilled into a single subject of science such as biology, physics, chemistry, and earth science. Afterwards, the content of STS emphasized the conceptions of science and methods.

To used an STS approach to teach students, many educators suggested the multiple ways of an STS approach. Yager (1996) described an STS approach as "starting with students and their questions, using all resources available to work for problem resolution and whenever possible, advancing to the stage of taking actual actions individually and in groups to resolve actual issues". Yager stressed that students identify problems or issues that are local to their community or environment and use local resources in resolving these problems. Yager also emphasized that students learn the concepts of science as they need them in the process of solving a problem. Similarly, Aikenhead (1992) described a model to implement STS in the curriculum as follows: 1) Instruction begins with a problem or question, 2) Students need to become familiar with technology in order to understand the question 3) Students learn the underlying science to understand the problem, 4) Students use their technology knowledge in order to better understand technology, and 5) Students make a decision of the social issue based on their understanding of the scientific concepts and relevant technology. Moreover, Dass (2005) employed an STS approach to teach students. He divided the STS learning experiences into four phases: invitation, exploration, proposing explanations and solutions, and taking action.

2.3.4 Benefits of an STS approach

Many research works suggested that STS approach improved achievement in science education (Lee & Erdogan, 2007; Mbajiorgu & Ali, 2003). Yager, Lim, and Yager (2006) used STS approach to teach students in comparison with the typical textbook approach. They found that students who learned by using STS approach were able to suggest and apply science concepts into new contexts better than students who studied science in a more traditional way. Keinonen (2007) used STS approach to teach electricity in primary school in Finland and found that STS approach increased pupils' understanding of electricity and supported pupils' minds and understanding of science phenomena. Similarly, Keinonen, Ismail and Havu-Nuutinen (2008) found that STS approach help pupils create water project by themselves.

STS approach could be an effective learning unit with various epistemological orientations toward science (Keinonen, Ismail, & Havu-Nuutinen, 2008). It enables students to look at science from several viewpoints; i.e, science, technology and society and therefore making the learning process more holistic (Havu-Nuutinen & Keinonen, 2009). STS education also help students interact with their peers, teachers, school, and community (Amirshokoohi, 2010), and encourage them to apply their knowledge to new situations and real world (Yager, Lim, & Yager, 2006). Furthermore, Amirshokoohi (2010) claimed that "STS curricular have been designed to help students develop skills that will enable them to be responsible citizens who are able to make educated and well-informed decisions."

Yager and Roy (1993) suggested that an STS instruction provide a context for the use of science process skills. In an STS learning, the student is the learner of science, instead of receiver of science because students resolve their own problems by themselves (NSTA, 1990-1991). Yager and Roy (1993) showed the comparison of process of traditional versus STS in Table 2-1.

Table 2-1 Comparison between traditional process and STS process

Traditional	STS
1. Science processes are skills scientists possess	1. Science processes are skills students themselves can use
2. Students see science processes as something to practice as a course requirement	2. Students see science processes as skills they need to refine and develop themselves more fully
3. Teacher emphasis on process skills not understood by students because these skills rarely contribute to actions out-side of, or even to, the course	3. Students readily see the relationship of science processes to their own actions
4. Students see science processes as abstract, glorified, unattainable skills	4. Students see processes as a vital part of what they do in science classes

Many researchers found that an STS approach increase students’ science process skills. Specifically, Padilla, Okey, and Garrard (1984) found that students who used integrated process skills for an extended duration of time showed growth in identifying variables and stating hypothesis. Roth and Roychoudhury (1993) found that authentic context supported the use of the process skills used in science. Thus, both duration and context play a role in the students acquiring of basic and integrated science processes.

Basic process skills include observing, classifying, communicating, measuring, using space/time relations, using numbers, and inferring and predicting. Integrated process skills include controlling variables, interpreting data, formulating hypotheses, defining operationally, and experimenting.

The STS classrooms provide opportunities for students to refine and develop the science process skills found in science. Students can select problems, issues, or investigations that are meaningful and relevant in their lives. Moreover, the STS approach is a student-centered way where process skills are introduced. STS investigations are facilitated by a teacher in a context that allows the student to act on questions, problems, or issues of personal significance. (Padilla, Okey, & Garrard, 1984; Roth & Roychoudhury, 1993).

2.4 Project-Based Learning (PBL) and Project-Based Science (PBS)

Project-based learning (PBL) is one of the most interesting instructional strategies based on constructivism. PBL has been defined as a teaching-learning approach that guides students to learn the concepts of selected disciplines while using inquiry skills to develop research or design products (Blumenfeld et al., 1991; Thomas, 2000). Thomas (2000) defined that PBL is a model organizes learning around the projects. Thomas (2000) found that PBL composed of five criteria: (1) centrality: PBL is the centrality of the curriculum, (2) driving question: PBL emphasizes the questions or problems that “drive” the students to encounter (and struggle with) the central concepts and principles of a discipline, (3) constructive investigations: projects involve the constructive investigation of students, (4) autonomy: students projects are student-driven to some significant degree, and (5) realism: projects are realistic, not school-like.

Project-based learning is a part of the instructional approaches originating from Dewey (Fallik, Eylon, & Rosenfeld, 2008) who argued for the importance of practical experience in learning. In project-based learning, students work in small groups on academic tasks. The task can be in the form of investigation and research on particular topic, and the topic being studied usually integrates concepts from a number of disciplines or fields of study (Blumenfeld et al., 1991). Students in small group collaborate with one another to reach a collective outcome over a period of time. They pursue solutions to a problem by asking and refining questions, debating ideas, making predictions, collecting and analyzing data, drawing conclusions, and communicating their findings to others. This approach is widely believed to be a powerful teaching strategy that can enhance student motivation and promote self-directed learning because the learning issues usually arise from problems that attract the interest of student (Hmelo-Silver, 2004).

Project-based learning has been based on different educational models. One version of PBL called project-based science (PBS) (Fallik, Eylon, & Rosenfeld, 2008; Schneider et al., 2002). PBS composted of five basic components: (1) driving questions that design projects or organize authentic investigation, (2) investigations, (3) artifacts, (4) collaboration with peers, teachers, and members of society, and (5) technological tools such as internet (Krajcik et al., 1994).

The goal of PBS is to engage students in authentic real-world tasks that enhance learning. PBS enhances higher order thinking skill, including data analysis, problem solving, decision-making and value judgment.

PBS is a reform-based pedagogy that emphasizes the students themselves constructing a usable or meaningful understanding (Ausubel, 1968) of the science they are learning. PBS aims to emphasize scientific inquiry in the classroom, but it also aims to motivate students' inquiry by their need to find a solution to a real problem, the resolution of which requires students to apply the ideas they have learned (Edelson, 2001; Singer et al., 2000).

Project-based science allows students to learn science by doing science and, as a consequence, actively construct their understanding of science by working with and using their ideas. In project-base science, students are engaged in real, meaningful problems that emulate what scientists do. A project-based science classroom will allow students to freely discuss their ideas, challenge the ideas of others, and try out their ideas.

2.5 Scientific Literacy

A major goal of science education is scientific literacy (Millar, 2006; Hurd, 1958). The definition of scientific literacy is very complex. Hurd (1998) defined that scientific literacy as the rational thinking skills of individuals about science in relation to personal, social, political, economic problems and issues to meet throughout life. Mbajiorgu and Ali (2003) defined scientific literacy as "the ability of individuals to live satisfactorily and conveniently in a techno science culture."

Scientific literacy may also be defined in terms of a framework consisting of four aspects: (1) the knowledge of science, (2) the investigative nature of science, (3) science as a way of thinking, and (4) interaction of science, technology and society (Boujaoude, 2002; Chiapetta, 1993).

Hurd (1998) suggested a definition of scientific literacy based on the seven dimensions of a scientifically-literate person.

1. Understand the nature of scientific knowledge.

2. Apply appropriate science concepts, principles, laws, and theories in interacting with his universe.

3. Use the process of science in solving problems, making decisions, and furthering his own understanding of the universe.

4. Interact with values that underlie science.

5. Understand and appreciate the joint enterprises of science and technology and the interrelationship of these with each and with other aspects of society.

6. Extend science education throughout his or her life.

7. Develop numerous manipulative skills associated with science and technology.

Bybee (1997) proposed a way of developing scientific literacy in learning biology as a continuum of understanding about the natural and the designed world. This starts from scientific illiteracy, moving to nominal, functional, conceptual and procedural, and multidimensional scientific literacy.

1. Scientific literacy, the indicator of scientific illiteracy is the fact that they cannot relate to or respond to a reasonable question about science. They do not have the vocabulary, concepts, contexts, or cognitive capability to identify the question as scientific.

2. Nominal Scientific Literacy, the students understand the topic as scientific but the level of understanding clearly indicates a misconception.

3. Function Scientific Literacy, students can memorize appropriate definitions of terms, and in this sense have some scientific knowledge, but they have limited knowledge, but they have limited knowledge and lack a full scientific understanding.

4. Conceptual and Procedural Scientific Literacy, students actually have ability and understand that scientific inquiry includes asking questions, designing scientific investigations, using appropriate tools and techniques, developing explanations and model using evidence and explanation, recognizing alternative explanations and communicating scientific procedures and explanations.

5. Multidimensional Scientific Literacy, students develop some understanding and appropriation of science and technology as they have been and are a part of the culture. Students begin to make connections within scientific disciplines, between science and technology and the larger issues of social challenges.

The Organization for Economic Cooperation and Development (OECD) framework suggests that science should be taught starting from science about the earth and environment, science in life and health and science in technology. This approach probably intends that science will be related to students' everyday life (The Manager, 2002).

The Organization for Economic Cooperation and Development (OECO)/ Program for International Student Assessment (PISA) (2003) defined scientific literacy as follows:

"Scientific literacy is the capacity to use scientific knowledge, to identify question and to draw evidence-based conclusions in order to understand and help make decisions about the natural world and the changes made to it through human activity." (Organization for Economic Cooperation and Development [OECO], 2003)

PISA has determined scientific literacy in three dimensions (OECD, 2007) as follows:

First, scientific concepts, which are needed to understand certain phenomena of the natural world and the changes made to it through human activity… The main content of the assessment is selected from within three broad areas of application: science in life and health; science of the earth and the environment and science in technology.

Second, scientific processes, which are centered on the ability to acquire, interpret and act upon evidence. Five such processes that are present in OECD/PISA relate to: the recognition of scientific questions, the identification of evidence, the drawing of conclusions, the communication of these conclusions, and the demonstration of understanding of scientific concepts.

Third, scientific situations, selected mainly from people's everyday lives rather than from the practice of science in a school classroom or laboratory, or the work of professional scientists. As with mathematics, science figures in people's lives in contexts ranging from personal or private situations to wider public, sometimes global issues.

Many researchers adopted an STS approach to promote scientific literacy and found that this approach increased students' scientific literacy (Lambert, 2006; Dori, Tal, & Tsaushu, 2003). Akcay and Yager (2010) examined the effectiveness of the Chautauqua Professional Development Program by using an STS teaching approach to promote student scientific literacy in five domains: 1) concept mastery ; 2) ability to define and use process skills; 3) developing more positive attitudes regarding science; 4) development of specific creativity skills; and 5) ability to use major concepts and processes in new situations, and found that students in the student-centered STS sections achieved significantly better than students in the teacher-directed STS sections. Especially, the terms of understanding and use of process skills, use of creativity skills, development of more positive attitudes, and the ability to apply science concepts in new contexts. Dori, Tal, and Tsaushu (2003) taught biotechnology through case studies by using STS approach aimed at elevating the level of students' scientific and technological literacy and their higher order thinking skills. The research goal was to investigate nonscience major students' ability to use various thinking skills in analyzing environmental and moral conflicts presented through case studies in the Biotechnology Module. They found that this approach could develop scientific and technological literacy along with higher order thinking skills of nonscience majors. Lambert (2006) studied the high school marine science curricula and instructional practices and/or field trips through an STS approach and constructivist approach, and found that marine science can be used as a model for teaching integrated science, and this learning process could encourage students to enjoy learning.

2.6 Science Process Skills

Science process skills are a set of broadly transferable abilities, appropriate to many science disciplines and reflective of the behavior of scientist (Padilla, 1990). Martin (2003) divided the processes into two groups: the basic processes that form the foundation for scientific investigation, and the integrated processes that form the method of actual scientific inquiry.

Basic processes include observing, classifying, communicating, measuring, predicting, and inferring.

Integrated processes include identifying and controlling variables, formulating and testing hypothesizes, interpreting data, defining operationally, experimenting, and constructing models.

Definitions of the science process skills are as follows (Padilla, 1990; Settlage & Southerland, 2007):

1. Observing: it is the most fundamental of the basic science process skills. It means the noting the properties of objects and situations using the five senses which are sight, hearing, taste, smell, and touch. When students observe, they should be unbiased and valued for their factual basis.

2. Classifying: it means the relating objects and events according to their properties or attributes. The keys to classification system include the absence of opinions and the reliance on categories.

3. Space/time relations: it means the visualizing and manipulating objects and events, dealing with shapes, time, distance, and speed.

4. Using numbers: it means the using quantitative relationships

5. Measuring: it means the expressing the amount of an object or substance in quantitative terms. It represents quantitative observations and is based on accepted standard units.

6. Inferring: it means the giving an explanation for a particular object or event and posing a statement that is intended to explain observations.

7. Predicting: it means the forecasting a future occurrence based on past observation or the extension of data. It allows students to test their ideas by forecasting what will happen.

8. Operationally: it means the developing statements that present concrete descriptions of an object or event by telling one what to do or observe.

9. Formulating models: it means the constructing images, objects, or mathematical formulas to explain ideas. Some indicators of proficiency in this process include identify appropriate needs of models, interprets models in terms of the real thing, and develops own accurate and appropriate models.

10. Controlling variables: it means the manipulating and controlling properties that relate to situations or events for the purpose of determining causation.

11. Interpreting data: it means the arriving at explanations, inferences, or hypotheses from data that have been graphed or placed in a table.

12. Hypothesizing: it means the stating a tentative generalization of observations or inferences that may be used to explain a relatively larger number of events but that is subject to immediate or eventual testing by one or more experiments.

13. Experimenting: it means the testing a hypothesis through the manipulation and control of independent variables and noting the effects on a dependent variable; interpreting and presenting results in the form of a report that others can follow to replicate the experiment.

2.7 Impacts of Pesticides on Environment and Human

Pesticides are poisons used to kill or control unwanted living organisms. They include herbicides, insecticides, fungicides, germicides, and others (Margni, Rossier, Crettaz, & Jolliet, 2002; Silver & Riley, 2001). Every year, approximately 2.5 million tons of pesticides are spent throughout the world including Thailand for control disease and insect pests (Van der Werf, 1996; Xia et al., 2009).

2.7.1 Impacts of pesticides on environment

Several effects of pesticides concerning natural environments have been reported. Burrow and Edwards (2000) found that some pesticides decreased soil nitrate concentrations and increased ammonia (NH_4) concentrations at higher application rates. Another study showed that pesticides affect to non-human biota (fish, birds, and beneficial arthropods than farm workers and consumers (Bues et al, 2004). Moreover, Silver and Riley (2001) showed that pesticides contaminate the environment namely:

Soil contamination

Pesticides can contaminate soil. Some pesticides can persist in soil from three to five years.

Surface water contamination

Pesticides can reach surface water through runoff from the agricultural lands.

Ground water contamination

The USGS (1995) studied the pesticides in ground water. They found that the some pesticides and some transformation products have been found in the ground water, including pesticides from every major chemical class.

Contamination of air, soil, and non-target vegetation

Johnson and Ware (1991) said that pesticide sprays can directly damage non-target plants, or can drift or volatilize from the treated area and contaminate air, soil, and non-target vegetations. Some pesticide drift occurs during every use.

Many pesticides can evaporate from soil and foliage, move away from the application, and contaminate the environment (Glotfelty & Schomburg, 1987; Que et al., 1975). About 80-90 percent of an applied pesticide can be volatilized within a few days of application (Majewski & Capel, 1995)

The pesticides contaminate the environment via drift, volatilization, leaching, and runoff. The details of these routes are shown in Table 2-2.

Table 2-2 Routes by which pesticides contaminate the environment.

Route	Definition	Impact
Drift	Pesticides carried away from the target pests by the wind or air.	The pesticides drift into the air about 2 to% and can spread can several hundred miles. (Schueler, 1995)
Volatilization	Pesticides can volatilize from soil, foliage or surface waters. The pesticides in air can move to vegetation or soil.	90% of certain pesticides volatilize from soil and surface waters within a few days after use.
Leaching	The pesticides can move to the soil by the water movement	Leached pesticide can lead to contamination of ground water
Runoff	Rainfall and watering can wash pesticides off soil or plants into storm drains and nearby waterways.	Schueler (1995) claimed that Runoff from agricultural area can contaminate surface water.

Harmful effects of pesticides of pesticides on non-target organisms

Pesticides can harm plants and animals ranging from beneficial soil microorganisms and insects, non-target plants, fish, birds, and other wildlife.

Fish

When pesticides contaminate water, they can be harmful to the fish that live there. Insecticides and Herbicides can be toxic to fish.

Other aquatic animals and plants

Moreover, other marine animals are hazarded by pesticide contamination. The ecologist said that the pesticides damage algae and diatoms' cells, blocked photosynthesis, and stunted growth in varying ways (U.S. Water News Online, 2000). Moreover, some pesticide (Trifluralin) inhibited the growth of cyanobacteria at all levels of application (Kobbia et al., 1991).

Insects and spiders

Insecticides have the potential to harm non-target insects such as beneficial natural predators and pollinators one study found that exposure of glyphosate (Roundup) damaged over 50 percent of beneficial insects: a parasitoid wasp, a lacewing, and a ladybug and over 80 percent of predatory beetle was also killed (Hassan et al., 1988).

Bird

The pesticides can be toxic to birds. The herbicide reduced successful hatching of chicken eggs, and caused feminization or sterility in pheasant chicks (Lutz & Lutz-Ostertag, 1972). Moreover herbicides can also adversely affect birds by destroying their habitat.

Beneficial soil microorganisms

The healthy soil has beneficial microorganisms namely fungi, bacteria, and a host of others. These microorganisms have an important role in helping plants to utilize soil nutrients needed to grow and thrive. Microorganisms also help soil reserve water and nutrients, regulate water flow, and filter pollutants (Marx et al., 1999). Overuse of pesticides have effects on the soil organisms, reduces the growth and activity of nitrogen-fixing blue-green algae, and inhibits the transformation by soil bacteria of ammonia into nitrates (Martens & Bremnu, 1993; Singh & Singh, 1989).

Non-target plants

The pesticide exposure can cause sublethal effects on plants. It can reduce seed quality and damage plants (Dreistadt, Clark, & Flint, 1994; Locke, Landivar, & Moseley, 1995).

2.7.2 Impacts of pesticides on human

Margni, Rossier, Crettaz, and Jolliet (2002) found that the human received the pesticides from food higher than induced by drinking water or inhalation. In addition, the pesticide exposure impacts on children higher than adults. The pesticides cause the symptoms of acute pesticide poisoning namely headaches, nausea, dizziness, memory loss, hyperactivity, moodiness, loss of coordination, respiratory problems, and inability to concentrate (Piper & Owens, 2002). Curl and co-workers (2003) claimed that the children with conventional foods had pesticide metabolite concentrations higher than children with organic foods. Panuwet and colleague (2009) studied about urinary pesticide metabolites in school students from northern Thailand. They found that students whose parents were agriculturists had the highest concentrations of pesticide metabolite in the urine. Kunstadter and co-workers (2001) studied the cholinesterase inhibition in blood. They found that the agriculturists who used the pesticides showed the levels of cholinesterase inhibition with risky or unsafe levels. Moreover, the agriculturists' blood has very high levels of organochloride pesticides (DDT) residues.

Nowadays, many agricultural researchers attempt to find the way to replace the pesticide. They found that the biocontrol is an appropriate way because biocontrol is the method to control several from pathogen and pests without pesticides.

2.8 Importance of Biocontrol

Biocontrol is a natural process that plays an important role in the suppression of field crop pests (Michaud, Sloderbeck, & Nechols, 2008) It refers to the use of natural enemies or living organisms against a pest population to reduce the pest's density and damage to a level lower than would occur in their absence instead of pesticides (Evans, 1999; Stoner, 1998; Charlet, Olson, & Glogoza, 2002). Biocontrol agents are non-dangerous to humans, animals and the environment. It can reduce chemical pesticide contamination in foods, vegetables and environment (Trigiano, Windham, & Windham, 2004). Biocontrol has been used to control several plants from diseases and insects without agricultural chemicals.

2.8.1 Biocontrol of plant diseases

Biocontrol agents such as microorganisms (bacteria, yeasts and fungi), living agents have been used to control plant diseases (Bleve, Grieco, Cozzi, Logrieco, & Visconti, 2006; Calvo, Calvente, De Orellano, Benuzzi, & De Tosetti, 2003). Microorganisms often employed in controlling plant pathogens are bacteria, fungi, nematodes, protozoa and viruses. These microorganisms interfere with plant pathogens through antibiosis, competition and parasitism (Trigiano, Windham, & Windham, 2004). The actions of these microorganisms may be competition for nutrients and spaces (Janisiewicz, Tworkoski, & Sharer, 2000; Chanchaichaovivat, Ruenwongsa, & Panijpan, 2007), induction of plant resistance (Arras, 1996; Droby et al., 2002; Nantawanit, Chanchaichaovivat, Panijpan, & Ruenwongsa, 2010) and production of cell-wall lytic enzymes (El-Ghaouth, Wilson, & Wisniewski, 1998; Wisniewski et al., 1991; Chanchaichaovivat, Ruenwongsa, & Panijpan, 2008).

Mechanisms of biocontrol of plant diseases

It is difficult to determine the mechanisms working in an interfungal interaction in the field, because the interactions between host, pathogen, antagonist and other microorganisms are very complex. Nowadays, most studies concerning these antagonistic relationships have been carried out in laboratory or greenhouse, where the conditions are controlled. So, possible biocontrol mechanisms have been suggested namely induced resistance in host plants, mycoparasitism, competition for space and nutrients, antibiotics and toxins, and hydrolytic enzymes (Cortes-Penagos, Olmedo-Monfil, & Herrera-Estrella, 2007).

Induction of resistance in host plants

Antagonists can control diseases by interacting directly with plants (Scala, Raio, Zoina, & Lorito, 2007). For example, *Trichoderma*, fungal antagonists, treated with the systemic resistance in plants. These defense responses of plants to pathogen attacks and involve signal molecules such as a salicylic acid, jasmonic acid, ethylene, and nitrous oxide. Signals trigger leads to the production of metabolites (phytoalexins) and proteins (pathogenesis-related proteins) that support plant disease resistance (Scala, Raio, Zoina, & Lorito, 2007).

Cortes-Penagos, Olmedo-Monfil, and Herrera-Estrella (2007) noted that plants are not passive elements during attack by phytopatogens. They have their own defense mechanisms. These include the so-called hypersensitive response (HR), which causes cells to die in the immediate vicinity of infection site, thereby preventing further pathogen spread, and cell wall accumulation of compounds at infected sited, providing a physical barrier to pathogen entry. Some fungi (for instance, *Fusarium*, *Rhizoctonia*, and *Trichoderma*) have the ability to promote the enhancement of plant growth and induce resistance to pathogens. Not only some fungi can induce resistance in plants but also some yeast can enhance resistance to pathogen. Natawanit and co-workers (2010) investigated the ability of the *P. guilliermondii* strain R13 to induce resistance against *C. capsici* in chili fruit. *P. guilliermondii* induces the accumulation of phytoalexin and increase the ability of the defense-related enzyme PAL, CHI, and β-1, 3-glucanse. Moreover, this yeast suppresses the fungal pathogens.

Parasitism

Parasitism is the process of eating organism on another organism (Trigiano, Windham, & Windham, 2004). Fungi that parasitize other fungi are called mycoparasites. In nature, some fungi establish antagonistic interactions with other fungal species. This kind of relationship is referred to as mycoparasitism and represents a useful tool in biological control due to the fact that many of the hosts are phytopathogens of field crops (Papavizas, 1985; Chet et al., 1997). The study of parasitic interfungal associations has been conducted according to its classification in two main classes: biotrophic and necrotrophic, based on parasites' aggressiveness toward their hosts. The first class groups antagonistic species the utilize nutrients and compounds produced by its host with no evident damage, at least during the early stages. The establishment of biotrophic associations requires high specificity in recognition between the host and the mycoparasite (Jeffries & Young, 1994). For example, ultrastructural analysis of the interaction between *Tetragoniomyces uligiosus* and its host *Rhizoctonia solani* revealed the formation of a micro-pore that allows a direct cytoplasmatic connection (Bauer & Oberwinkler, 1990). The second class: necrotrophic, fungi are facultative parasites that can grow by using organic compounds of dead material, through a saprotrophic lifestyle. But they are also able to parasitize living hosts in order to obtain the necessary nutrients. This fact reflects the relevance of this particular parasitic process as a successful tool in the development of strategies to control fungal diseases. Examples of mycoparasites conclude *T. hamatum*, *T. harzianum*, *T. knoningii*, *T. virens*, *T. viride*, *Pythium nunn*, and *P. oligandrum*.

Competition for space and nutrients

Competition is one of the most often cited mechanisms in biocontrol of fruit diseases, especially between yeasts and postharvest pathogens. Nutrient competition was cited between *S. roseus* and *P. expansum* and *B. cinerea* on apple (Janisiwicz et al., 1994), *E. cloacae* and *R. stolonifer* on peach (Wisniewski et al., 1989). *Aureobusidium pullulans* which consumes the amino acids inhibits germination of *P. expansum* in apple juice (Janisiwicz et al., 2000).

Trigiano, Windham and Windham (2004) noted that competition is the process of two or more organisms that try to use the food such as carbon and nitrogen or mineral source. Nitrogen, carbon, and iron competition have been associated with *Fusarium* suppression by *Trichoderma* and nonpathogenic *Fusarium* species (Sivan & Chet, 1989). Finstein and Alexander (1962) reported that competition for carbon and nitrogen by the pathogen *Fusarium* and rhizobacteria would also trigger a protective mechanism. The interactions between fluorescent pseudomonades and nonpathogenic *Fusarium* may also provide control of *Fusarium* diseases (Lemanceau & Alabouvette, 1993). Moreover, Strains of *A. pullulans* have been reported to against fungal pathogens through competition for nutrients (Bencheqroun et al., 2007). Iron competition is the best-understood mechanism. Iron is commonly present in an insoluble form. Some bacterial and fungal species have developed a system for iron uptake. This consists in the production of siderophores, peptides working as iron-binding legend, and the transport for both molecules inside the cell. *Pseudomonas* species constitute the best prokaryotic system studied in relation to siderophore synthesis.

Competition for nutrients played a significant effect on the biocontrol activities of *A. pullulans* PL5 against the pathogens. *A. pullulans* PL5 can inhibit the mycelia growth of pathogens (Zhang et al., 2010). Chanchaichaovivat and co-workers (2008) reported that *P. guilliermondii*; strain R13, competed with *C. capsici* for both sugars and nitrates.

Antibiotics and toxins

Antibiosis is the destruction of organism by a metabolite produced by another organism. Antagonists produce bioactive compounds that are effective against different plant pathogens (Trigiano, Windham & Windham, 2004). Fungal antagonists produce antibiotics such as *Gliocladium* and *Trichoderma*. Most fungi produce antimicrobial secondary metabolites, either as part of their normal growth and developmental program or in response to a biotic stress (parasitism). The production of toxins and antibiotics by fungi is very simply demonstrated in vitro (Cortes-Penagos, Olmedo-Monfil, & Herrera-Estrella, 2007). However, the relevance of antibiotic production during in vivo biological control remains unclear. Species of *Trichoderma* are well-known biological control agents that produce a range of antibiotics that are active against pathogens in vitro and, consequently, antibiotic production has commonly been suggested as an advantageous trait for these fungi (Ghisalberti & Sivasithamparam, 1991).

Hydrolytic enzymes

Production and secretion of lytic enzymes is referred to as one of the most important characteristics of mycoparasites used in biocontrol (Cortes-Penagos, Olmedo-Monfil, & Herrera-Estrella, 2007). The major enzymatic activities reported for different fungal species have as targets the structural components of the cell wall; among them are chitinases, glucanases, glucosaminidases, and proteases. Studies concerning hydrolytic enzyme production have analyzed the process at the biochemical level, evaluating the enzymatic profile shown by mycoparsites in the presence of their hosts or structural components of them, such as cell walls, chitin, and glucan. Chanchaichaovivat and co-workers (2008) reported that *P. guilliermondii*, strain R13, can produce hydrolytic enzyme. Hydrolytic enzymes play an important role in degradation of the *C. capsici* cell wall, especially when the yeast attaches to the pathogen hypha.

2.8.2 Biocontrol of insect pests

The biocontrol of insect pests refer to the use of the living natural enemies to control insect pests instead of synthetic chemical fungicides (Evans, 1999) or the use of living organism against a pest population (Charlet, Olson, & Glogoza, 2002; Michaud, Sloderbeck, & Nechols, 2008; Stoner, 1998).

Natural enemies of insect pests include parasites, predators, and pathogens. Parasite or parasitoid is the immature insect that lives on or inside a host and kills the host before the host completes its development (Charlet, Olson, & Glogaza, 2002). It feeds on the host and requires only a single individual prey to complete its development such as wasps, flies, and plant nectar (Charlet, Olson, & Glogaza, 2002). Predators include birds, fish, amphibians, reptiles, small mammals, and arthropods. Arthropods are most important predators in pest management and include lady beetles, ground beetles, sysphid flies, green lacewings, assassin bugs, predaceous bugs, minute pirate bugs, predatory mites, and spiders (Charlet, Olson, & Glogaza, 2002; Stoner, 1998). Pathogens include fungi, viruses, bacteria, protozoan, and other microorganisms. Insect viral pathogens attack insect pests such as the *Helicoverpa* NPV. The bacteria attacked insect pest management is in the genus *Bacillus*. Insect pathogenic fungi attack the insect pest such as *Metarhizium*, *Beauveria*, *Entomophthora*, and *Zoopthora* (Charlet, Olson, & Glogaza, 2002; Evans, 1999; Stoner, 1998).

2.8.3 Teaching-Learning about biocontrol

Chanchaichaovivat, Panijpan, and Ruenwongsa (2008) studied the relationship between the three organisms: red chili fruit, the yeast biocontrol agent *Saccharomyces cerevisiae*, and the pathogenic fungus. Results from this study were used to design hands-on biological control activities for 11th grade students based on the experiential learning model. Students in the experiential learning class showed higher conceptual understanding of organism interactions in biocontrol systems and were more critical about their roles in the environment compared to the traditional learning class. They were assessed for their abilities to give better explanations in open-ended questions and interviews, and to construct a more complex concept map. The students also applied their knowledge to design science projects, which were evaluated as ‘superior’ using the rubric score. They had positive attitudes towards this hands-on activity, not only in their learning outcomes, but also in their environmental awareness. This advanced instructional method, using yeast biocontrol experiment, enhanced students ‘conceptual understanding and critical thinking skills. It could thus be used as an alternative teaching method to improve learning outcomes of students studying biology. Moreover, Nantawanit, Panijpan, and Ruenwongsa (in press) studied the ability of the *P. guilliermondii* strain R13, the yeast isolated from Thai rambutan, in suppression the growth fungal pathogen, *Colletotrichum capsici*, in harvested chili. Its multiple modes of action include nutrient competition, tight attachment to the fungus, and hydrolytic enzyme secretion. Some of the results were then used to develop the learning unit for high school students.

Several researchers have reported about the plant neglect problem in biology curriculum. Most students think animal studies are more interesting than those of plants because they believe that plants are inferior to animals in that they are passive and unable to respond to external challenges, particularly biological invaders such as microorganisms and insect herbivores. Therefore, Nantawanit (2009) developed on the inquiry-based learning unit on promoting students' conceptual understanding of plant defense responses to biological invaders as well as raising students' awareness in studying plants. The study also investigated students' perceptions of the learning unit implemented in a constructivist classroom. This learning unit was implemented to grade 12 science students. The results showed that the students developed a better conceptual understanding of plant defense mechanisms. In addition, they appeared to have positive attitudes toward the learning unit as evidenced by their preference for inquiry-based activities in a constructivist learning environment. Their perspectives on plant study had been favorably changed by the active learning experience.

2.9 Summary of the Chapter

The chapter describes the theoretical framework employed to guide development of the learning unit. The benefit of STS-approach in promoting student scientific literacy has been reviewed. The scientific background of the science content of the learning unit is described. The importance of using biocontrol and impact of pesticides as the science content of the learning unit are described.

CHAPTER III
METHODOLOGY

Overview

This chapter presents the theoretical framework and methodology employed in this study. The first section describes the theory of an STS approach and the framework of this study. The next section describes the research design and the last section is on the methodology and method employed to collect, analyze and interpret the data.

3.1 Theoretical Framework of Education Research

3.1.1 The theory of an STS approach

The Thai National Education Act (Office of the National Education Commission [ONEC], 2003) emphasizes that the learning process shall aim at scientific and technological knowledge and skills, as well as knowledge, understanding and experience in management, conservation, and utilization of natural resources and the environment in a balanced and sustainable manner. Moreover, Thai students must have knowledge about Thai wisdom, and the application of wisdom into local communities. This is in accordance with the Thai National Science Content Standard (Institute for the Promotion of Teaching Science and Technology [IPST], 2002) that an important goal for science education is to encourage students to develop their own scientific knowledge for understanding and explaining natural phenomena. It requires teachers to design activities concerning students' life, and provide the learning processes based on the real life experiences (Caseau & Norman, 1997). STS approach is the learning process in human's experience context (Caseau & Norman, 1997). It focuses on social problems and local community issues, including cooperative work on real problems. STS pedagogy contributes chance to bring the knowledge into community and develop investigation and analysis skill (Caseau & Norman, 1997).

3.1.2 Mixed method research

Mixed method research may include both quantitative and qualitative method (Wiersma & Jurs, 2005). Quantitative research focuses on deduction, confirmation, theory/hypothesis testing, explanation, prediction, standardized data collection, and statistical analysis (Johnson & Onwuegbuzie, 2004). It is commonly called a positivist philosophy. Quantitative research is to do with generalizability. The results from this method can be generalized to the population group through the statistical data (Bryman, 2001) Qualitative research focuses on induction, discovery, exploration, theory/hypothesis generation, the researcher as the primary “instrument” of data collection, and qualitative analysis (Johnson & Onwuegbuzie, 2004). Qualitative research is called constructivists and interpretivist (Johnson & Onwuegbuzie, 2004). It is not based on statistical samples, and it lacks generalizability. Many researchers employed both quantitative and qualitative research in their study (e.g. Parkins, Stedman, & Varghese, 2001; Hohenthal, 2006). They called combining qualitative and quantitative research as mixed method approach.

The mixed method approach is to encourage the triangulation. The main goal of triangulation is to confirm a study’s results by using both qualitative and quantitative methods (Dunning, Williams, Abonyi, & Crooks, 2008). Dunning and co-workers (2008) noted that a mixed method approach confirms the results by using different method or data sets. Shih (1998) and Thurmond (2001) stated that mixed methods had two goals: confirmation and comprehension of results. In confirmation of the results, researchers used various statistical techniques to confirm mixed method results (Dunning et al., 2008). In comprehension of results, researchers must use both qualitative and quantitative approaches to provide a more comprehensive and detailed understanding of the phenomenon (Dunning et al., 2008). There are many benefits of mixed method research such as increasing a researcher’s confidence in the data and findings.

3.1.3 Framework of the study

Theoretical framework of this study is based on science, technology, and society which focus on the context of a real-world situation. The learning process involved researcher, community people, teachers, and students. A framework for this study is shown in Figure 3-1. This study consisted of theory, practical work, and an STS-based learning and teaching process.

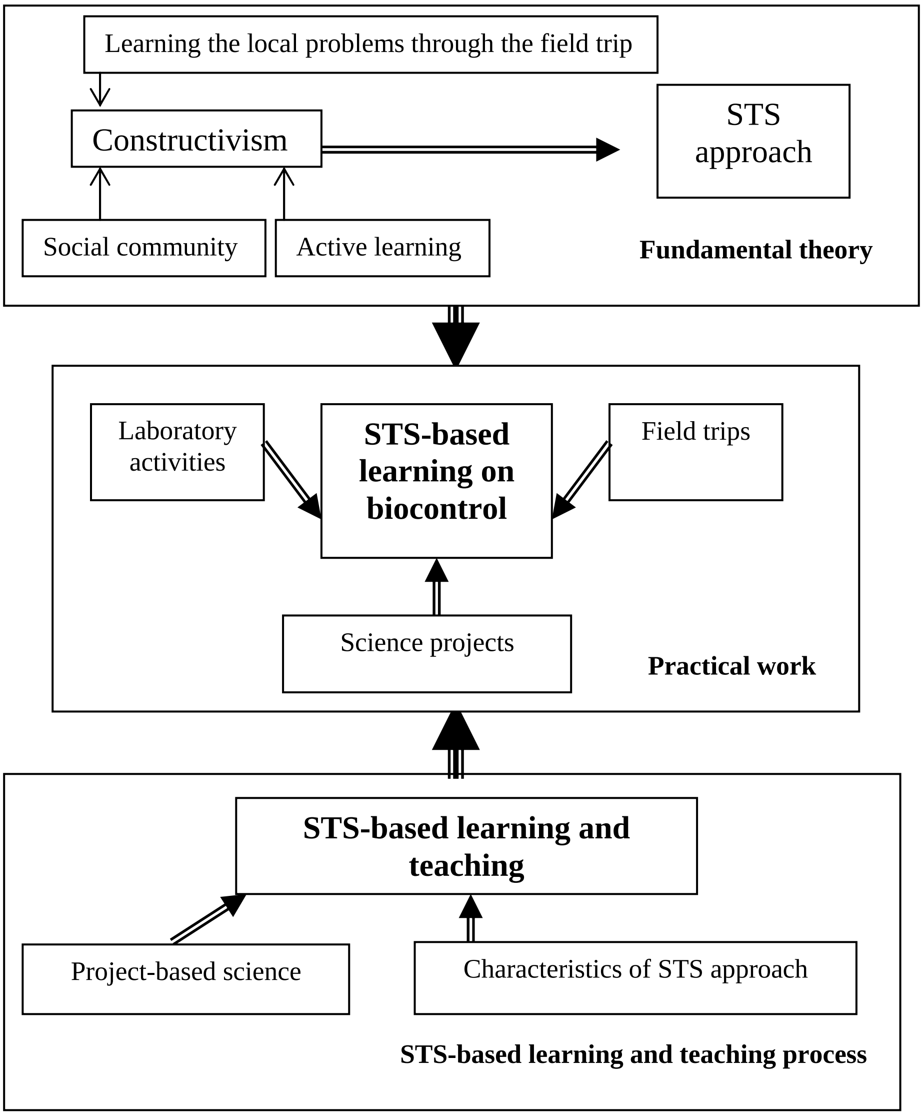

Figure 3-1 Diagram of the framework of this study

A framework of this study in Figure 3-1 was applied from constructivist theory. This theory focuses on the effective and productive of existing, social and natural resources for learning. The real expert is not the teacher, or any other person, but is the local expert/local sage or the community of practice (Brown, 2006). The researcher used the inquiry-based science to build a greater understanding of the relationships between science, technology, and society (Hammerman, 2006) for the learning process. Hammerman (2006) noted that it is important to recognize the links that exist between science and technology and to address the effects or impacts on society, the lives of students, the local community, and the global society. So, the teaching and learning science should focus on providing students to use technology and scientific knowledge in real life. Students can use technology and scientific knowledge to help them solve problems and learn more about the world around them.

In practical work, students have opportunity to observe and engage in scientific investigation like the scientist does. They gain an understanding of science concepts by doing the laboratory activities and science projects. Moreover, they have chance to learn through discussion, group work, problem solving, and field trip.

In an STS-based learning and teaching, the learning process starts with the question. Students identify and analyze the local problems. They seek the appropriate way to solve the local problems. At the end of the learning process, students do science projects to support their idea in applying to daily life.

In the framework of this study, the researcher aims to enhance students' understanding of biocontrol concepts. The students are expected to acquire science process skills and have good attitude toward natural environment. This study employs the constructivist theory, and science, technology and society to develop the learning unit on biocontrol for secondary school students.

3.1.4 Data collection in educational research

In mixed method research, researchers and educators have developed and used different instruments to evaluate student achievements. These instruments include conceptual understand test, concept mapping, questionnaire, classroom observation, and semi-structured interviews. In this study, conceptual knowledge test, concept mapping, experimental skill test, questionnaire, interview, and classroom observation are preferred to assess students' achievements from the STS-based learning unit. The details of each instrument used in this study are discussed.

3.1.4.1 Conceptual knowledge test

The two-tier test was used for constructing the conceptual knowledge test. This test supports understanding of students' scientifically correct/incorrect ideas, and explores students' reasoning behind these ideas (Tsai & Chou, 2002). This test has been recommended by science educators as an effective assessment used to diagnose alternative conceptions (Treagust, 1986). Treagust (1988) suggested the procedures to identify student understanding and conceptions in a specific content area. Each item of the conceptual test comprised of two tiers. The first tier of the items consisted of a content question/ statement of content that was a multiple-choice question to allow students to answer either true, false, or not sure. The second tier of each item consisted of a reasoning response in a set of four possible multiple choice reasons for students' answer to the first tier.

3.1.4.2 Experimental skill test

There are two general forms of assessment for students' skills in experimentation pen-and-paper tests and practical or laboratory performance test (Hammann, Phan, Ehmer, & Grimm, 2008). Hammann and co-workers (2008) suggested that open-response tests and performance assessment allow for a more detailed description of students' achievement. Performance assessment provides insights into qualitatively different strategies of planning experiments and analyzing data. It is more appropriate than multiple-choice tests in providing the information necessary for planning new steps in the learning process.

The experimental skill test is open-response test. The test consists of four subscales: pose questions and hypothesis, identify variables, design experiments, and collect data (Dirks & Cunningham, 2006).

3.1.4.3 Concept mapping

Concept mapping has been shown to be a classroom technique that can enhance learning in the science (Lawless, Smee, & O'Shea, 1998). Concept mapping can be a helpful metacognitive tool, and promoting student understanding (Kinchin, Hay, & Adams, 2000). Novak (2002) stated that concept map has been an effective tool for investigating student understanding of scientific concepts.

The structure of a map is unique to its author reflecting student experiences, beliefs and biases of student understanding of a content knowledge (Kinchin, Hay, & Adams, 2000). Kinchin and co-workers (2000) noted that the ability to construct a concept map shows two essential properties of understanding: the representation and the organization of ideas (Halford, 1993). Concept map is composed of concept words or phrases that are connected together with linking words (Moni, Beswick, & Moni, 2005)

3.1.4.4 Questionnaire

A questionnaire is one of the instruments used for investigating the perception/intention of the learning process. In quantitative assessment, the questionnaire is very popular for obtaining the information of the student perception and intention (Borg, 1963; Bryman, 1984). It is used when factual information is desired, and when opinions rather than facts are desired (Best & Kahn, 1998). The questionnaire is appropriate for collecting a wide range of data in a variety of different conditions (Moore, 2000), and from a large number of respondents (Hinds, 2000). Best and Kahn (1998) stated that a good questionnaire must deal with a significant topic. It is only used for seeking information that cannot be obtained from other sources. It should be as short as possible and long enough to get the essential data. It should be neatly arranged, clear and complete, objective with no leading suggestions, presented in good psychological order, and easy to tabulate and interpret.

3.1.4.5 Interview

An interview is one of the qualitative assessments involved the collection of data through direct verbal interaction between individuals (Borg, 1963). It has provided to be a remarkably powerful way of getting to know how students describe and explain the world around them (Lythcoll & Duschl, 1990). It provided more in-depth information (Cohen, Manion, & Morrison, 2000).

Interviews are used to gather information regarding an individual’s experience and knowledge; his or her opinions, beliefs, and feelings; and demographic data (Best & Kahn, 1998). The questions for interview are usually in one of three forms: structured, semi-structured, or unstructured (McMillan & Schumacher, 2006). Structured questions are followed by a set of choices, and the respondent selects one of the choices as the answer. Semi-structured questions have no choices from which the respondent selects an answer. The question is an open-ended question but is fairly specific in its intent. Unstructured questions allow the interviewer great latitude in asking broad questions in whatever order seems appropriate (McMillan & Schumacher, 2006). In qualitative assessment, a combination of structured and semi-structured questions has been used in most interviews.

3.1.4.6 Classroom Observation

Observation, one of the research instruments for collecting in-depth data, was used to investigate how students learned and how teachers taught. When observation is used in qualitative research, it usually consists of detailed notation of behaviors, events, and the contexts surrounding the events and behaviors (Best & Kahn, 1998). Bell (2005) stated that the researcher as participant-as-observer was able to get more detail of behavior or organizations from observation.

Observation can be of the setting or physical environment, social interaction, physical activities, nonverbal communications, planned and unplanned activities and interactions, and unobtrusive indicators (Best & Kahn, 1998). Best and Kahn (1998) stated that a good observation must be carefully planed, systematic, and perceptive. The observers are aware of the wholeness of what is observed, and not biases.

3.2 Research Methodology

A quasi-experimental design was employed within an interpretative paradigm. This study used both qualitative and quantitative approach. Diverse procedures were used for collecting, analyzing, and mixing both quantitative and qualitative data in a control and experimental groups to answer the research questions and to support research findings (Cohen, Manion, & Morrison, 2000).

A learning unit based on an STS approach was developed for enhancing students' understanding of biocontrol concept, experimental skills, and attitude to natural environment. A scheme of research design and the methodology for this study is shown in Figure 3-2.

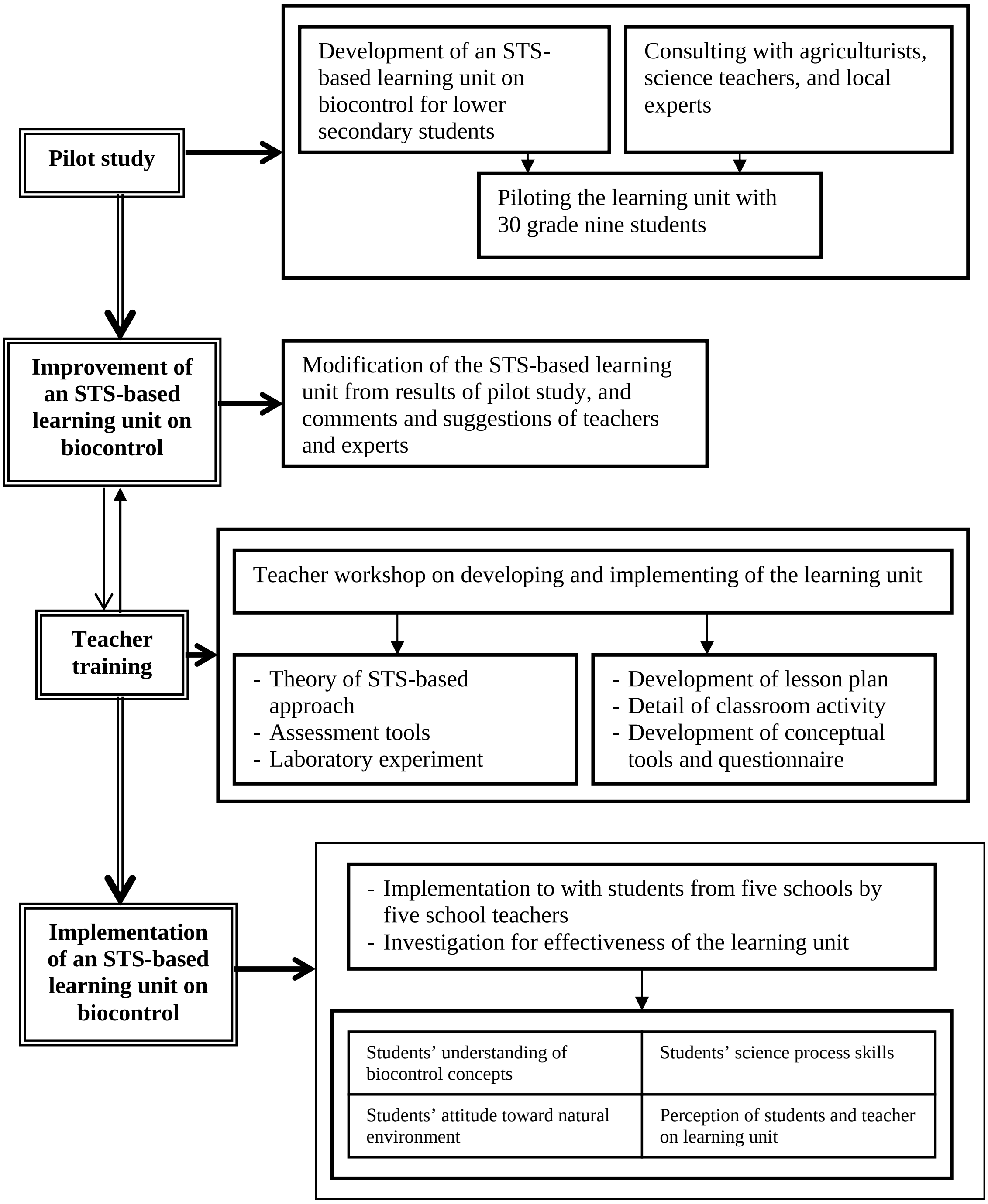

Figure 3-2 Research design for development and implementation of an STS-based learning unit on biocontrol

This research design was divided into four main steps as follows:

3.2.1 Pilot study

An STS-based learning unit on biocontrol was developed based on the science curriculum in the secondary level (IPST, 2002). The learning unit was developed in collaboration with science teachers, science educators, agriculturists, and local sages. The newly developed learning unit was piloted with 30 grade nine students from a secondary school in agricultural area of central Thailand. The data from pilot study, which included the conceptual test, questionnaire on attitude toward environment and on perception of the learning unit, were carefully analyzed. The appropriateness of standard measures was also checked.

3.2.2 Development of an STS-based learning unit on biocontrol for secondary students

3.2.2.1 The STS-based learning unit

The lesson learned from the pilot study together with comments from teachers, experts, and local sages was used to modify the learning unit both in the science content and the learning process. The learning unit on biocontrol was then developed in collaboration with science teachers, science educators, and local sages. This learning unit employed STS approach as a framework of the unit. The inquiry-based approach and cooperative strategy were also used in the learning unit. The STS-based learning unit on biocontrol comprised four units as follows:

The first unit: Biocontrol of plant diseases in the community

At the beginning of the learning process, the students are to discuss problems in their local environment with their peers, with special emphasis on plant’s diseases and chemical agents. Then they would be given opportunity to visit farm, vegetables plantation in their home and/or school vicinity and discuss the issues on plant diseases with local experts. Each group of the students would observe plants’ disease by using magnifying lens and use work sheets to collect data. The students are to interview the farmer about using chemical agents for disease management, including use of pesticide on the farm. These activities enable the students to identify agricultural problems in their local area. After visiting the farm, each group of students would discuss their findings to class and use the knowledge gained to plan and set up and a simple preliminary experiment on biocontrol according to their idea. The teacher acts as facilitator to give feedbacks and suggestions on how to improve their plan before conducting the experiment. The teacher supports them by providing laboratory materials and equipment as well as necessary textbooks and journals. During this activity the students would learn basic techniques to control plants diseases of their choice by using biocontrol agents such as fungi and yeast provided by the teacher.

The second unit: Biocontrol of insect pests in the community

In secondary activity, the students study about the insect pests and natural enemies. At the beginning of the learning process, students are to observe an insect population in the school neighborhood, rice fields, and vegetable plantations. The students would survey and look for local problems to identify the causes of local problems. Then, the students would discuss the impacts of pesticides in their local environment with their peers, farmers, and the teachers. In this activity, the students would be given the opportunity to visit farms, vegetable plantations in their home and/or school vicinity and discuss the impact of pesticides with farmers. The students are to interview the farmers about using pesticides for farm pest management. These activities enable the students to discuss the impacts of pesticides on their community. After visiting the farms, each group of students would present their findings to class based on the knowledge gained from the study about the insect pests and their natural enemies. In the meantime they would also learn about the parasites and predators for controlling insect pests. Students are supposed to learn more about the insect pests by conducting the experiment and searching information from internet.

In the activity that followed, the students would visit chemical-free rice fields in their community to observe the interrelationships between the insect pests, pests, predators, and natural enemies and interview experts. The students would search for information on parasites and predators from the internet, interview their parents and local scholars and consult with the teacher. Then they are supposed to draw the interrelationships between the insect pests, pests, predators, and natural enemies in the rice field on a poster with their group and share with their peers in the classroom.

The third unit: Students' science projects

In this activity, the students would visit the chemical-free farm in their community to observe the local practices and interview the knowledgeable experts. The students would also search the information on biocontrol from internet, interview their parents and local scholars and consult with the teacher. Then, each group of students would plan and conduct science projects of their own design on the selected problems in their communities. They are supposed to create ideas for their projects from visiting farms in their community in which they observe and learn with local sages and experts. They are expected to search for information from internet and consult science teachers before setting up the projects. They then would conduct their experiments, collect data, and interpret data, and draw conclusion for the results by themselves. The students are to submit reports and present their findings to class. In all these activities teacher would encourage students to undergo various aspects of the scientific practice: asking questions, setting hypotheses, experimenting, identifying and controlling variables, collecting and interpreting their data.

The fourth unit: Bringing science to society

After presenting their results to class, the students then would visit the community again to share their findings with farmers, local experts as well as their parents and relatives. The students are expected to discuss with the community people on how to implement their findings, knowledge on biocontrol of plant diseases and insect pests to their own communities. The students would be encouraged to start the implementation with their family and relatives.

3.2.2.2 Laboratory experiment on biocontrol of plant diseases

Materials and methods

1. The fungal pathogen

Colletotrichum capsici DOAC 1511 and *Fusarium Oxysporum* DOAF 1280 were obtained from the Mycological Laboratory of Department of Agriculture (DOA), Thailand. The fungal pathogen was maintained on potato dextrose agar (PDA) slants at 4^oC.

2. The yeasts and fungus to control the fungal pathogen

This experiment used two yeasts and one fungus: *Pichia guilliermondii, Saccharomyces cerevisiae*, and *Trichoderma reesei*.

The yeast *P. guilliermondii* strain R13, previously isolated from rambutan fruit (*Nephelium lappaceum L.*) in Thailand, was obtained from the Institute for Innovative Learning, Mahidol University, Thailand. Both *P. guilliermondii* and *Saccharomyces cerevisiae* (commercially available from the Microbiological Research Centre, Thailand Institute of Scientific and Technological Research) were maintained on potato dextrose agar (PDA) slants at 4^{o}C.

Trichoderma reesei (TISTR 3080) was obtained from the Microbiological Research Centre, Thailand Institute of Scientific and Technological Research. This fungus was maintained on potato dextrose agar (PDA) slants at 4^{o}C.

3. Sources of fruits

The fruits used in this experiment were collected from the market in central of Thailand, namely mango (*Mangifera indica L.*), chili (*C. annuum L. var. acuminatum Fingerh.*), eggplant (*Solanum melongena L.*), guava (*Psidium guajava L.*), gros michel (*Musa acuminate L.*), and tomato (Lycopersicon esculentum Mill).

4. Studies on the effects of the yeasts and fungus on preventing infection of wounded fruits

Each fruit of chili, tomato, and Gros Michel was wounded (one wound per fruit, 2-mm deep and 6-mm wide) with a sterile cork borer. About 10-15 wounded fruits were inoculated with the fungal pathogen at concentrations of 5 x 10^{6} spores ml^{-1}. Then the wounded fruits were treated with *T. reesei*, *S. cerevisiae*, and *P. guilliermondii*. These microorganisms (5 x 10^{6} spores ml^{-1}) were added to the wounded area and the all fruits were put on 17x11x4 cm^{2}. plastic trays wrapped with high density polyethylene sleeve and kept at 28^{o}C for 5 days. The lesion diameter (average length of lesion in x-axis and y-axis) was measured 5 days after inoculation.

3.2.2.3 Laboratory experiment on biocontrol of insect pests

Materials and methods

1. The materials were used (1) insect net; (2) bottle; (3) worm; (4) the food for the worm; and (4) magnifying lens.

2. The students are supposed to collect the worms from the field and foster them for five days. In everyday, the students would observe the behaviors of these worms. They would collect the data, analyze, and make conclusion. The students are supposed to communicate their findings to class. .

3.2.3 Teacher workshops on the learning unit

Since the research study aimed at transferring the knowledge to school, thus, the teacher should be the one who implement the lesson plan to students. Before this, the teacher should have enough knowledge on both the content and learning process. Therefore, a workshop for training the teachers to use an STS-based learning unit on biocontrol was organized for five teachers from the five schools that volunteered to participate in this study. The 6-day workshop provided teachers with an overview of theoretical background of an STS approach as well as the scientific aspects of the unit. These included biocontrol concepts, laboratory experiment on control of plant diseases by using microorganism as well as on biocontrol of the insect pests. The teacher was also trained on how to select and construct the assessment tools.

There were three major components in the workshop. The first component was to provide the teachers with instruction on how to use an STS approach related to real-life issues. The second component was to train the teachers on how to conduct the experiments on plant diseases and insect pests so that the teacher would be able to transfer this knowledge to the students. The local sages were invited to give information to the teachers about control of plant diseases and insect pests. The third component was on how to assess students’ achievement.

At the end of the teacher training, the five science teachers were encouraged to modify activity of the lesson plan so that it would be more appropriate to use with their students.

3.2.4 Implement of the STS-based learning unit on biocontrol for secondary students

The STS-based learning unit on biocontrol was implemented to grade nine students in five schools with the already trained teachers (see Table 3-1). The teachers conducted the learning activity while the researcher observed all activities both in and out of classroom and gave suggestions when necessary. The learning-teaching sequence last for ten weeks. The researcher and the five science teachers worked together to evaluate the effectiveness of the STS-based learning unit by analyzing conceptual knowledge test, concept mapping, experimental skill test, and the questionnaire of attitude to natural environment. Prior to the implementation, the students were tested for prior knowledge on biocontrol, experimental skills, and attitude toward environment. The students conducted their own learning and constructed their own knowledge according to the learning-teaching sequence in Table 3-1.

In each activity, the students were expected to acquire knowledge as well as various science process skills as shown in Table 3-1. The teacher acted as facilitator to encourage and give suggestion when necessary.

Table 3-1 The teaching-learning outlines on biocontrol unit based on STS approach

Phase	Activity	Expected Outcome	Assessment
Before intervention	Students take conceptual knowledge test (pre-test), pre-concept map, pre experimental skill test, and pre-questionnaire on attitude toward natural environment.	- Students' prior knowledge - Students' prior experimental skills - Students' attitude toward natural environment	- Conceptual knowledge test - Concept map - Experimental skill test - questionnaire
Phase I (1 week) Identifying the local problems	- Students discuss and list the local problems in the class. - Students visit the farm in school vicinity. - Students survey and identify local problems on plant diseases and	- Ability to observe, infer, and communicate	Work sheet Classroom Observation

Phase	Activity	Expected Outcome	Assessment
	pesticides in their communities. - Each group of students discusses with groupmates and class about the causes of the local problems and the impact of pesticides on their community.		
Phase II (3 weeks) Biocontrol of plant diseases	- Students pose question and formulate hypothesis on biocontrol of plant diseases. - Each group of students designs a preliminary laboratory experiment on plant diseases based on the surveying results and guided protocol on the science experiment. - Each group of students conducts experiment in science room. - Students collect and interpret data, discuss and then share result with classmates.	- Ability to predict - Ability to formulate hypothesis - Ability to identify variable - Ability to conduct experiment - Ability to classify - Ability to measure - Ability to infer - Ability to communicate - Ability to interpret data - Ability to make conclusion - students' conceptual understanding on biocontrol of plant disease	Work sheet Concept map Classroom Observation Laboratory report
Phase III (3 weeks) Biocontrol of insect pests	Students visit the farms - Each group of students surveys and discusses with local experts, identifies insect pests and enemy insects in their local areas. - Each group of students uses the surveying results to discuss with classmates and teacher about the effects of insect pests and the benefits of enemy insects. - Each group of students observes the interrelationship between the insect pests and natural enemies in	- Ability to predict - Ability to formulate hypothesis - Ability to identify variable - Ability to conduct experiment - Ability to classify - Ability to measure - Ability to infer - Ability to communicate - Ability to interpret data - Ability to make	Work sheet Concept map Classroom Observation Laboratory report

Phase	Activity	Expected Outcome	Assessment
	the rice field. - Each group of students plans and conducts its own short project on insect pests, and shares results with class. - Each group of students draws the relationship between insect pests and natural enemies of insect pests and shares their results to the class. - Students conclude the impact of biocontrol on the environment and humans. - Teacher conducts the debriefing session of activities in phases I -III.	conclusion - students' understanding on biocontrol of insect pests	
Phase IV (2 weeks) Science projects	- Students visit the farm again to share their findings with local sages. - Each group of students discusses with local sages to extend their findings in laboratory to science project in the field. - Each group of students searches more information from internet and other local experts for the science project. - Each group of students conducts the science project in the field with the support from local sages. - Each group of students collects, analyzes and interprets data, and makes conclusion. - Each group of students searches related scientific knowledge from the internet and other sources to support results from their science project.	- Ability to pose question, formulate hypothesis, predict, identify variable, define variables, conduct experiment, collect data, interpret data, and make conclusion	Science project Classroom Observation

Phase	Activity	Expected Outcome	Assessment
Phase V (1 weeks) Transfer to community	- Each group of students brings their results from science project to their class and local sages. - Each group of students visits the local community and shares their finding from science project with farmers and local experts	- Ability to make conclusion, discuss and communicate	Classroom Observation Science project Presentation
After intervention	- Students take posttest on conceptual knowledge test and experimental skill test, and draw concept map. - Students are administered questionnaire on attitude toward natural environment and on perception of the learning unit. -25 volunteered students are interviewed.	- Students' conceptual knowledge - Students' experimental skills - Students' attitude toward natural environment - Students' perception on the learning unit	-Conceptual knowledge test - Concept map - Experimental skill test - Questionnaire on attitude toward the environment - Semi-structure interview protocol - Questionnaire on students' perception

The control group students were taught in the traditional style with the same teacher on the same objectives. These students were not assigned to perform laboratory experiment nor the science project. However, they were encouraged to search information from internet and experts on the issues of biocontrol of plant diseases and insect pests. They also presented their finding to class and discussed in class. The teaching-learning sequence of the students in traditional teaching was shown in Table 3-2.

Table 3-2 The teaching-learning outline on biocontrol unit for the traditional group

Phase	**Activity**
Before intervention	Students take conceptual knowledge test (pre-test), pre-concept map, pre experimental skill test, and pre-questionnaire on attitude toward natural environment.
Phase I (1 week) Identifying the local problem	Students discuss and list the local problem in their class with teacher and classmates.
Phase II (2 weeks) Biocontrol of plant diseases and insect pests	- Students listen to the lecture and search for more (internet, experts, textbook, etc) information on biocontrol of plant diseases. - Students study the dry laboratory on biocontrol of plant diseases.
Phase III (1 week) Biocontrol of insect pests	- Students listen to the lecture knowledge of biocontrol of insect pests. - Students search for more information about the biocontrol of insect pests. - Students conclude the biocontrol concepts.
Phase IV (2 weeks) Writing report	- Students search information on biocontrol from internet, and write report on biocontrol in the community by interviewing their parents, agriculturists and collecting information from internet, etc. - Students present report to class.
After intervention	-Students take posttest on conceptual knowledge test and experimental skill test, and draw concept map. - Students were administered questionnaire on attitude toward natural environment. - 25 volunteered students are interviewed.

3.3 Participants

The participants in this study were 357 grade nine students from ten classrooms from five schools in agricultural area of the central part of Thailand. The students in each classroom (27-42 students) were of mixed ability with age 14-15 years old. In each of the five schools (A, B, C, D, and E), one classroom served as control while another class was used as an experimental group. Background of the students in the five schools and their pre-test scores on conceptual knowledge are shown in Table 3-3.

Table 3-3 Students' background in the five schools (A, B, C, D, and E)

School	Type	Experimental group				Control group			
		Gender		Mean		Gender		Mean	
		Boy	Girl	Age (yrs.)	Pre-test (100 pts)	Boy	Girl	Age (yrs.)	Pre-test (100 pts)
A	Secondary school	7	33	14.6	55.05	12	30	14.5	56.90
B	Opportunity extended school	18	17	14.5	45.94	18	21	14.6	44.85
C	Opportunity extended school	12	30	14.6	35.14	33	8	14.6	34.15
D	Opportunity extended school	24	6	14.5	34.63	17	15	14.7	35.44
E	Opportunity extended school	9	18	14.3	38.04	11	18	14.5	37.59

3.3.1 Schools

3.3.1.1 School A

School A is a large government secondary school in the central part of Thailand. Students in school A are classified according to national test as medium achievers. This school is co-educational school. The school has its own rice field and canal nearby. Majority of the students' families are agriculturists and employees. This school has applied the philosophy of sufficient economy to teach students.

3.3.1.2 School B

School B is a large government opportunity extended school in the central part of Thailand. This is a medium achiever co-educational school. Around the vicinity of the school are markets and canal. Majority of the students' families are agriculturists and fruit seller.

3.3.1.3 School C

School C is a medium size government opportunity extended school in the central part of Thailand. This is a medium achievers co-educational school. This school is surrounded by the villages. Majority of the students' families are the employees.

3.3.1.4 School D

School D is a small government opportunity extended school in the central part of Thailand. This is a medium achiever co-educational school. This school is surrounded by rice field and vegetable plantation. Majority of the students' families are agriculturists.

3.3.1.5 School E

School E is a small government opportunity extended school in the central part of Thailand. This school is classified as medium achiever, however, the students' performance are much lower than the other four schools. This school is surrounded by vegetable plantation. Majority of the students' families are the agriculturists and the employees.

3.3.2 Teachers

3.3.2.1 Background of teachers from the five schools

Background of the teachers who participated in this study is shown in Table 3-4. The teachers from the five schools are one male, and four female age 28-50 years. They have experiences in teaching science for grade nine students for 2-7 years. These teachers are not familiar with the active learning-teaching process. None of them have knowledge about STS approach.

Table 3-4 Background of teachers from five schools

Teacher from school	**Age (yrs.)**	**Teaching experience (yrs.)**	**Science teaching experience in grad nine (yrs)**
A	30	7	7
B	50	30	3
C	46	16	3
D	36	13	2
E	28	2	2

3.4 Ethics

Ethics is important in research educations because it protects the participants from any harm both physical and mental harm. This research study was approved by Documentary Proof of The Committee for Research Ethics (Social Sciences) from Mahidol University. The consent forms were given to the principles of the schools and science teachers to ask for their permission to do research in their schools and in their classes. All data from observation in class and student works were kept confidential. Pseudonyms for school names, teachers and students were used to preserve anonymity and their privacy was protected. At the end of research process, all data was destroyed by researcher.

3.5 Data Collection

3.5.1 The conceptual knowledge test (CKT)

The conceptual knowledge test was 20 items of two-tier multiple-choice (see Appendix A). The first tier of each item consisted of a multiple-choice question with three choices. The second tier of each item consisted of four possible reasons. This test was developed based on the objectives of life and environment standard stated in Thai science standard curriculum (IPST, 2002). These questions were derived from a pilot study on students' open-ended tests, literature and interview. It was administered to the students before and after the learning process. The conceptual knowledge test was divided into three topics namely biocontrol concept, harm of chemical substances and environmental conservation. The Cronbach's alpha reliability was estimated to be 0.90 using the test on one hundred students. The difficulty value was 0.59-0.70 and the discrimination index was 0.40-0.56.

3.5.2 Concept map

The concept map was employed to examine and evaluate students' knowledge about the biocontrol of plant disease and insect pests at the beginning and the end of the learning unit. It was evaluated by using scoring rubric adapted from Moni, Beswick, and Moni (2005). The scoring rubric comprised of three criteria:

content, understanding, and presentation. The total score of concept map was 15 points, a maximum of five points for each criterion

Table 3-5 Scoring rubric for analyzing concept maps

score **Level**	**5 points**	**4 points**	**3 points**	**2 points**	**1 point**
content	All relevant concepts of are correct with multiple connections.	Most relevant concepts of biocontrol are correct with multiple connections.	Few relevant concepts of biocontrol are correct with two or more connections.	Few relevant concepts of biocontrol are correct with one connection.	Few relevant concepts of biocontrol are correct with no connection.
understanding	Understanding of facts and concepts of biocontrol are clearly demonstrated by correct links.	Understanding of facts and concepts of biocontrol are demonstrated by correct links but some verbs are not appropriate.	Understanding of facts and concepts of biocontrol are demonstrated but some incorrect link and verbs.	Understanding of facts and concepts of biocontrol are demonstrated but very incorrect link and verbs.	Poor understanding of facts and concepts of biocontrol with significant errors
Presentation	-Concept map is neat, clear, legible and has easy-to-follow links - has no spelling errors	-Concept map is neat, clear, legible and has easy-to-follow links - has some spelling errors	-Concept map is neat, legible but with some link difficult to follow - has some spelling errors	- Concept map is untidy with links difficult to follow - has some spelling errors	- Concept map is untidy and no links - has some spelling errors

3.5.3 Experiment skill test (EST)

The experimental skill test is an open-response question consisting of three topics (see Appendix B). These tests focused on the basic principles of experimental skill which consisted of four criteria; 1) asking questions and setting hypotheses; 2) identifying and controlling variables; 3) designing experiments; and 4) planning data collection (Dirks & Cunningham, 2006). The overall scores were 36 points with the maximum of three points for each criterion. The test had been verified by three experts. The Cronbach’s alpha reliability test on one hundred students was estimated to be 0.89. The difficulty value was 0.59-0.70 and the discrimination index was 0.40-0.56. The experimental skill test was analyzed by using the scoring rubric adapted from Dirks and Cunningham (2006).

Table 3-6 Scoring rubric for analyzing experimental skills

Criteria	Excellent (5)	Exemplary (4)	Accomplished (3)	Developing (2)	Beginning (1)
Pose questions & hypothesis	The question is clear and contains a dependent and independent variables. The hypothesis is clear, concise, falsifiable, and testable hypothesis.	The question is clear and hypothesis answers the question of problem.	The problem and hypothesis are incomplete.	The problem and hypothesis are confusing.	Does not meet the previous criteria.
Identify variables	Variables have been identified, controls are appropriate, in place, and explained.	Variables have been identified, controls are appropriate, in place.	Variables have some what been identified, controls are somewhat know.	Missing one variable or control.	Missing two or more of variable or control.
Design Experiment	Procedure is clear and capable of falsifying or confirming the hypothesis.	Procedure is clear and some parts can confirm the hypothesis.	Procedure is inadequate.	Procedure is confusing	Procedure is not correct
Collect data	Students demonstrate their understanding of the relationship between experimental design and the representation of data.	Students can represent the data but data are incomplete.	Students can represent the data but data are inadequate.	Students can represent the data but some part is incorrect.	The process for collecting data is not correct.

Another experimental skill test as proposed by was also used to observe students’ behavior on experimenting. The details of the test are shown in Table 3-7.

Table 3-7 Students’ behaviors for experimental skills

Type	Behaviors for experimental skills
1	Students plan no experiment.
2	Students plan a single experiment with no experimental control.
3	Students plan more than one experiment, but unsystematically and without an experimental control. All experiments are contradictory.
4	Students plan more than one experiment, but the experiments are not fully systematically planned and partially contradictory.
5	Students plan all experiments systematically and none of them is contradictory, but there is no experimental control.
6	Students plan all experiments systematically, include an experimental control and very few experiments give contradictory results.
7	Students plan all experiment systematically, include an experimental control and no experiment is contradictory.

3.5.4 The questionnaire of attitude on natural environment (QANE)

A twenty-item questionnaire (see Appendix C) was developed by the researcher based on the objectives of “Life and Environment” standard in the science curriculum. This questionnaire measured the students’ attitude to the natural environment. The QANE was administered to the students a week before and after the teaching-learning process.

The questionnaire items were divided into three categories: the impact of pesticides on humans and the environment, the impacts of biocontrol of insect pests on humans and the environment, and the attitude to the natural environment. The QANE was verified by expert science educator who tried out this questionnaire with 100 students. Each item consisted of five responses on the Likert scale: strongly agree, agree, undecided, disagree, and strongly disagree. Scores of 5, 4, 3, 2, and 1 were assigned for positive items and a reverse scoring was used for negative items. The possible QANE total scores ranged from 20-100. From pilot testing, the Cronbach’s alpha reliability of this questionnaire was 0.82.

3.5.5 Students’ science projects

Students’ science projects were analyzed by using the scoring rubric adapted from Sutherland (2003). This rubric consisted of seven main criteria: 1) hypothesis; 2) experimental design; 3) data analysis; 4) discussion and conclusion; 5) presentation; 6) answering question; and 7) knowledge transfer to community. The overall scores were 35 points, a maximum of five points for each criterion.

Table 3-8 Science project scoring rubric

Criteria	**Excellent (5)**	**Exemplary (4)**	**Accomplished (3)**	**Developing (2)**	**Beginning (1)**
Pose questions & hypothesis	The question is clear and contains a dependent and independent variables. The hypothesis is clear, concise, falsifiable, and testable hypothesis.	The question is clear and hypothesis answers the question of problem.	The problem and hypothesis are incomplete.	The problem and hypothesis are confusing.	Does not meet the previous criteria.
Design Experiment	Procedure is clear and capable of falsifying	Procedure is clear and some parts can	Procedure is inadequate.	Missing one variable or	Procedure is not correct.

Criteria	**Excellent (5)**	**Exemplary (4)**	**Accomplished (3)**	**Developing (2)**	**Beginning (1)**
	or confirming the hypothesis.	confirm the hypothesis.		control. Procedure is confusing.	
Data analysis	Students demonstrate their understanding of the relationship between experimental design and the representation of data.	Students can represent the data but data are incomplete.	Students can represent the data but data are inadequate.	Students can represent the data but some part is incorrect.	The process for collecting data is not correct.
Discuss & conclusion	Discuss has been interpreted correctly and discuss, good understanding of results is conveyed. Conclusion has been clearly made, students shows good understanding	Discuss has been correctly interpreted and discuss, only minor improvements are needed. Conclusion has been drawn, could be better stated.	Some of the results have been correctly interpreted and discussed. Conclusions regarding major points are drawn, but many are misstated, indicating a lack of understanding	Very incomplete interpretation of trends and comparison of data indicating a lack of understanding of results. Conclusion missing the important points.	Very incorrect interpretation of trends and comparison of data indicating a lack of understanding of results. Conclusion missing.
Presentation	Each student speaks loudly and clearly, using appropriate sentence, and is able to present background knowledge in a succinct manner.	Each student speaks clearly, using appropriate sentence, and is able to present background knowledge in a clear manner.	Each student speaks clearly, using appropriate sentence, and is able to present background knowledge in a some what clear manner.	Each student speaks using moderate sentence, and is able to present background knowledge in a some what clear manner.	One or more students do not speak, and the background knowledge is unclear.
Answering question	Students display a high level of subject knowledge from research and the process of completing the experiment. Students speak clearly.	Students display a moderate level of subject knowledge from research and the process of completing the experiment. Students speak clearly.	Students display a fair level of subject knowledge from research and the process of completing the experiment. Students speak clearly.	Students display a low level of subject knowledge from research and the process of completing the experiment. Students speak unclearly.	Students display a poor level of subject knowledge from research and the process of completing the experiment. Students speak unclearly.
Knowledge transfer	Students demonstrate three or more value ideas and can apply to community.	Students demonstrate one or two value ideas and can apply to community.	Students demonstrate one value ideas and can apply to community.	Students show one ideas and cannot apply to community.	Students show a poor idea and not apply to community

3.5.6 Students' laboratory reports

Students' laboratory reports were evaluated by a scoring rubric adapted from Merced Country Office of Education (2006). This rubric consisted of five main criteria: 1) hypothesis; 2) procedure; 3) results; 4) discussion and conclusion; and 5) knowledge transfer to community. The overall scores were 25 points with the maximum of five points for each criterion.

Table 3-9 Laboratory report rubric

Criteria	**Excellent (5)**	**Exemplary (4)**	**Accomplished (3)**	**Developing (2)**	**Beginning (1)**
Pose questions & hypothesis	The question is clear and contains a dependent and independent variables. The hypothesis is clear, concise, falsifiable, and testable hypothesis.	The question is clear and hypothesis answers the question of problem.	The problem and hypothesis are incomplete.	The problem and hypothesis are confusing.	Does not meet the previous criteria.
Procedure	Procedure is clear and capable of falsifying or confirming the hypothesis.	Procedure is clear and some parts can confirm the hypothesis.	Procedure is inadequate.	Missing one variable or control. Procedure is confusing.	Procedure is not correct.
Data analysis/ results	Students demonstrate their understanding of the relationship between experimental design and the representation of data.	Students can represent the data but data are incomplete.	Students can represent the data but data are inadequate.	Students can represent the data but some part is incorrect.	The process for collecting data is not correct.
Discuss & conclusion	Discuss has been interpreted correctly and discuss, good understanding of results is conveyed. Conclusion has been clearly made, students shows good understanding	Discuss has been correctly interpreted and discuss, only minor improvements are needed. Conclusion has been drawn, could be better stated.	Some of the results have been correctly interpreted and discussed. Conclusions regarding major points are drawn, but many are misstated, indicating a lack of understanding	Very incomplete interpretation of trends and comparison of data indicating a lack of understanding of results. Conclusion missing the important points.	Very incorrect interpretation of trends and comparison of data indicating a lack of understanding of results. Conclusion missing.

Criteria	**Excellent (5)**	**Exemplary (4)**	**Accomplished (3)**	**Developing (2)**	**Beginning (1)**
Knowledge transfer	Students demonstrate three or more value ideas and can apply to community.	Students demonstrate one or two value ideas and can apply to community.	Students demonstrate one value ideas and can apply to community.	Students show one ideas and cannot apply to community.	Students show a poor idea and not apply to community

3.5.7 Semi-structured interview

Semi-structured interviews were carried out with ten volunteer students from each school: Five students for experimental group and another five for traditional group both before and after the intervention. The interviewing questions emphasized four points: the impacts of pesticide on environment, attitude toward the natural environment, the impacts of biocontrol of insect pests on environmental conservation, and the science process skills from the learning process. These questions are as follows: 1) How would you solve the local problem or preserve the local environment? 2) What knowledge do you bring to apply to your local environment? 3) How do pesticides impact to yourself, family, community, and environment? 4) How do you avoid the toxic from pesticides? 5) What are your ideas in conserving the environment and natural resource? 6) Do the biocontrol of plant disease and insect pests have impact on the environment and human? 7) What skills did you acquire from the STS-based learning unit on biological control? and 8) What process skills do you use in everyday life? How?

The 25-min interviews were conducted one-on-one outside of the classroom by researcher. The data from interview were audio-taped and fully transcribed.

3.5.8 Student reflection

Three open-ended questions were used in order to encourage students to reflect on their idea about the impact of pesticide on environment. The following questions were administered to students before and after intervention. The open-ended questions are as follows: 1) How do pesticides impact the environment and human?;

2) How do biocontrol method effect the environment and human?; and 3) What are the activities that support students' learning?

3.5.9 Classroom observation

Classroom observation, as performed by the researcher, was employed to explore the students' activities that occurred both in and out of the class. The observation focused on both student-student interactions and student-teacher interactions. This was used for the in-depth data that refer to the students' behavior on planning the experiment skill, as adapted from Hammann and co-worker (2008), and other student activities. The researcher used the video, audio taped and camera to record the teaching and learning method (Cohen, Manion, & Morrison, 2000).

3.6 Data Analyses

This research generated both qualitative and quantitative data. The quantitative data from conceptual knowledge test, concept map, experimental skill test, students' science project, students' laboratory report and questionnaire toward natural environment were analyzed by using the SPSS for Window version 11.0 reporting means and standard deviations. The differences in mean values were tested by using a *t*-test and ANOVA for determining significance. The qualitative data from the semi-structured interviews, and classroom observation were recorded by using teachers' note and the audiotape which were fully transcribed. Each transcript was analyzed for knowledge of biocontrol concepts, attitude to the natural environment, and understanding of the impact of pesticides. These data were used for triangulation to corroborate those from other sources.

CHAPTER IV
RESULTS

Overview

This chapter presents the results on the effectiveness of the STS-based learning units on grade nine students. The results from pilot study were used to modify the learning unit on biocontrol. The results of students' outcomes from five schools were described. These are results on students' conceptual knowledge, students' experimental skills, students' attitude toward natural environment, and students' perception on the learning unit.

4.1 Results from Pilot Study

4.1.1 Pilot study on an STS-based learning unit on biocontrol for grade nine students

The results from pilot study comprised three aspects: the results from research instruments, from observations, and modification of the STS-based learning unit from pilot study' results

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A. Results from research instruments

Before and after completing the learning unit, all students were given pretest and posttest on both conceptual knowledge and attitude toward local environment. The results revealed that after participating in the learning unit the students had better knowledge about biocontrol and became more aware of the local problem.

4.1.1.1 Conceptual knowledge test on biocontrol

The results in Table 4-1 show the mean scores of pre-test and post-test on conceptual knowledge in biocontrol (The maximum scores were 60).

Table 4-1 The pre-test and post-test scores of grade nine students (*N* = 30)

Test	**Mean**	**SD**	***t***	**% increase**
Pre-test	25.63	6.44	11.68***	31.12
Post-test	44.30			

***Significant difference (p<0.001)

The post-test scores were significantly higher (p< 0.001) than those of the pre-test scores.

4.1.1.2 Concept maps on biocontrol of plant diseases

Each student was asked to draw a concept map on biocontrol of plant diseases to probe students' understanding both before and after the intervention. In an attempt to create the map, the students shared ideas and had extensive discussions. The mean scores of students' pre and post concept maps, analyzed according to Moni, Beswick, and Moni (2005) are shown in Table 4-2.

Table 4-2 Mean scores of pre and post concept maps (*N* = 30)

Concept map	**Mean**	**SD**	***t***	**% increase**
Pre concept map	8.10	1.55	12.63***	23.80
Post concept map	11.67			

***Significant difference (p<0.001)

After completing the learning unit, the mean scores of concept maps significantly increased from 8.10 in pre concept map to 11.67 in post concept map (The maximum scores were 15). The mean scores of each of the three criteria of concept map was shown in Table 4-3. The highest mean score was in the "presentation", i.e. 4.33 (of total 5). The lowest mean score was in the "content", i.e. 3.53 (of total 5).

Table 4-3 Comparison of students' concept maps before and after exposure to the learning unit

Criterion	Pre concept map		Post concept map		*t*
	Mean	**SD**	**Mean**	**SD**	
1. Content (5)	2.67	0.61	3.53	0.51	6.97***
2. Understanding (5)	2.40	0.72	3.80	0.55	8.57***
3. Presentation (5)	3.03	0.72	4.33	0.71	8.12***
Total (15 pts)	8.10	1.45	11.67	1.32	12.63***

***Significant difference ($p<0.001$)

Pre concept map showed less complex conceptualization than post concept map. The example of the pre and post-concept maps are presented in Figures 4-1 and 4-2.

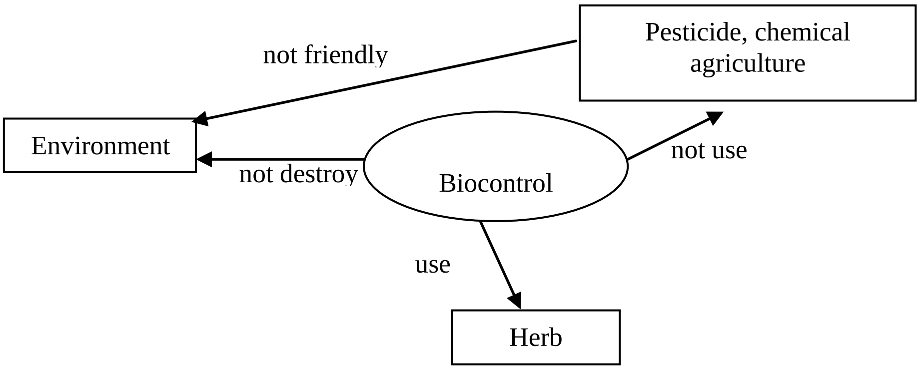

Figure 4-1 Example of pre concept map of one of grade nine students

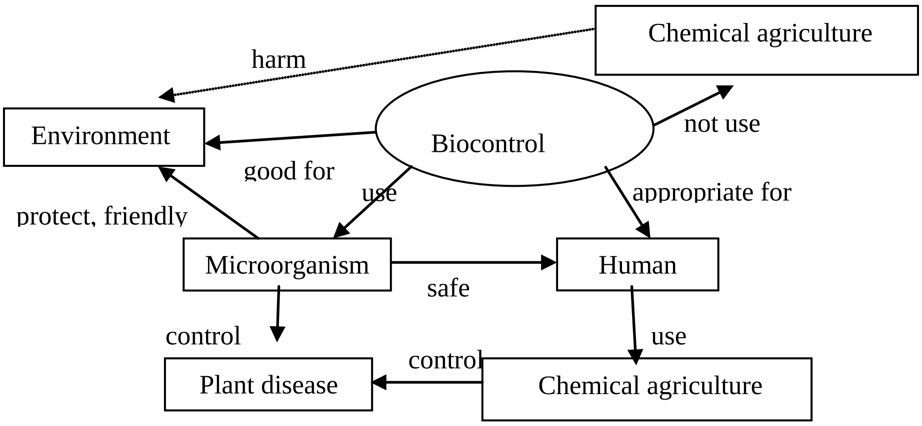

Figure 4-2 Example of post concept map of one of grade nine students

The mean scores of the three criteria of the post concept map were significantly higher than those of the pre concept map (Table 4-3). Posttest score showed that most relevant concepts of biocontrol in the post concept map were correct with multiple biocontrol concepts (score 3.53). These facts and concepts are demonstrated by a few error links (score 3.80), and the concept map was net, clear, and legible, has easy-to-follow links and has some spelling errors (score 4.33).

4.1.1.3 Students' attitude toward natural environment

The students' attitude toward their local environment as measured by questionnaire on attitude toward natural environment (QANE) both before and after participating in the STS-based learning unit is shown in Table 4-4. The maximum scores were 60.

Table 4-4 Mean scores of pre QANE and post QANE of grade nine students

Questionnaire	**Mean**	**SD**	***t***	**% increase**
Pre QANE	46.73	6.12	8.81^{***}	6.45
Post QANE	50.60			

***Significant difference (p<0.001)

After the learning, mean score of the post QANE was significantly higher than those of the pre QANE. However, the percentage increase was only 6.45%.

4.1.1.4 Students' perception on the learning unit

The interviews focused mainly on students' satisfaction. The students stated that the learning unit helped them acquire knowledge by doing instead of only listening to the lecture. They also felt that problem used in the learning unit was relevant to their life. Moreover, the students said that they gained knowledge from group learning. However, the students voiced that more time should be given. Examples of students' comments were shown in the following excerpts:

"I enjoyed this learning unit because it related to my life."

"I like to learn about plant diseases because my vegetable plantation has problem about plant diseases."

"The biocontrol unit is very interesting and motivates me to learn."

"Biocontrol knowledge gained from this unit can be exploited to solve real-life problems."

"We enjoyed sharing ideas with my friends during group mate."

"My friends helped in explaining and constructing knowledge within group."

"The time allocated for the biocontrol unit was not enough. I could have produced more work if more time were given."

"I really enjoyed learning through this activity and would like to spend more time on it."

B. Results from classroom observation

Results from classroom observation revealed that the students have never been taught by the STS approach, although the school used a few local topics and examples of local problems in some parts of the curriculum. The students were also not familiar with the teaching process based on inquiry approach. They were mainly taught by traditional type of either lecture or laboratory. Thus, the teacher had to use much more time than expected in implementation of the STS-based learning unit. The students although liked to work in group, they did not really know how to work cooperatively for better learning. They would need guidance from teacher. These students had no or little experience in performing scientific experiment and thus had difficulty in acquiring the scientific technique and in producing acceptable results. The students were also not familiar with the test question on the high level of Bloom taxonomy and had problem in application of knowledge as well as higher thinking and/or systematic thinking. For the assessment tools on concept mapping, the students did not know how to draw a proper concept map with systematic linking. Nevertheless, the students had positive attitude of the learning unit because they realized that the knowledge gained could be used in the real-life situation.

C. Modification of the STS-based learning unit from pilot study's results

The lesson learned from the pilot study was used to modify the STS-based learning unit for better effectiveness for students. In the process of modification, teachers from five schools, experts in science education, educators of educational districts, local sages, community people including agriculturists were invited to join the process. The advantages and drawbacks of the learning unit were thoroughly discussed for improvement. There were three main points that should be modified: the laboratory experiment, the details of the learning process, and the assessment tools. The laboratory experiment should be simplified to suit students with rather low background in scientific experiment. The content of laboratory experiment and time allocated should be balanced. In the learning process, although teacher should act as facilitator they should also put their hands upon request or necessary. Some students would need more guidance than the others. The students needed time for adaptation to the new type of learning process. For the assessment, the conceptual test and questionnaire had to be modified for better reliability, validity and in terms of difficulty index. For the concept map, students needed to train how to write a proper concept map.

Since the researcher intended not to implement the learning unit by herself, but the school teachers should do it themselves. Thus, there was a need for those teachers to be trained on the above points as well.

4.2 Results from an STS-Based Learning Unit on Biocontrol for Secondary Students from Five Schools

In order to determine the effectiveness of the STS-based learning unit, the results from conceptual knowledge test, concept map, experimental skill test, students' document, and classroom observation were utilized to evaluate students' achievements. The questionnaire was employed to measure students' attitude toward natural environment and on students' perception on the learning unit.

4.2.1 Effects of the STS-based learning unit on students' understanding

The STS-based learning unit was implemented with grade nine students from two schools (schools B and C) in the first semester of 2009 and three schools (schools A, D, and E) in the first semester of 2010 academic year. The conceptual knowledge test and concept map were used to measure the students' understanding of biocontrol. The students in the experimental group received the STS-based learning unit, while those in the control group were taught with the traditional lecture.

4.2.1.1 Students' conceptual knowledge on biocontrol

The mean pre-test scores on conceptual knowledge test of the five schools are shown in Table 4-5.

Table 4-5 Mean scores of pre-test on conceptual knowledge test (CKT) from five schools

Topic	**School A**		**School B**		**School C**		**School D**		**School E**	
	Trad Mean (SD)	**Expt Mean (SD)**	**Trad Mean (SD)**	**Expt Mean (SD)**	**Trad Mean (SD)**	**Expt Mean (SD)**	**Trad Mean (SD)**	**Expt Mean (SD)**	**Trad Mean (SD)**	**Expt Mean (SD)**
Biocontrol concept (55)	27.31 (5.83)	26.75 (5.89)	23.15 (6.48)	24.40 (6.01)	15.32 (2.98)	16.48 (3.58)	16.66 (3.41)	17.17 (3.66)	17.66 (3.03)	18.27 (2.89)
	t = 0.43		*t* = 0.84		*t* = 1.60		*t* = 0.57		*t* =0.81	
Harm of pesticides (15)	10.69 (2.64)	10.95 (2.88)	7.62 (2.75)	8.03 (2.61)	5.93 (1.85)	4.90 (1.41)	5.38 (1.60)	4.20 (1.83)	5.69 (1.54)	6.04 (1.93)
	t = 0.42		*t* = 0.73		*t* = 2.84		*t* = 2.69		*t* = 0.75	
Conservation of environment (30)	18.90 (4.17)	17.35 (4.68)	14.10 (4.40)	13.51 (3.77)	12.90 (2.53)	13.76 (2.83)	13.41 (2.46)	13.27 (2.48)	14.24 (2.75)	13.70 (2.35)
	t = 1.59		*t* = 1.21		*t* = 1.46		*t* = 0.22		*t* = 0.78	
Total (100)	56.90 (8.65)	55.05 (10.56)	44.87 (11.53)	45.94 (8.67)	34.15 (5.24)	35.14 (5.46)	35.44 (4.37)	34.63 (5.16)	37.59 (4.63)	38.04 (2.89)
	t = 0.87		*t* = 0.46		*t* = 0.85		*t* = 0.66		*t* = 0.43	

There was no significant difference in the pre-test scores on CKT between the experimental and traditional groups of the five schools. Similar results were found in each of the three topics, i.e., biocontrol concept, harm of pesticides, and conservation of environment. However, the mean pre-test scores in each school were different. The highest mean scores of the pre-test was found in school A, followed by those of school B, school E, and Schools C, and D, respectively.

The One - Way Analysis of Variance (One - Way ANOVA) was used to compare the difference of the mean pre-test scores among groups. The results of data analysis are shown in Table 4-6.

Table 4-6 Analysis of variance results for pre-test scores of the experimental group

Test	**Source**	**SS**	**df**	**MS**	**F**	**Sig.**
Biocontrol concept	Between Group	3219.99	4	804.99	36.61	.000*
	Within Group	3716.17	169	21.99		
	Total	6936.17	173			
Harm of pesticides	Between Group	1105.66	4	276.41	56.27	.000*
	Within Group	830.25	169	4.91		
	Total	1935.91	173			
Conservation of environment	Between Group	443.97	4	110.99	9.44	.000*
	Within Group	1986.96	169	11.76		
	Total	2430.93	173			
Total	Between Group	4138.79	4	1034.70	10.94	.000*
	Within Group	15979.93	169	94.56		
	Total	20118.72	173			

*Significant difference (p<0.05)

The results from one - way ANOVA (Some of Squares: 4138.79; df: 4; Mean Square: 1034.70; F: 10.94; Sig.: 0.000) suggested a significant difference between the experimental group students of the five school (p<0.05). Multiple comparisons among the five schools suggested a statistically significant difference of the experimental students between school A, school B, school C, school D, and school E (p< 0.05). There was statistically significant difference between school A, school B, school C, school D, and school E. The results showed that school A had the highest mean scores in topics on harm of pesticides and conservation of environment. The results indicated that school A seemed to be at high achievement level when compared to those of schools B, school C, school C, and school E.

The post-test scores in each topic of CKT of the five schools are shown in Table 4-7. The mean post-test scores on CKT of all experimental groups from the five schools were significantly higher than those of all traditional groups. Similar results were observed in each of the three related topics on biocontrol concept, harm of pesticides, and conservation of environment.

Table 4-7 Mean scores of post-test on conceptual knowledge test (CKT) from five schools

Topic	**School A**		**School B**		**School C**		**School D**		**School E**	
	Trad Mean (SD)	**Expt Mean (SD)**	**Trad Mean (SD)**	**Expt Mean (SD)**	**Trad Mean (SD)**	**Expt Mean (SD)**	**Trad Mean (SD)**	**Expt Mean (SD)**	**Trad Mean (SD)**	**Expt Mean (SD)**
Biocontrol concept (55)	35.79 (3.95)	39.58 (4.21)	29.38 (4.64)	38.09 (8.04)	26.56 (4.44)	36.98 (7.26)	26.19 (7.54)	39.87 (5.18)	22.72 (4.28)	29.85 (4.04)
	$t = 4.20^{***}$		$t = 3.69^{***}$		$t = 7.91^{***}$		$t = 8.27^{***}$		$t = 6.39^{***}$	
Harm of pesticides (15)	11.69 (2.28)	12.23 (2.02)	8.31 (2.17)	10.97 (1.76)	9.17 (2.56)	10.76 (2.59)	7.88 (2.15)	11.23 (3.31)	9.59 (3.11)	11.67 (2.97)
	$t = 1.12^{***}$		$t = 1.03^{***}$		$t = 2.76^{***}$		$t = 4.71^{***}$		$t = 2.55^{*}$	
Conservation of environment (30)	24.12 (2.64)	24.93 (2.98)	20.79 (4.86)	21.86 (4.55)	17.32 (5.60)	19.48 (4.93)	17.44 (3.15)	20.60 (3.32)	18.62 (3.09)	20.11 (3.00)
	$t = 1.29^{***}$		$t = 1.68^{***}$		$t = 1.87^{***}$		$t = 3.85^{***}$		$t = 1.83^{*}$	
Total (100)	71.59 (5.41)	76.73 (7.52)	58.49 (9.66)	70.89 (12.69)	53.05 (9.47)	67.21 (11.42)	51.50 (9.68)	71.70 (8.11)	50.93 (6.82)	61.63 (6.34)
	$t = 3.56^{***}$		$t = 4.68^{***}$		$t = 6.16^{***}$		$t = 8.85^{***}$		$t = 6.06^{***}$	

*Significant difference ($p<0.05$)
***Significant difference ($p<0.001$)

The highest mean scores of post-test in the experimental group was found in school A, followed by those of school D, school B, school C, and school E, respectively.

The One - Way Analysis of Variance (One - Way ANOVA) was used to compare the difference of the mean post-test scores among groups. The results of data analysis are shown in Table 4-8.

Table 4-8 Analysis of variance results for secondary students' post-test scores of the experimental group among group

Test	Source	SS	df	MS	F	Sig.
Biocontrol concept	Between Group	1929.37	4	481.59	13.02	.000*
	Within Group	6250.37	169	36.98		
	Total	8176.74	173			
Harm of pesticides	Between Group	53.26	4	13.31	2.07	.000*
	Within Group	1086.93	169	6.43		
	Total	1140.19	173			
Conservation of environment	Between Group	720.76	4	180.19	11.72	.000*
	Within Group	2598.72	169	15.38		
	Total	3319.48	173			
Total	Between Group	11372.02	4	2843.004	52.69	.000*
	Within Group	9118.86	169	53.96		
	Total	20490.87	173			

*Significant difference (p<0.05)

Results from one-way ANOVA for the relationships between the group (Sum of Squares: 11372.02; df: 4; Mean Square: 2843.004; F: 52.69; Sig.: 0.000) suggested a statistically significant difference in total scores between the experimental groups from the five schools (p<0.05). Multiple comparisons among the five schools suggested a statistically significant difference of the experimental students between school A, school B, school C, school D, and school E (p< 0.05). In the topic of biocontrol concepts, school D had the highest mean scores, followed by school A, school B, school C, and school E, respectively. In the topic of harm of pesticides, school A had the highest mean scores, followed by school E, school D, school B, and school C, respectively. In the topic of conservation of environment, school A had the highest mean scores, followed by school B, school D, school E, and school C, respectively. School A was the high achiever while schools C and D seemed to be the low achievers.

The mean pre-test and post-test scores of CKT of the experimental group from the five schools are presented in Table 4-9.

Table 4-9 Comparison of the pre-test and post-test between experimental groups from five schools

Topic	School A		School B		School C		School D		School E	
	Pre Mean (SD)	Post Mean (SD)	Pre Mean (SD)	Post Mean (SD)	Pre Mean (SD)	Post Mean (SD)	Pre Mean (SD)	Post Mean (SD)	Pre Mean (SD)	Post Mean (SD)
Biocontrol concept (55)	26.75 (5.89)	39.58 (4.21)	24.40 (6.01)	38.09 (8.04)	16.48 (3.58)	36.98 (7.26)	17.17 (3.66)	39.87 (5.18)	18.27 (2.89)	29.85 (4.04)
	$t = 14.79^{***}$		$t = 9.09^{***}$		$t = 17.61^{***}$		$t = 17.68^{***}$		$t = 13.55^{***}$	
	<g> = 0.45		<g> = 0.45		<g> = 0.53		<g> = 0.60		<g> = 0.32	
Harm of pesticides (15)	10.95 (2.88)	12.23 (2.02)	8.03 (2.61)	10.97 (1.76)	4.90 (1.41)	10.76 (2.59)	4.20 (1.83)	11.23 (3.31)	6.04 (1.93)	11.67 (2.97)
	$t = 4.01^{***}$		$t = 5.06^{***}$		$t = 13.32^{***}$		$t = 9.23^{***}$		$t = 8.28^{***}$	
	<g> = 0.32		<g> = 0.42		<g> = 0.58		<g> = 0.65		<g> = 0.63	
Conservation of environment (30)	17.35 (4.68)	24.93 (2.98)	13.51 (3.77)	21.86 (4.55)	13.76 (2.83)	19.48 (4.93)	13.27 (2.48)	20.60 (3.32)	13.70 (2.35)	20.11 (3.00)
	$t = 10.65^{***}$		$t = 7.79^{***}$		$t = 6.88^{***}$		$t = 10.55^{***}$		$t = 9.48^{***}$	
	<g> = 0.60		<g> = 0.51		<g> = 0.35		<g> = 0.44		<g> = 0.39	
Total (100)	55.05 (10.56)	76.73 (7.52)	45.94 (8.67)	70.89 (12.69)	35.14 (5.46)	67.21 (11.42)	34.63 (5.16)	71.70 (8.11)	38.04 (2.89)	61.63 (6.34)
	$t = 15.07^{***}$		$t = 10.66^{***}$		$t = 18.53^{***}$		$t = 18.95^{***}$		$t = 17.07^{***}$	
	<g> = 0.48		<g> = 0.46		<g> = 0.49		<g> = 0.57		<g> = 0.39	

***Significant difference ($p<0.001$)

The results in Table 4-9 showed that the post-test scores of total CKT of the experimental group were significantly higher than those of the pre-test scores in all five schools studied. When the results between pre-test and post-test in all three topics were compared, all the post-test scores were significantly higher than those of the pre-test scores.

The One - Way Analysis of Variance (One - Way ANOVA) was used to compare the difference of the mean pre-test and post-test scores among groups. The results of data analysis are shown in Table 4-10.

Table 4-10 Analysis of variance results for secondary students' pre-test and post-test scores of the experimental group among group

Test	Source	SS	df	MS	F	Sig.
Pre-test	Between Group	4138.79	4	1034.70	10.94	.000*
	Within Group	15979.93	169	94.56		
	Total	20118.72	173			
Post-test	Between Group	11372.02	4	2843.004	52.69	.000*
	Within Group	9118.86	169	53.96		
	Total	20490.87	173			

*Significant difference ($p<0.05$)

The results of pre-test from one - way ANOVA (Sum of Squares: 4138.79; df: 4; Mean Square: 1034.70; F: 10.94; Sig.: 0.000) suggested a significant difference between the experimental students of the five school ($p<0.05$).

In the post-test, results from one-way ANOVA for the relationships between the group (Sum of Squares: 11372.02; df: 4; Mean Square: 2843.004; F: 52.69; Sig.: 0.000) suggested a statistically significant difference in total scores between the experimental groups from the five schools ($p<0.05$). The results found that each school showed different results in different topics.

The normalized gain scores derived from pre-test and post-test score of the experimental groups from the five schools are shown in Table 4-11.

Table 4-11 Pre-test and post-test mean scores, and normalized gains of the five school students in the STS-based learning unit

School	N	Mean ± SD		*t*	<g>
		Pre-test (100)	Post-test (100)		
A	40	55.05 ± 10.56	76.73 ± 7.52	15.07***	0.48
B	35	45.94 ± 8.67	70.86 ± 12.69	10.66***	0.46
C	42	35.14 ± 5.46	67.21 ± 11.42	18.53***	0.49
D	30	34.63 ± 5.16	71.70 ± 8.11	18.95***	0.57
E	27	38.04 ± 2.89	61.63 ± 6.34	17.07***	0.39

The highest normalized gain scores were found in school D, followed by these of school C, school A, school B, and school E, respectively. The results found on each of the three related topics are shown in Table 4-12.

Table 4-12 Pre-test and post-test mean scores and normalized gains for each item

Item	**School**	**Mean ± SD**		***t***	**<g>**
		Pre-test	**Post-test**		
Biocontrol concept (55)	A	26.75 ± 5.89	39.58 ± 4.21	14.79^{***}	0.45
	B	24.40 ± 6.01	38.09 ± 8.04	9.09^{***}	0.45
	C	16.48 ± 3.58	36.98 ± 7.26	17.61^{***}	0.53
	D	17.17 ± 3.66	39.87 ± 5.18	17.68^{***}	0.60
	E	18.29 ± 2.89	29.85 ± 4.04	13.55^{***}	0.32
Harm of pesticides (15)	A	10.95 ± 2.88	12.23 ± 2.02	4.01^{***}	0.32
	B	8.03 ± 2.61	10.97 ± 1.76	5.06^{***}	0.42
	C	4.90 ± 1.41	10.76 ± 2.59	13.32^{***}	0.58
	D	4.20 ± 1.83	11.23 ± 3.31	9.23^{***}	0.65
	E	6.04 ± 1.93	11.67 ± 2.97	8.28^{***}	0.63
Conservation (30)	A	17.35 ± 4.68	24.93 ± 2.98	10.65^{***}	0.60
	B	13.51 ± 3.77	21.80 ± 4.55	7.79^{***}	0.51
	C	13.76 ± 2.83	19.48 ± 4.93	6.88^{***}	0.35
	D	13.27 ± 2.48	20.60 ± 3.32	10.55^{***}	0.44
	E	13.70 ± 2.35	20.11 ± 3.00	9.48^{***}	0.39

The normalized gain scores in the topics of biocontrol concept and harm of pesticides were highest in school D when compared to other schools.

In topic of conservation, the highest normalized gain scores were found in school A, when compared to other schools. The results showed that the learning unit with authentic problem encouraged the students to learn.

4.2.1.2 Concept maps on biocontrol of plant diseases and insect pests

The mean scores of pre concept map of the experimental and traditional groups from the five schools are shown in Table 4-13.

Table 4-13 Mean scores of pre concept map from five schools

Topic	**School A**		**School B**		**School C**		**School D**		**School E**	
	Trad Mean (SD)	**Expt Mean (SD)**	**Trad Mean (SD)**	**Expt Mean (SD)**	**Trad Mean (SD)**	**Expt Mean (SD)**	**Trad Mean (SD)**	**Expt Mean (SD)**	**Trad Mean (SD)**	**Expt Mean (SD)**
Content (5)	1.83 (0.44)	1.70 (0.46)	1.54 (0.51)	1.74 (0.44)	1.46 (0.50)	1.50 (0.51)	1.47 (0.57)	1.33 (0.55)	1.17 (0.38)	1.48 (0.51)
	t = 1.34		t = 1.85		t = 0.33		t = 0.96		t = 2.55	
Understanding (5)	1.62 (0.49)	1.58 (0.55)	1.62 (0.49)	1.49 (0.51)	1.68 (0.47)	1.64 (0.48)	1.59 (0.56)	1.60 (0.56)	1.48 (0.51)	1.67 (0.48)
	t = 0.38		t = 1.12		t = 0.38		t = 0.04		t = 1.39	
Presentation (5)	1.43 (0.63)	1.65 (0.77)	1.54 (0.68)	1.74 (0.61)	1.24 (0.49)	1.36 (0.73)	1.19 (0.64)	1.17 (0.65)	1.41 (0.50)	1.48 (0.51)
	t = 1.43		t = 1.35		t = 0.83		t = 0.12		t = 0.50	
Total (15)	4.88 (1.04)	4.93 (1.16)	4.69 (1.15)	4.97 (1.07)	4.39 (0.95)	4.50 (1.23)	4.25 (1.41)	4.10 (1.40)	4.07 (1.03)	4.63 (1.18)
	t = 0.18		t = 1.10		t = 0.45		t = 0.42		t = 1.89	

There was no significant difference in the mean scores of pre concept map between the experimental and traditional groups of five schools. Similar results were found in each of the three topics, i.e., content, understanding, and presentation. The total mean scores of pre concept map of the five schools were very low in both experimental and traditional groups ranged from 4.07 to 4.93 (out of 15)

The One - Way Analysis of Variance (One - Way ANOVA) was used to compare the difference of the mean pre concept map scores among groups. The results of data analysis are shown in Table 4-14.

Table 4-14 Analysis of variance results for grade nine students' pre concept map scores of the experimental group

Test	Source	SS	df	MS	F	Sig.
Content	Between Group	3.81	4	.95	3.93	.004*
	Within Group	40.99	169	.24		
	Total	44.81	173			
Understanding	Between Group	.67	4	.17	.62	.647
	Within Group	45.36	169	.27		
	Total	46.03	173			
Presentations	Between Group	7.14	4	1.79	3.95	.004*
	Within Group	76.34	169	.45		
	Total	83.48	173			
Total	Between Group	16.67	4	4.17	2.85	.026*
	Within Group	247.24	169	1.46		
	Total	263.91	173			

*Significant difference (p<0.05)

The results from one - way ANOVA (Sum of Squares: 16.67; df: 4; Mean Square: 4.17; F: 2.85; Sig.: 0.026) suggested a significant difference between the experimental groups of the five school (p<0.05). Multiple comparisons among the five schools on content and presentation topics suggested a statistically significant difference of the experimental group between school A, school B, school C, school D, and school E (p< 0.05). However, in the topic of understanding, there were no significant differences between the five schools.

The mean scores of post concept map of experimental and traditional groups of the five schools are shown in Table 4-15. In all five schools, the mean scores of the experimental groups were significantly higher than those of the traditional groups. Similar results were observed in each of the three related topics on content, understanding, and presentation.

Table 4-15 Mean scores of post concept map on conceptual knowledge from five schools

Criteria	School A		School B		School C		School D		School E	
	Trad Mean (SD)	Expt Mean (SD)	Trad Mean (SD)	Expt Mean (SD)	Trad Mean (SD)	Expt Mean (SD)	Trad Mean (SD)	Expt Mean (SD)	Trad Mean (SD)	Expt Mean (SD)
Content (5)	3.40 (0.59)	4.22 (0.62)	2.79 (0.47)	3.91 (0.61)	2.88 (0.64)	3.36 (0.62)	2.53 (0.67)	3.63 (0.81)	2.28 (0.48)	3.30 (0.47)
	$t = 6.16^{***}$		$t = 8.88^{***}$		$t = 3.47^{**}$		$t = 5.85^{***}$		$t = 8.29^{***}$	
Understanding (5)	3.36 (0.76)	4.08 (0.62)	3.00 (0.51)	3.94 (0.42)	3.51 (0.51)	3.55 (0.63)	2.69 (0.86)	3.90 (0.80)	3.21 (0.41)	3.85 (0.53)
	$t = 4.69^{***}$		$t = 8.62^{***}$		$t = 0.28$		$t = 5.73^{***}$		$t = 5.08^{***}$	
Presentation (5)	3.14 (0.61)	4.05 (0.68)	3.92 (0.66)	4.62 (0.57)	3.32 (0.69)	3.60 (0.70)	2.84 (1.30)	4.03 (0.85)	3.14 (0.79)	4.56 (0.51)
	$t = 6.39^{***}$		$t = 2.32^{***}$		$t = 1.83^{*}$		$t = 4.29^{***}$		$t = 7.93^{***}$	
Total (15)	9.90 (1.59)	12.35 (1.49)	9.72 (1.17)	12.11 (1.16)	9.71 (1.17)	10.50 (1.58)	8.06 (2.70)	11.57 (1.87)	8.62 (0.94)	11.70 (0.99)
	$t = 7.17^{***}$		$t = 8.85^{***}$		$t = 2.59^{**}$		$t = 5.90^{***}$		$t = 11.93^{***}$	

*Significant difference ($p<0.05$)
**Significant difference ($p<0.01$)
***Significant difference ($p<0.001$)

In the experimental group, the highest scores were found in school A, followed by those of school B, school E, school D, and school C, respectively.

The One – Way Analysis of Variance (One – Way ANOVA) was used to compare the difference of the mean post concept map scores among groups. The results of data analysis are shown in Table 4-16.

Table 4-16 Analysis of variance results for secondary students' post concept map scores of the experimental group

Test	Source	SS	df	MS	F	Sig.
Content	Between Group	22.09	4	5.52	13.74	.000*
	Within Group	67.96	169	.40		
	Total	90.05	173			
Understanding	Between Group	6.24	4	1.56	4.17	.003*
	Within Group	63.17	169	.37		
	Total	69.41	173			
Presentations	Between Group	17.09	4	4.27	9.46	.000*
	Within Group	76.34	169	.45		
	Total	93.43	173			
Total	Between Group	82.83	4	20.71	9.66	.000*
	Within Group	362.14	169	2.14		
	Total	444.97	173			

*Significant difference ($p<0.05$)

The results from one - way ANOVA (Sum of Squares: 82.23; df: 4; Mean Square: 20.71; F: 9.66; Sig.: 0.000) suggested a significant difference between the experimental groups of the five schools ($p<0.05$).

The mean scores of pre and post concept map of the experimental group from the five schools are presented in Table 4-17.

Table 4-17 Comparison of the mean scores of pre and post concept map of the experimental group from five schools

Criteria	**School A**		**School B**		**School C**		**School D**		**School E**	
	Pre Mean (SD)	**Post Mean (SD)**	**Pre Mean (SD)**	**Post Mean (SD)**	**Pre Mean (SD)**	**Post Mean (SD)**	**Pre Mean (SD)**	**Post Mean (SD)**	**Pre Mean (SD)**	**Post Mean (SD)**
Content (5)	1.70 (0.46)	4.22 (0.62)	1.74 (0.44)	3.91 (0.61)	1.50 (0.51)	3.36 (0.62)	1.33 (0.55)	3.63 (0.81)	1.48 (0.51)	3.30 (0.47)
	$t = 18.22^{***}$		$t = 15.63^{***}$		$t = 15.37^{***}$		$t = 13.76^{***}$		$t = 13.84^{***}$	
	<g> = 0.76		<g> = 0.67		<g> = 0.53		<g> = 0.63		<g> = 0.52	
Understanding (5)	1.58 (0.55)	4.08 (0.62)	1.49 (0.51)	3.94 (0.42)	1.64 (0.48)	3.55 (0.63)	1.60 (0.56)	3.90 (0.80)	1.67 (0.48)	3.85 (0.53)
	$t = 21.05^{***}$		$t = 22.12^{***}$		$t = 15.04^{***}$		$t = 13.23^{***}$		$t = 18.24^{***}$	
	<g> = 0.73		<g> = 0.70		<g> = 0.57		<g> = 0.68		<g> = 0.66	
Presentation (5)	1.65 (0.77)	4.05 (0.68)	1.74 (0.61)	4.62 (0.57)	1.36 (0.73)	3.60 (0.70)	1.17 (0.65)	4.03 (0.85)	1.48 (0.51)	4.56 (0.51)
	$t = 14.36^{***}$		$t = 15.16^{***}$		$t = 15.14^{***}$		$t = 15.58^{***}$		$t = 23.66^{***}$	
	<g> = 0.72		<g> = 0.88		<g> = 0.62		<g> = 0.75		<g> = 0.88	
Total (15)	4.93 (1.16)	12.35 (1.49)	4.97 (1.07)	12.11 (1.16)	4.50 (1.23)	10.50 (1.58)	4.10 (1.40)	11.57 (1.87)	4.63 (1.18)	11.70 (0.99)
	$t = 24.46^{***}$		$t = 22.66^{***}$		$t = 20.61^{***}$		$t = 19.21^{***}$		$t = 25.54^{***}$	
	<g> = 0.74		<g> = 0.71		<g> = 0.57		<g> = 0.69		<g> = 0.69	

***Significant difference ($p<0.001$)

Results in Table 4-17 show that the mean scores of post concept maps of the experimental group were significantly higher than those of the pre concept map in all five schools. The highest mean scores of all attributes were found in school A, followed by those of school B, school E, School D, and school C, respectively.

The One - Way Analysis of Variance (One - Way ANOVA) was used to compare the difference of the mean pre and post concept map scores among groups. The results of data analysis are shown in Table 4-18.

Table 4-18 Analysis of variance results for grade nine students' pre and post concept map scores of the experimental group

Test	Source	SS	df	MS	F	Sig.
Pre-test	Between Group	16.67	4	4.17	2.85	.026*
	Within Group	247.24	169	1.46		
	Total	263.91	173			
Post-test	Between Group	82.83	4	20.71	9.66	.000*
	Within Group	362.14	169	2.14		
	Total	444.97	173			

*Significant difference (*p*<0.05)

After the intervention, the results from one - way ANOVA for the relationships between the groups (Sum of Squares: 82.83; df: 4; Mean Square: 20.71; F: 9.66; Sig.: 0.000) suggested a significant difference in total scores between the experimental students of the five school (*p*<0.05).

The mean scores of concept map from five schools in all attributes are shown in Table 4-19.

Table 4-19 The mean scores of concept map from all five schools in all attributes

criteria	N	Pre concept map		Post concept map		*t*
		Mean	**S.D.**	**Mean**	**S.D.**	
Content (5)	174	1.56	0.51	3.71	0.72	11.73***
Understanding (5)	174	1.59	0.52	3.86	0.63	13.81***
Presentation (5)	174	1.49	0.69	4.06	0.73	15.77***
Total (15)	174	4.64	1.24	11.62	1.60	17.34***

Results in Table 4-19 summarized the mean scores of each attribute in pre and post concept map from five schools. All schools showed similar pattern of each attribute of the concept map, i.e. higher scores were in presentation, followed by understanding and content. The overall pictures of the post concept map showed higher complexity. All concept maps were neat, clear, and legible, has easy-to-follow links. Understanding of biocontrol concepts is demonstrated by a few error links. In content, some concept map has misconception about the example of biocontrol of plant diseases and insect pests.

The normalized gain scores of concept map of the experimental groups from the five schools are presented in Table 4-20.

Table 4-20 Pre and post mean scores of concept map, and normalized gains of students in the five schools

School	**N**	**Mean ± SD**		***t***	**<g>**
		Pre (15 pts)	**Post (15 pts)**		
A	40	4.93 ± 1.16	12.35 ± 1.49	24.46***	0.74
B	35	4.97 ± 1.07	12.11 ± 1.16	22.66***	0.71
C	42	4.50 ± 1.23	10.50 ± 1.58	20.61***	0.57
D	30	4.10 ± 1.40	11.57 ± 1.87	19.21***	0.69
E	27	4.63 ± 1.18	11.70 ± 0.99	25.54***	0.69

The normalized gain scores of concept map from the five schools are shown in Table 4-20. School A showed higher normalized gain scores of concept map, followed by those of school B, school D, school E, and school C, respectively. The normalized gain score of school D is equal to that of school E.

When consider all criteria, higher percentage gain scores of the five schools was in presentation (Table 4-21), followed by those of understanding and content. All schools had the lowest normalized gain scores in the content due to students’ misconception about the example of predators, parasite, and insect pests.

Table 4-21 Pre and post mean scores of concept map and percentage gains for each item

Item	School	Mean ± SD		t	% gain	
		Pre concept map	**Post concept map**		**Each school**	**Mean of 5 schools**
Content (5)	A	1.70 ± 0.46	4.22 ± 0.62	18.22***	50.40	42.68
	B	1.74 ± 0.44	3.91 ± 0.61	15.63***	43.40	
	C	1.50 ± 0.51	3.36 ± 0.62	15.37***	37.20	
	D	1.33 ± 0.55	3.63 ± 0.81	13.76***	46.00	
	E	1.48 ± 0.51	3.30 ± 0.47	13.84***	36.40	
Understanding (5)	A	1.58 ± 0.55	4.08 ± 0.62	21.05***	50.00	46.44
	B	1.49 ± 0.51	3.94 ± 0.42	22.12***	49.00	
	C	1.64 ± 0.48	3.55 ± 0.63	15.04***	38.20	
	D	1.60 ± 0.56	3.90 ± 0.80	13.23***	46.00	
	E	1.67 ± 0.48	3.85 ± 0.53	18.24***	43.60	
Presentation (5)	A	1.65 ± 0.77	4.05 ± 0.68	14.36***	48.00	56.24
	B	1.14 ± 0.61	4.62 ± 0.56	15.16***	69.60	
	C	1.36 ± 0.73	3.60 ± 0.70	15.14***	44.80	
	D	1.17 ± 0.65	4.03 ± 0.85	15.58***	57.20	
	E	1.48 ± 0.51	4.56 ± 0.51	23.66***	61.60	

Examples of the students' pre and post concept maps of the five schools are shown in Figures 4-3 to 4-12.

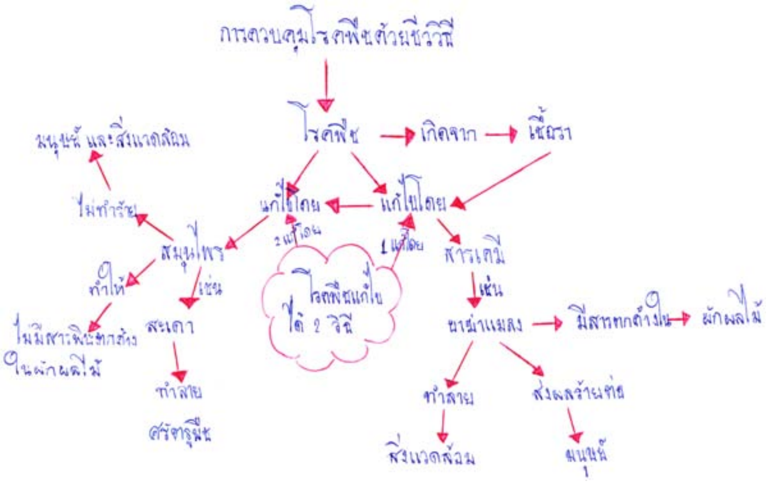

Figure 4-3 Example of pre concept map from school A student

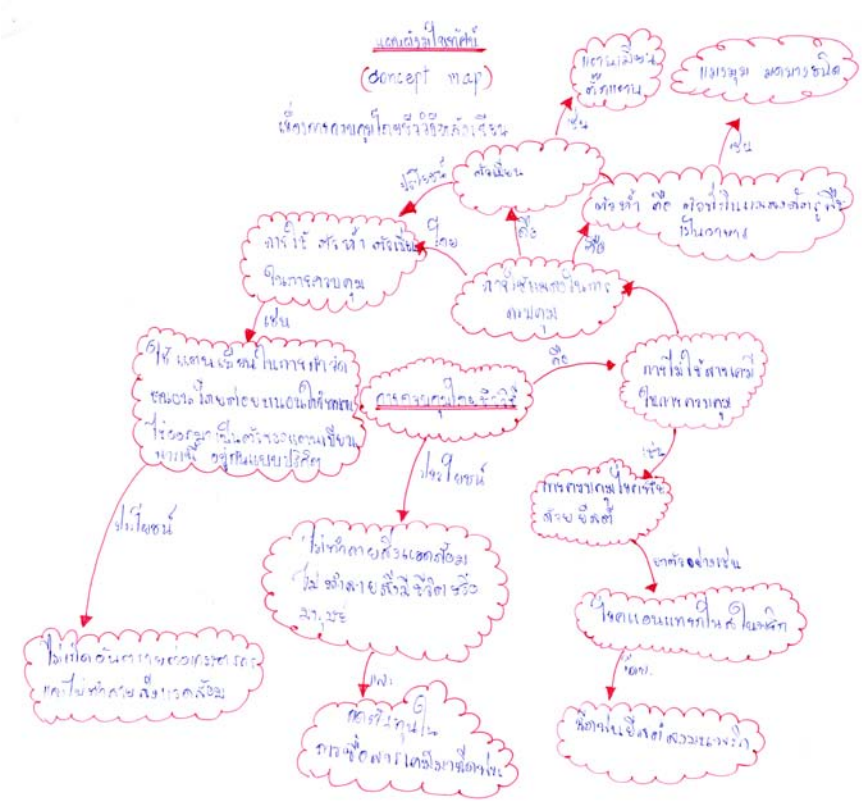

Figure 4-4 Example of post concept map from school A student

Figure 4-5 Example of pre concept map from school B student

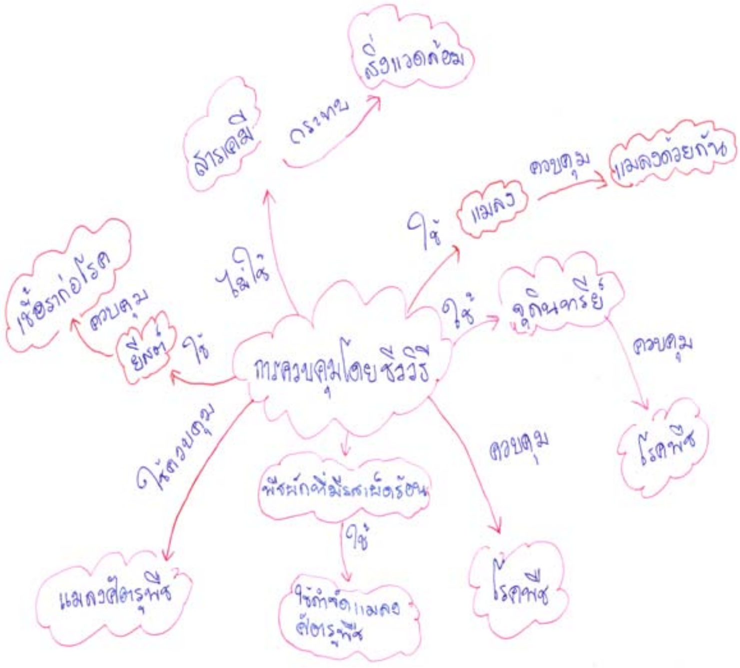

Figure 4-6 Example of post concept map from school B student

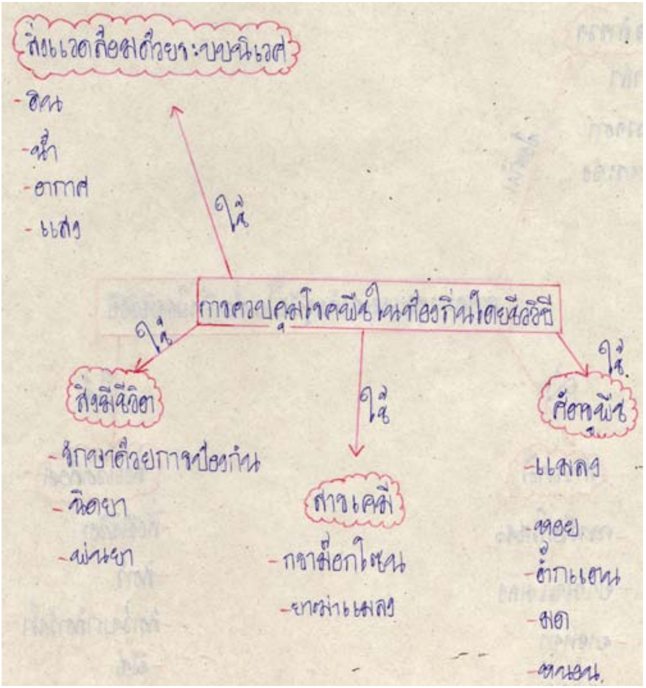

Figure 4-7 Example of pre concept map from school C student

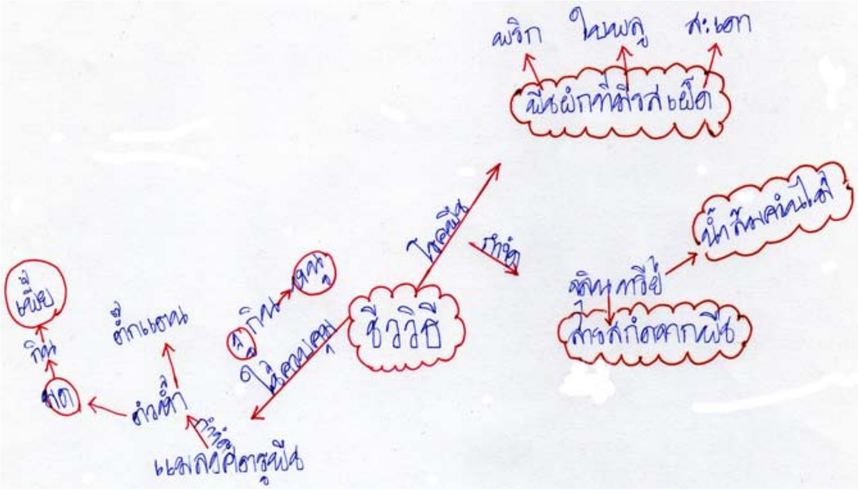

Figure 4-8 Example of post concept map from school C student

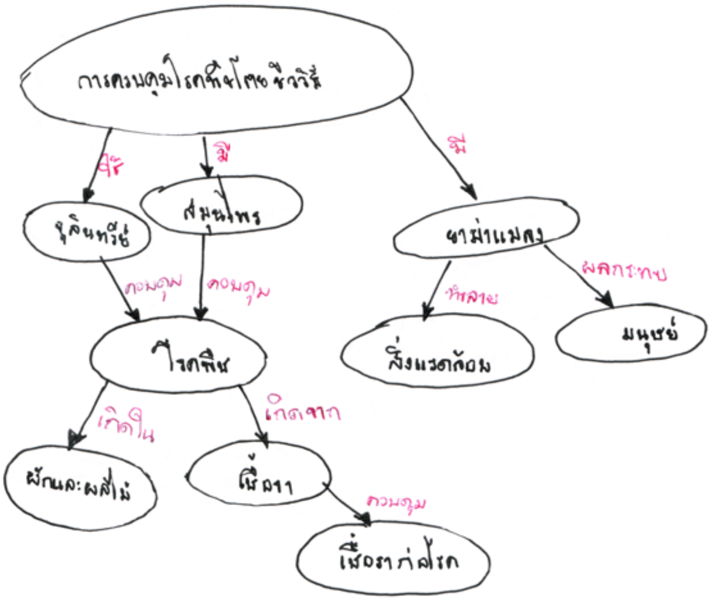

Figure 4-9 Example of pre concept map from school D student

Figure 4-10 Example of post concept map from school D student

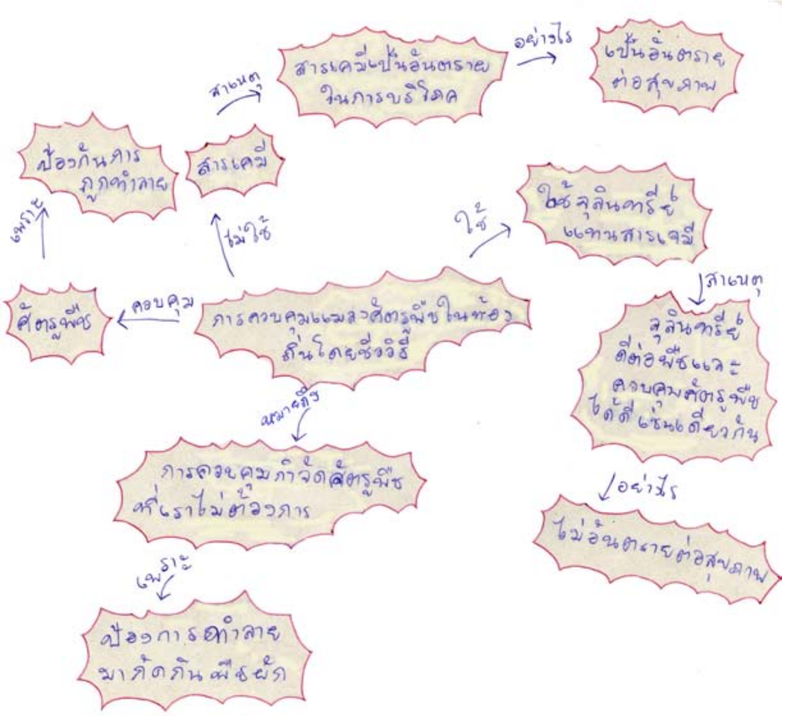

Figure 4-11 Example of pre concept map from school E student

Figure 4-12 Example of post concept map from school E student

4.2.2 Students' experimental skill test (EST) from five schools

The mean scores of pre experimental skill test from the five schools are shown in Table 4-22. In the EST, the students had to read the given scenario and set the hypothesis to questions in the scenario as well as plan the experiment to prove the hypothesis. The students did not conduct experiment in the test; the teachers evaluated their abilities in four criteria (Table 4-22) according to what they wrote in the answer sheet.

Table 4-22 Mean scores of pre EST on biocontrol from five schools

Topic	School A		School B		School C		School D		School E	
	Trad Mean (SD)	**Expt Mean (SD)**	**Trad Mean (SD)**	**Expt Mean (SD)**	**Trad Mean (SD)**	**Expt Mean (SD)**	**Trad Mean (SD)**	**Expt Mean (SD)**	**Trad Mean (SD)**	**Expt Mean (SD)**
Problem and hypothesis (15)	2.14 (1.24)	1.53 (1.41)	2.82 (1.09)	3.20 (2.07)	0.68 (1.08)	0.55 (0.80)	2.31 (1.59)	2.00 (1.78)	2.69 (0.89)	2.96 (1.09)
	t = 2.11		*t* = 0.97		*t* = 0.82		*t* = 0.73		*t* = 1.03	
Identify variables (15)	1.62 (1.27)	2.18 (2.01)	0.64 (1.09)	2.91 (2.05)	0.17 (0.44)	0.14 (0.42)	2.97 (0.82)	3.60 (1.75)	2.24 (1.06)	2.27 (1.20)
	t = 1.49		*t* = 5.86		*t* = 0.30		*t* = 1.79		*t* = 0.18	
Experimental design (15)	1.31 (1.14)	1.55 (1.38)	0.77 (1.11)	0.94 (1.41)	0.15 (0.36)	0.14 (0.33)	1.59 (1.07)	1.17 (0.99)	1.41 (1.27)	1.81 (1.30)
	t = 0.86		*t* = 0.59		*t* = 0.04		*t* = 1.63		*t* = 1.17	
Collect data (15)	0.79 (1.05)	0.98 (1.09)	0.69 (1.06)	0.26 (0.44)	0.20 (0.40)	0.24 (0.26)	1.28 (1.28)	0.83 (1.09)	0.17 (0.78)	0.26 (0.45)
	t = 0.80		*t* = 2.35		*t* = 0.47		*t* = 1.48		*t* = 0.78	
Total (60)	5.86 (3.25)	6.23 (4.35)	4.92 (2.73)	7.31 (4.53)	1.19 (1.71)	1.02 (1.34)	7.81 (3.93)	7.60 (4.49)	6.52 (1.84)	7.33 (2.22)
	t = 0.44		*t* = 2.71		*t* = 0.49		*t* = 0.19		*t* = 1.50	

In each school, there was no significant difference in the pre EST scores between the experimental and traditional groups. Similar results were found in each of the four topics, i.e., problem and hypothesis, identify variables, experimental design, and collect data. When compared the pre EST mean scores in the five schools, the highest mean score was found in school D, while the lowest score was found in school C.

The One - Way Analysis of Variance (One - Way ANOVA) was used to compare the difference of the mean pre EST scores among groups. The results of data analysis are shown in Table 4-23.

Table 4-23 Analysis of variance results for secondary students' pre EST scores of the experimental group

Test	Source	SS	df	MS	F	Sig.
Problem and hypothesis	Between Group	177.84	4	44.46	20.14	.000*
	Within Group	373.04	169	2.21		
	Total	550.87	173			
Identify variables	Between Group	252.85	4	63.21	24.59	.000*
	Within Group	434.49	169	2.57		
	Total	687.34	173			
Experimental design	Between Group	61.14	4	15.28	11.68	.000*
	Within Group	221.17	169	1.31		
	Total	282.31	173			
Collect data	Between Group	18.82	4	4.70	7.90	.000*
	Within Group	100.63	169	.59		
	Total	119.45	173			
Total	Between Group	1199.15	4	299.79	22.61	.000*
	Within Group	2240.69	169	13.26		
	Total	3439.84	173			

*Significant difference (p<0.05)

The results from one - way ANOVA (Sum of Squares: 1199.15; df: 4; Mean Square; 299.79; F: 22.61; Sig.: 0.000) suggested a significant difference between the experimental groups of the five schools (p<0.05). Multiple comparisons among the five schools suggested a statistically significant difference of the experimental groups between school A, school B, school C, school D, and school E (p< 0.05). There was statistically significant difference between school A, school B, school C, school D, and school E.

The post EST of the five schools is shown in Table 4-24. The mean post EST of all experimental students from the five schools was significantly higher than that of all traditional groups. Similar results were observed in each of the four related criteria on problem and hypothesis, identify variables, experimental design, and collect data.

Table 4-24 Mean scores of post EST from five schools

Topic	School A		School B		School C		School D		School E	
	Trad Mean (SD)	**Expt Mean (SD)**	**Trad Mean (SD)**	**Expt Mean (SD)**	**Trad Mean (SD)**	**Expt Mean (SD)**	**Trad Mean (SD)**	**Expt Mean (SD)**	**Trad Mean (SD)**	**Expt Mean (SD)**
Problem and hypothesis (15)	2.57 (1.02)	12.66 (1.75)	2.97 (1.14)	10.51 (2.28)	1.17 (1.30)	10.17 (1.95)	2.94 (1.48)	9.93 (1.95)	3.07 (0.37)	9.26 (1.26)
	$t = 25.38^{***}$		$t = 13.01^{***}$		$t = 19.27^{***}$		$t = 11.32^{***}$		$t = 16.64^{***}$	
Identify variables (15)	2.10 (1.27)	10.45 (1.75)	1.05 (1.17)	9.94 (2.52)	0.22 (0.48)	9.31 (1.89)	3.31 (0.82)	9.63 (2.16)	2.76 (0.64)	8.81 (1.30)
	$t = 18.88^{***}$		$t = 14.81^{***}$		$t = 23.52^{***}$		$t = 10.29^{***}$		$t = 14.65^{***}$	
Experimenting (15)	1.38 (1.17)	10.10 (1.19)	0.82 (1.09)	8.77 (1.72)	0.24 (0.54)	7.21 (1.25)	1.69 (1.12)	7.43 (1.83)	1.45 (1.24)	7.89 (0.97)
	$t = 33.43^{***}$		$t = 17.54^{***}$		$t = 28.19^{***}$		$t = 12.21^{***}$		$t = 14.94^{***}$	
Collect data (15)	0.86 (1.05)	11.38 (1.68)	0.82 (1.02)	8.11 (1.76)	0.19 (0.40)	7.62 (1.15)	1.31 (1.28)	7.93 (1.78)	0.21 (0.49)	7.52 (1.31)
	$t = 27.74^{***}$		$t = 16.00^{***}$		$t = 28.89^{***}$		$t = 11.79^{***}$		$t = 19.79^{***}$	
Total (60)	6.90 (3.07)	44.59 (4.85)	5.67 (2.80)	37.33 (7.34)	1.76 (1.93)	34.31 (5.22)	8.91 (3.62)	34.65 (7.21)	7.48 (1.32)	33.48 (3.95)
	$t = 35.52^{***}$		$t = 17.94^{***}$		$t = 29.68^{***}$		$t = 12.99^{***}$		$t = 22.55^{***}$	

***Significant difference ($p<0.001$)

In Table 4-24, the highest mean scores of the posttest in experimental group was found in school A, followed by those of school B, school D, school C, and school E, respectively.

The One - Way Analysis of Variance (One - Way ANOVA) was used to compare the difference of the mean post EST scores among groups. The results of data analysis are shown in Table 4-25.

Table 4-25 Analysis of variance results for secondary students' post EST scores of the experimental group

Test	Source	SS	df	MS	F	Sig.
Problem and hypothesis	Between Group	237.99	4	59.49	16.68	.000*
	Within Group	602.73	169	3.57		
	Total	840.72	173			
Identify variables	Between Group	50.67	4	12.67	3.24	.014*
	Within Group	660.65	169	3.91		
	Total	711.31	173			
Experimental design	Between Group	461.35	4	115.34	57.03	.000*
	Within Group	341.78	169	2.02		
	Total	803.13	173			
Collect data	Between Group	409.09	4	102.27	42.38	.000*
	Within Group	407.87	169	2.41		
	Total	816.97	173			
Total	Between Group	3976.54	4	994.13	28.91	.000*
	Within Group	5811.17	169	34.39		
	Total	9787.70	173			

*Significant difference ($p<0.05$)

In post EST, results from one-way ANOVA for the relationships between the group (Sum of Squares: 3976.54; df: 4; Mean Square: 994.13; F: 28.91; Sig.: 0.000) suggested a statistically significant difference in total scores between the experimental groups from the five schools ($p<0.05$). Multiple comparisons among the five schools suggested a statistically significant difference of the experimental students between school A, school B, school C, school D, and school E ($p< 0.05$). There was statistically significant difference between school A, school B, school C, school D, and school E.

The mean scores of pre and post EST of the experimental group from the five schools are presented in Table 4-26.

Table 4-26 Comparison of the pre EST and post EST experimental group from five schools

Topic	**School A**		**School B**		**School C**		**School D**		**School E**	
	Pre Mean (SD)	**Post Mean (SD)**	**Pre Mean (SD)**	**Post Mean (SD)**	**Pre Mean (SD)**	**Post Mean (SD)**	**Pre Mean (SD)**	**Post Mean (SD)**	**Pre Mean (SD)**	**Post Mean (SD)**
Problem and hypothesis (15)	1.53 (1.41)	12.66 (1.75)	3.20 (2.07)	10.51 (2.28)	0.55 (0.80)	10.17 (1.95)	2.00 (1.78)	9.93 (1.95)	2.96 (1.09)	9.26 (1.26)
	$t = 15.94^{***}$		$t = 4.76^{***}$		$t = 14.63^{***}$		$t = 7.65^{***}$		$t = 3.76^{**}$	
	<g> = 0.68		<g> = 0.45		<g> = 0.53		<g> = 0.46		<g> = 0.36	
Identify variables (15)	2.18 (2.01)	10.45 (1.68)	2.91 (2.05)	9.94 (2.52)	0.14 (0.42)	9.31 (1.89)	3.60 (1.75)	9.63 (2.16)	2.27 (1.20)	8.81 (1.30)
	$t = 8.17^{***}$		$t = 3.68^{***}$		$t = 14.22^{***}$		$t = 2.27^{*}$		$t = 4.01^{***}$	
	<g> = 0.49		<g> = 0.42		<g> = 0.48		<g> = 0.35		<g> = 0.36	
Experimental design (15)	1.55 (1.38)	10.10 (1.19)	0.94 (1.41)	8.77 (1.72)	0.14 (0.33)	7.21 (1.25)	1.17 (0.99)	7.43 (1.83)	2.27 (1.20)	7.89 (0.97)
	$t = 17.39^{***}$		$t = 7.38^{***}$		$t = 15.15^{***}$		$t = 5.57^{***}$		$t = 3.51^{**}$	
	<g> = 0.64		<g> = 0.41		<g> = 0.41		<g> = 0.38		<g> = 0.28	
Collect data (15)	0.98 (1.09)	11.38 (1.68)	0.26 (0.44)	8.11 (1.76)	0.24 (0.26)	7.62 (1.17)	0.83 (1.09)	7.93 (1.78)	0.26 (0.45)	7.52 (1.31)
	$t = 17.63^{***}$		$t = 8.91^{***}$		$t = 13.25^{***}$		$t = 6.05^{***}$		$t = 9.11^{***}$	
	<g> = 0.59		<g> = 0.40		<g> = 0.36		<g> = 0.36		<g> = 0.35	
Total (60)	6.23 (4.35)	44.59 (4.85)	7.31 (4.53)	37.33 (7.34)	1.02 (1.34)	34.31 (5.29)	7.60 (4.49)	34.65 (7.21)	7.33 (2.22)	33.48 (3.95)
	$t = 20.09^{***}$		$t = 6.76^{***}$		$t = 16.57^{***}$		$t = 6.03^{***}$		$t = 6.67^{***}$	
	<g> = 0.60		<g> = 0.42		<g> = 0.45		<g> = 0.43		<g> = 0.35	

**Significant difference ($p<0.01$)
***Significant difference ($p<0.001$)

As shown in Table 4-26, the post scores on total EST of the experimental group were significantly higher than those of the pre EST scores in all five schools.

The One - Way Analysis of Variance (One - Way ANOVA) was used to compare the difference of the mean pre and post EST scores among groups. The results of data analysis are shown in Table 4-27.

Table 4-27 Analysis of variance results for students' pre EST and post EST scores of the experimental group

Test	Source	SS	df	MS	F	Sig.
Pre EST	Between Group	1199.15	4	299.79	22.61	.000*
	Within Group	2240.69	169	13.26		
	Total	3439.84	173			
Post EST	Between Group	3976.54	4	994.13	28.91	.000*
	Within Group	5811.17	169	34.39		
	Total	9787.70	173			

*Significant difference ($p<0.05$)

Results of post EST from one-way ANOVA for the relationships between the group (Sum of Squares: 3976.54; df: 4; Mean Square: 994.13; F: 28.91; Sig.: 0.000) suggested a statistically significant difference in total scores between the experimental groups from the five schools ($p<0.05$).

The scores of five schools in all criteria are shown in Table 4-28. The results from one - way ANOVA (Sum of Squares: 1199.15; df: 4; Mean Square: 299.79; F: 22.61; Sig.: 0.000) suggested a significant difference between the experimental students of the five schools ($p<0.05$).

Table 4-28 Mean scores of EST from five schools in all criteria

Criteria	N	Pre EST		Post EST		*t*
		Mean	S.D.	Mean	S.D.	
Problem and hypothesis (15)	174	1.92	1.78	10.51	3.23	17.15^{***}
Identify variables (15)	174	2.10	1.99	9.63	3.03	14.97^{***}
Experimental design (15)	174	1.06	1.28	8.28	3.14	14.81^{***}
Collect data (15)	174	0.52	0.83	8.51	3.17	14.94^{***}
Total (60)	174	5.60	4.46	36.87	8.51	23.21^{***}

The normalized gain scores derived from pre and post EST scores of the experimental groups from the five schools are shown in Table 4-29.

Table 4-29 Pre and post mean scores of experimental skill, and normalized gains of students in the five schools

School	N	Mean ± SD		*t*	<g>
		Pre EST (60)	Post EST (60)		
A	40	6.23 ± 4.35	44.59 ± 4.85	20.09^{***}	0.71
B	35	7.31 ± 4.53	37.33 ± 7.34	6.76^{***}	0.57
C	42	1.02 ± 1.34	34.31 ± 5.22	16.57^{***}	0.56
D	30	7.60 ± 4.49	34.65 ± 7.21	6.03^{***}	0.52
E	27	7.33 ± 2.22	33.48 ± 3.95	6.67^{***}	0.50

***Significant difference (p<0.001)

The normalized gain scores of the post EST scores were higher than the pre EST scores from the five schools. The highest normalized gain scores were found in school A, followed by these of school B, school D, school C, and school E, respectively. The results for each of the four criteria were shown in Table 4-30.

Table 4-30 Pre and post mean scores of experimental skill and percentage gains for each item

Item	**School**	**Mean ± SD**		***t***	**% gain**	
		Pre EST	**Post EST**		**Each school**	**Mean of 5 schools**
Problem question and hypothesis (15)	A	1.53 ± 1.41	12.66 ± 1.75	15.94^{***}	74.20	56.39
	B	3.20 ± 2.07	10.51 ± 2.28	4.76^{***}	48.73	
	C	0.55 ± 0.80	10.17 ± 1.95	14.63^{***}	64.13	
	D	2.00 ± 1.78	9.93 ± 1.95	7.65^{***}	52.87	
	E	2.96 ± 1.09	9.26 ± 1.26	3.76^{**}	42.00	
Identify variables (15)	A	2.18 ± 2.01	10.45 ± 1.68	8.17^{***}	51.13	48.99
	B	2.91 ± 2.05	9.94 ± 2.52	3.68^{***}	48.87	
	C	0.14 ± 0.42	9.31 ± 1.95	14.22^{***}	61.13	
	D	3.60 ± 1.75	9.63 ± 2.16	2.27^{*}	40.20	
	E	2.27 ± 1.20	8.81 ± 1.30	4.01^{***}	43.60	
Experimental design (15)	A	1.55 ± 1.38	10.10 ±1.19	17.39^{***}	57.00	47.73
	B	0.94 ± 1.41	8.77 ± 1.72	7.38^{***}	52.20	
	C	0.14 ± 0.33	7.21 ± 1.25	15.15^{***}	47.13	
	D	1.16 ± 0.99	7.43 ± 1.83	5.57^{***}	41.80	
	E	1.81 ± 1.30	7.89 ± 0.97	3.51^{**}	40.53	
Collect data (15)	A	0.98 ± 1.09	11.38 ± 1.68	17.63^{***}	69.33	53.32
	B	0.26 ± 0.44	8.11 ± 1.76	8.91^{***}	52.33	
	C	0.24 ± 0.26	7.62 ± 1.17	13.25^{***}	49.20	
	D	0.83 ± 1.09	7.93 ± 1.78	6.05^{***}	47.33	
	E	0.26 ± 0.45	7.52 ±1.31	9.11^{***}	48.40	

***Significant difference ($p<0.001$)

As shown, in Table 4-30, the higher percentage gain scores of the five schools were on the problem question and hypothesis, followed by those of experimental design and collect data, and identify variables.

4.2.3 Students' laboratory reports

The laboratory reports of students in an STS context were evaluated by rubric scoring using the five criteria. Table 4-31 shows the mean scores of each of the five criteria in the five schools. In all five schools, highest average score was in the hypothesis, while the lowest score was in the discussion and conclusion. This suggested that some students might draw a conclusion that was not based on the data and their discussions are not adequate and/or incomplete. The highest mean score was in school A, followed by those of school B, school E, school D, and school C.

Table 4-31 Mean scores of laboratory reports of experimental students from five schools

Criteria	School A		School B		School C		School D		School E		Average 5 schools	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Hypothesis (5)	4.28	0.51	4..34	0.68	3.59	0.70	3.67	0.71	3.70	0.47	3.93	0.70
Procedure (5)	3.85	0.79	3.66	0.59	3.12	0.55	3.23	0.63	3.19	0.56	3.43	0.69
Results (5)	3.80	0.61	3.49	0.56	2.95	0.44	3.06	0.37	3.11	0.42	3.29	0.59
Discuss & conclusion (5)	3.02	0.57	2.97	0.38	2.26	0.49	2.55	0.89	2.33	0.48	2.63	0.66
Knowledge transfer (5)	3.77	0.57	3.68	0.71	3.45	0.55	3.70	0.70	3.55	0.64	3.63	0.63
Total (25)	18.73	2.16	18.14	1.75	15.38	1.86	16.20	2.64	15.88	1.62	16.92	2.43
Mean (5)*	3.75	0.72	3.62	0.61	3.07	0.56	3.24	0.60	3.17	0.46	3.38	0.65

* 1= beginning, 2= developing, 3 = accomplished, 4= exemplary, and 5 = excellent

Table 4-32 Summary of the mean scores of laboratory reports (*N* = 174)

Criteria	Mean	SD	Quality*
1. Hypothesis	3.93	0.70	Accomplished
2. Procedure	3.43	0.69	Accomplished
3. Results	3.29	0.59	Accomplished
4. Discussion and conclusion	2.63	0.66	Developing
5. Knowledge transfer to community	3.63	0.63	Accomplished
Mean (5)	3.39	0.64	Accomplished

* 1= beginning, 2= developing, 3 = accomplished, 4= exemplary, and 5 = excellent

Table 4-32 summarize the mean scores of each criteria from all five schools. All criteria, except discussion were at the accomplished level. The discussion and conclusion was at developing level from the five schools. However, the overall quality of the reports was in the accomplished level. The students' ability to transfer their knowledge to the community was at the accomplished level.

The One - Way Analysis of Variance (One - Way ANOVA) was used to compare the difference of the mean scores of laboratory report among groups. The results of data analysis are shown in Table 4-33.

Table 4-33 Analysis of variance results for secondary students' laboratory report scores of the experimental group

Test	Source	SS	df	MS	F	Sig.
Hypothesis	Between Group	18.89	4	4.72	12.05	.000
	Within Group	66.27	169	0.39		
	Total	85.17	173			
Procedure	Between Group	15.69	4	3.92	9.92	.000
	Within Group	66.83	169	0.39		
	Total	82.52	173			
Results	Between Group	18.87	4	4.72	19.18	.000
	Within Group	41.58	169	0.24		
	Total	60.46	173			
Discuss & conclusion	Between Group	18.65	4	4.66	13.70	.000
	Within Group	57.53	169	0.34		
	Total	76.19	173			
Knowledge transfer	Between Group	2.57	4	0.64	1.60	.177
	Within Group	67.89	169	0.40		
	Total	70.46	173			
Total	Between Group	326.39	4	81.59	19.71	.000
	Within Group	699.63	169	4.14		
	Total	1026.03	173			

The scores of five schools in all criteria are shown in Table 4-33. The results from one - way ANOVA (Sum of Squares: 326.39; df: 4; Mean Square: 81.59; F: 19.71; Sig.: 0.000) suggested significant difference between the experimental groups of the five schools.

4.2.4 The students' science projects

Groups of students from each school designed and conducted science project by themselves with some consultation from the local sages. Most of the projects are on biocontrol of plant diseases by using natural microorganism. Some projects were on insect pests. Examples of students' science projects are controlling of anthracnose disease in guava by using *S. cerevisea*, using *S. cerevisea* to control the crown rot of banana, using *T. reesei* to control anthracnose disease of tomato, and using the extracts from Holy basil to replace methyl eugenol. The mean scores of students' science projects are shown in Table 4-34.

Table 4-34 Mean scores of each criterion of science projects from five schools

Criteria	**School A**		**School B**		**School C**		**School D**		**School E**		**Average 5 schools**	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Post question & hypothesis (5)	3.80	0.45	4.00	0.82	3.00	0.71	3.50	0.71	3.00	0.00	3.50	0.71
Experimental design (5)	3.60	0.55	3.25	0.50	3.40	0.55	3.50	0.71	2.50	0.71	3.33	0.59
Data analysis (5)	3.60	0.55	3.25	0.50	3.20	0.84	3.00	0.00	3.00	0.00	3.28	0.57
Discuss & conclusion (5)	3.40	0.55	2.75	0.95	2.40	0.55	2.50	0.71	2.00	0.00	2.72	0.75
Presentation (5)	4.40	0.55	3.75	0.96	4.00	0.00	5.00	0.00	4.00	0.00	4.17	0.62
Answer the question (5)	4.00	0.71	4.00	0.82	3.40	0.55	4.00	0.00	4.00	0.00	3.83	0.62
Knowledge transfer (5)	4.00	0.00	4.25	0.50	3.60	0.35	3.50	0.71	3.50	0.71	3.83	0.51
Total (35)	27.00	2.12	25.00	4.83	23.60	1.52	26.50	2.12	22.00	1.41	25.00	3.03
Mean (5)*	3.86	0.57	3.57	0.45	3.37	0.56	3.78	0.58	3.14	0.72	3.57	0.59

* 1= beginning, 2= developing, 3 = accomplished, 4= exemplary, and 5 = excellent

The quality of science projects were evaluated by rubric scoring of the seven criteria (Table 4-34). The average scores range from 3.14 in school E to 3.86 in school A. Most schools had high scores in the presentation, knowledge transfer, and answering questions. The lowest score was in the discussion and conclusion. The results suggested that most groups of students from the five schools were able to transfer the knowledge gained to their communities. The scores of this criteria ranged from 3.50 (schools D and E) to 4.25 (school B). At the end of the project the students had the idea to transfer the knowledge gained or results from the science project to their parents, neighbors, or communities if possible.

The One - Way Analysis of Variance (One - Way ANOVA) was used to compare the difference of the mean scores of science projects among groups. The results of data analysis are shown in Table 4-35.

Table 4-35 Analysis of variance results for secondary students' science projects scores of the experimental group

Test	Source	SS	df	MS	F	Sig.
Pose question & hypothesis	Between Group	3.20	4	0.80	1.96	0.16
	Within Group	5.30	13	0.41		
	Total	8.50	17			
Experimental design	Between Group	1.85	4	0.46	1.44	0.27
	Within Group	4.15	13	0.32		
	Total	6.00	17			
Data analysis	Between Group	0.86	4	0.22	0.58	0.67
	Within Group	4.75	13	0.37		
	Total	5.61	17			
Discuss & conclusion	Between Group	3.96	4	0.99	2.27	0.12
	Within Group	5.65	13	0.44		
	Total	9.61	17			
presentation	Between Group	2.55	4	0.64	2.09	0.14
	Within Group	3.95	13	0.30		
	Total	6.50	17			
Answer the question	Between Group	1.30	4	0.33	0.81	0.53
	Within Group	5.20	13	0.40		
	Total	6.50	17			
Knowledge transfer	Between Group	1.55	4	0.38	1.71	0.21
	Within Group	2.95	13	0.23		
	Total	4.50	17			
Total	Between Group	52.30	4	13.08	1.63	0.22
	Within Group	103.70	13	7.98		
	Total	156.00	17			

The scores of five schools in all criteria are shown in Table 4-35. The results from one - way ANOVA (Sum of Squares: 52.30; df: 4; Mean Square: 13.08; F: 1.64; Sig.: 0.224) suggested no significant difference between the experimental groups of the five schools.

In addition, teachers also observed students' performance (for experimental skills) during their experimentation according to their competencies as listed in Table 3-9 in the "Methodology". The scores given by the teacher ranged from 1 (students plan no experiment) to 7 (students plan all experiment systematically, include an experimental control and no experiment is contradictory). The results from teacher observation of students' experimental skills are shown in Table 4-36.

Table 4-36 Mean scores for level of students' experimental skills as observed by teacher

School	**Mean scores**		
	Min.	**Max.**	**Mean**
A	2	5	4.75
B	2	5	4.25
C	2	4	3.73
D	2	4	3.67
E	2	4	3.15

Experimental skills of students in schools A and B ranged from levels 2 to 5 while those in schools C, D, and E ranged from level 2 to 4. The students in schools A and B were in levels 4 to 5 (as judged from mean scores of 4.75 and 4.25); they had ability to plan all experiments systematically and none of them is contradictory, but there is no experimental control. The students in schools C and D were in levels 3 to 4 (mean scores of 3.73 and 3.67); they had ability to plan more than one experiment, but the experiments are not fully systematically planned and partially contradictory. Most of students in school E had lowest experimental skills in level 3; they had ability to plan more than one experiment, but unsystematically and without an experimental control.

4.2.5 Summary of results of conceptual test and experimental skill test from the five schools

The overall results on conceptual test and experimental skill test of the students from both traditional and experimental groups from the five schools were summarized in Table 4-37. The normalized gain of each item was shown in Table 4-38. After participating in the learning unit, the students from school A seemed to have more conceptual understanding, as measured by conceptual knowledge test and concept mapping, compared to those of the other four schools. The second best seemed to be those of schools B and D, albeit, school D had lower prior knowledge. Students in school C performed a little bit better than those in school E which had lowest pretest scores. Results in Table 4-38 show the normalized gain of all items test of both groups of the students from five schools. Highest normalized gain on conceptual test was found in school A. Similar results were observed in the science process skills which were measured from experiment skill test, laboratory report, science project as well as from classroom observation. Teachers observed the expected science process skills from each learning activity (as shown in Table 3-9 in Methodology) and found that the students from all schools did gain those science process skills, however, to a different extent. The amount gained seemed to corroborate the scores of experimental skill test, laboratory report, and science project. The skills that most students gained were ability to ask question, hypothesize, conduct experiment, collect data, interpret, and communicate. The rather low achievers seemed not to gain their abilities in making conclusion and discussing while the high achievers had gained all the expected skills.

Table 4-37 Comparison of all results from five schools

Assessment test	Mean scores									
	School A		School B		School C		School D		School E	
	Trad	Expt	Trad	Expt	Trad	Expt	Trad	Expt	Trad	Expt
1. Conceptual knowledge test (100 pts.)	71.59	76.73	58.49	70.89	53.05	67.21	51.50	71.70	50.93	61.63
2. Concept map (15 pts.)	9.90	12.35	9.72	12.11	9.71	10.50	8.06	11.57	8.62	11.70
3. Experimental skill test (60 pts.)	6.90	44.59	5.67	37.33	1.76	34.31	8.91	34.65	7.48	33.48
4. Laboratory report (25 pts.)	-	18.73	-	18.14	-	15.38	-	16.20	-	15.88
5. Science project (35 pts.)	-	27.00	-	25.00	-	23.60	-	26.50	-	22.00

Table 4-38 Comparison of the normalized gain scores on assessment tests of the experimental and traditional groups of schools A, B, C, D, and E

Assessment test	Normalized gain									
	School A		School B		School C		School D		School E	
	Trad	Expt	Trad	Expt	Trad	Expt	Trad	Expt	Trad	Expt
1. Conceptual knowledge test (100 pts.)	0.34	0.48	0.25	0.46	0.29	0.49	0.25	0.57	0.21	0.39
2. Concept map (15 pts.)	0.49	0.74	0.48	0.71	0.50	0.57	0.35	0.69	0.42	0.69
3. Experimental skill test (60 pts.)	0.02	0.71	0.01	0.57	0.01	0.56	0.02	0.52	0.02	0.50

4.2.6 Students’ attitude toward natural environment

The questionnaire on attitude toward natural environment (QANE) was used to measure students’ attitude on their local environment. This questionnaire was administered to the students both before and after the intervention. The students’ attitudes toward their local environment are shown in Table 4-39.

Table 4-39 Mean scores of pre QANE of students from five schools

Topic	**School A**		**School B**		**School C**		**School D**		**School E**	
	Trad Mean (SD)	**Expt Mean (SD)**	**Trad Mean (SD)**	**Expt Mean (SD)**	**Trad Mean (SD)**	**Expt Mean (SD)**	**Trad Mean (SD)**	**Expt Mean (SD)**	**Trad Mean (SD)**	**Expt Mean (SD)**
Impact of pesticides (35)	28.33 (5.00)	29.10 (2.15)	25.15 (1.98)	25.49 (3.29)	25.58 (4.09)	27.45 (3.34)	27.63 (3.11)	29.57 (1.96)	29.10 (2.08)	28.55 (2.10)
	t = 0.91		*t* = 0.23		*t* = 2.28		*t* = 2.96		*t* = 0.98	
Impact of biocontrol (30)	20.19 (2.94)	21.15 (1.64)	21.51 (2.22)	21.91 (2.37)	22.29 (2.82)	20.79 (2.20)	20.25 (2.38)	19.87 (2.16)	22.17 (1.95)	20.93 (2.40)
	t = 1.84		*t* = 0.35		*t* = 2.72		*t* = 0.66		*t* = 2.14	
Attitudes (35)	29.38 (4.64)	29.90 (2.79)	26.41 (2.04)	26.77 (2.71)	28.91 (3.46)	28.55 (3.58)	29.03 (3.16)	31.10 (2.29)	31.28 (1.94)	30.67 (2.27)
	t = 0.62		*t* = 0.41		*t* = 0.46		*t* = 2.94		*t* = 1.08	
Total (100)	77.90 (11.00)	80.15 (3.37)	73.08 (4.38)	74.17 (5.81)	76.07 (7.36)	76.79 (6.38)	76.91 (5.78)	80.53 (3.81)	82.55 (4.09)	80.15 (3.96)
	t = 1.26		*t* = 0.92		*t* = 0.47		*t* = 2.94		*t* = 2.23	

Table 4-39 shows the mean scores of each topic of the pre QANE of the two groups of students from five schools. In each school, there was no significant difference in the mean scores between the experimental and traditional groups. The mean scores of pre QANE was rather high ranged from 73% to 82% suggested that most students already had good attitude on impact of biocontrol.

The One - Way Analysis of Variance (One - Way ANOVA) was used to compare the difference of the mean pre QANE scores among groups. The results of data analysis are shown in Table 4-40.

Table 4-40 Analysis of variance for students' pre QANE scores of the experimental group

Topic	Source	SS	df	MS	F	Sig.
Impact of pesticides	Between Group	364.08	4	91.02	12.49	.000*
	Within Group	1230.78	169	7.28		
	Total	1594.86	173			
impact of biocontrol	Between Group	70.49	4	17.62	3.82	.000*
	Within Group	480.23	169	4.62		
	Total	850.72	173			
Attitude	Between Group	409.43	4	102.36	12.66	.000*
	Within Group	1366.88	169	8.09		
	Total	1776.31	173			
Total	Between Group	1069.94	4	267.49	11.04	.000*
	Within Group	4094.02	169	24.23		
	Total	5163.96	173			

*Significant difference (p<0.05)

The results from one - way ANOVA (Sum of Squares: 1069.94; df: 4; Mean Square: 267.49; F: 11.04; Sig.: 0.000) suggested a significant difference between the experimental groups of the five school (p<0.05). Multiple comparisons among the five schools suggested a statistically significant difference in the mean scores of the experimental groups between school A, school B, school C, school D, and school E (p< 0.05).

The post QANE scores in each topic of five schools are shown in Table 4-41. The mean post QANE scores of all experimental groups from the five schools were significantly higher than those of the traditional groups. Similar results were observed in each of the three related topics on the impact of pesticides on human and environment, the impact of biocontrol on human and environment, and attitude to natural environment.

Table 4-41 Mean scores of post QANE from five schools

Criteria	School A		School B		School C		School D		School E	
	Trad Mean (SD)	**Expt Mean (SD)**	**Trad Mean (SD)**	**Expt Mean (SD)**	**Trad Mean (SD)**	**Expt Mean (SD)**	**Trad Mean (SD)**	**Expt Mean (SD)**	**Trad Mean (SD)**	**Expt Mean (SD)**
Impact of pesticides (35)	29.52 (3.76)	30.73 (1.22)	26.03 (3.70)	29.57 (2.44)	28.61 (2.88)	30.62 (2.34)	29.38 (2.69)	31.00 (1.31)	29.84 (1.41)	30.93 (1.38)
	$t = 1.96^{*}$		$t = 3.16^{***}$		$t = 3.49^{**}$		$t = 3.06^{**}$		$t = 2.66^{*}$	
impact of biocontrol (30)	22.33 (2.66)	24.65 (1.72)	22.79 (2.75)	24.63 (2.56)	24.32 (2.67)	24.02 (2.45)	22.84 (3.05)	24.53 (1.98)	23.72 (1.93)	25.70 (1.51)
	$t = 4.71^{***}$		$t = 2.29^{***}$		$t = 0.52$		$t = 2.60^{*}$		$t = 4.26^{***}$	
attitudes (35)	30.05 (3.73)	31.98 (1.99)	27.95 (4.20)	31.46 (2.08)	30.15 (2.22)	30.74 (2.41)	30.47 (2.60)	32.13 (1.83)	31.62 (1.61)	32.37 (1.71)
	$t = 2.93^{**}$		$t = 4.43^{***}$		$t = 1.16$		$t = 2.93^{*}$		$t = 1.69$	
Total (100)	81.90 (9.07)	87.35 (2.93)	76.77 (9.70)	85.66 (4.79)	83.07 (5.89)	85.38 (5.28)	82.69 (6.04)	87.67 (2.95)	85.28 (3.26)	89.00 (3.21)
	$t = 3.70^{***}$		$t = 5.07^{***}$		$t = 1.88^{*}$		$t = 4.16^{***}$		$t = 4.30^{***}$	

*Significant difference ($p<0.05$)
**Significant difference ($p<0.01$)
***Significant difference ($p<0.001$)

The One - Way Analysis of Variance (One - Way ANOVA) was used to compare the difference of the mean post QANE scores among groups. The results of data analysis are shown in Table 4-42.

Table 4-42 Analysis of variance results for students' post QANE scores of the experimental group

Test	Source	SS	df	MS	F	Sig.
Impact of pesticides	Between Group	44.83	4	11.21	3.24	.014*
	Within Group	584.30	169	3.46		
	Total	629.13	173			
impact of biocontrol	Between Group	46.85	4	11.71	2.61	.037*
	Within Group	757.34	169	4.48		
	Total	804.19	173			
Attitude	Between Group	61.45	4	15.36	3.64	.007*
	Within Group	713.54	169	4.22		
	Total	774.99	173			
Total	Between Group	295.25	4	73.81	4.49	.002*
	Within Group	2781.56	169	16.46		
	Total	3076.81	173			

*Significant difference (*p*<0.05)

Results from one-way ANOVA for the relationships between the group (Sum of Squares: 295.25; df: 4; Mean Square: 73.81; F: 4.49; Sig.: 0.002) suggested a statistically significant difference in total scores between the experimental groups from the five schools (*p*<0.05). Multiple comparisons among the five schools suggested a statistically significant difference of the experimental students between school A, school B, school C, school D, and school E (*p*<0.05). There was statistically significant difference between school A, school B, school C, school D, and school E.

The mean scores of pre and post QANE of the experimental groups from the five schools are presented in Table 4-43.

Table 4-43 Comparison of the pre QANE and post QANE of the experimental groups from five schools

Topic	**School A**		**School B**		**School C**		**School D**		**School E**	
	Pre Mean (SD)	**Post Mean (SD)**	**Pre Mean (SD)**	**Post Mean (SD)**	**Pre Mean (SD)**	**Post Mean (SD)**	**Pre Mean (SD)**	**Post Mean (SD)**	**Pre Mean (SD)**	**Post Mean (SD)**
Impact of pesticides (35)	29.10 (2.15)	30.73 (1.22)	25.49 (3.29)	29.57 (2.44)	27.45 (3.34)	30.62 (2.34)	29.57 (1.96)	31.00 (1.31)	28.55 (2.10)	30.93 (1.38)
	$t = 6.38^{***}$		$t = 6.09^{***}$		$t = 6.46^{***}$		$t = 5.58^{***}$		$t = 5.93^{***}$	
	<g> = 0.28		<g> = 0.43		<g> = 0.42		<g> = 0.26		<g> = 0.26	
impact of biocontrol (30)	21.15 (1.64)	24.65 (1.72)	21.91 (2.37)	24.63 (2.56)	20.79 (2.20)	24.02 (2.45)	19.87 (2.16)	24.53 (1.98)	20.93 (2.40)	25.70 (1.51)
	$t = 15.46^{***}$		$t = 4.89^{***}$		$t = 8.47^{***}$		$t = 8.91^{***}$		$t = 11.07^{***}$	
	<g> = 0.40		<g> = 0.34		<g> = 0.35		<g> = 0.46		<g> = 0.53	
attitudes (35)	29.90 (2.79)	31.98 (1.99)	26.77 (2.71)	31.46 (2.08)	28.55 (3.58)	30.74 (2.41)	31.10 (2.29)	32.13 (1.83)	30.67 (2.27)	32.37 (1.71)
	$t = 7.79^{***}$		$t = 7.89^{***}$		$t = 4.59^{***}$		$t = 4.27^{***}$		$t = 4.57^{***}$	
	<g> = 0.41		<g> = 0.57		<g> = 0.34		<g> = 0.26		<g> = 0.40	
Total (100)	80.15 (3.37)	87.35 (2.93)	74.17 (5.81)	85.66 (4.79)	76.79 (6.38)	85.38 (5.28)	80.53 (3.81)	87.67 (2.95)	80.15 (3.96)	89.00 (3.21)
	$t = 14.51^{***}$		$t = 10.66^{***}$		$t = 7.92^{***}$		$t = 11.92^{***}$		$t = 9.64^{***}$	
	<g> = 0.36		<g> = 0.45		<g> = 0.37		<g> = 0.37		<g> = 0.46	

***Significant difference ($p<0.001$)

The results in Table 4-43 showed that the post QANE of the experimental groups were significantly higher than those of the pre QANE in all five schools. The normalized gain ranged from 0.37 in school C to 0.46 in school E. The low normalized gain was observed in the topic on impacts of pesticides, suggested that the students has already realized the importance of this issue.

The One - Way Analysis of Variance (One - Way ANOVA) was used to compare the difference of the mean of pre and post QANE scores among groups. The results of data analysis are shown in Table 4-44.

Table 4-44 Analysis of variance results for secondary students' pre QANE and post QANE scores of the experimental group

Test	Source	SS	df	MS	F	Sig.
Pre QANE	Between Group	1069.94	4	267.49	11.04	.000*
	Within Group	4094.02	169	24.23		
	Total	5163.96	173			
Post QANE	Between Group	295.25	4	73.81	4.49	.002*
	Within Group	2781.56	169	16.46		
	Total	3076.81	173			

*Significant difference (*p*<0.05)

In pre QANE, the results from one - way ANOVA (Sum of Squares: 1069.94; df: 4; Mean Square: 267.49; F: 11.04; Sig.: 0.000) suggested a significant difference between the experimental groups of the five school (*p*<0.05).

Results of post QANE from one-way ANOVA for the relationships between the group (Sum of Squares: 295.25; df: 4; Mean Square: 73.81; F: 4.49; Sig.: 0.002) suggested a statistically significant difference in total scores between the experimental groups from the five schools (*p*<0.05).

The normalized gain scores derived from pre and post QANE of the experimental groups from the five schools are shown in Table 4-45.

Table 4-45 Pre and post mean scores of students' attitude toward natural environment, and normalized gains of students in the five schools

School	N	Mean ± SD		*t*	<g>
		Pre QANE (100 pts)	Post QANE (100 pts)		
A	40	80.15 ± 3.37	87.35 ± 2.93	14.51***	0.36
B	35	74.17 ± 5.81	85.66 ± 4.79	10.66***	0.45
C	42	76.79 ± 6.38	85.38 ± 5.28	7.92***	0.37
D	30	80.53 ± 3.81	87.67 ± 2.95	11.92***	0.37
E	27	80.15 ± 3.96	89.00 ± 3.21	9.64***	0.46

***Significant difference (*p*<0.001)

The normalized gain scores of the post QANE were higher than pre QANE from the five schools. The high normalized gain scores (0.45-0.46) were found in schools E and B. School A, school C, and school D showed similar normalized gain of 0.36-0.37. The results on each of the three related topics are shown in Table 4-46.

Table 4-46 Pre and post mean scores of questionnaire and normalized gains for each item

Item	**School**	**Mean ± SD**		***t***	**<g>**	
		Pre QANE	**Post QANE**		**Each school**	**Mean of 5 schools**
Pesticides (35)	A	29.10 ± 2.15	30.73 ± 1.22	6.38^{***}	0.28	0.33
	B	25.49 ± 3.29	29.57 ± 2.44	6.09^{***}	0.43	
	C	27.45 ± 3.34	30.62 ± 2.34	6.46^{***}	0.42	
	D	29.57 ± 1.96	31.00 ± 1.31	5.58^{***}	0.26	
	E	28.55 ± 2.10	30.93 ± 1.38	5.93^{***}	0.26	
Biocontrol concept (30)	A	21.15 ± 1.64	24.65 ± 1.72	15.46^{***}	0.40	0.42
	B	21.91 ± 2.37	24.63 ± 2.56	4.89^{***}	0.34	
	C	20.79 ± 2.20	24.02 ± 2.45	8.47^{***}	0.35	
	D	19.87 ± 2.16	24.53 ± 1.98	8.91^{***}	0.46	
	E	20.93 ± 2.40	25.70 ± 1.51	11.07^{***}	0.53	
Conservation (35)	A	29.90 ± 2.79	31.98 ± 1.99	7.79^{***}	0.41	0.40
	B	26.77 ± 2.71	31.46 ± 2.08	7.89^{***}	0.57	
	C	28.55 ± 3.58	30.74 ± 2.41	4.59^{***}	0.34	
	D	31.10 ± 2.29	32.13 ± 1.83	4.27^{***}	0.26	
	E	30.67 ± 2.27	32.37 ± 1.71	4.57^{***}	0.40	

***Significant difference ($p<0.001$)

As shown in Table 4-46, the highest normalized gain scores of all five schools were in biocontrol concept, followed by those of conservation of environment, and the impact of pesticides on human and environment.

4.2.7 Students' reflection from five schools

After completing the STS-based learning unit, the students were asked to reflect on what they have learned through their writing. Their answers to the three questions were categorized and reported as percentage of students covering the reflection points. The results summarised in Table 4-47.

Table 4-47 Students' reflection after participating in the STS-based learning process

Questions	Students' reflection	% students covering the reflection points*
How do pesticides impact the environment and human?	- Pesticides harm human's health and the environment (soil surface, ground waters, and other animals).	97.12
	- Pesticides do not harm human, if the farmers do not over use.	2.87
How do biocontrol methods impact the environment and human?	- Biocontrol is a safe method to control the plant disease and insect pests.	97.10
	- Biocontrol does not have negative impact on human and the environment, like the chemical agents.	94.83
What are the activities that support students' learning?	- I enjoy visiting the rice field and learning out-of the classroom	100.00
	- I like to learn with local sages.	97.13
	- Experiment on plant disease control is very interesting because it is relevant to our real life.	42.53
	- Cooperative works in groupmates help our learning, because we can consult each other.	32.76

* number of students = 174 (from five schools)

4.2.8 Semi-structured interviews

The results of semi-structured interviews of five students/school for control and five students/school for experimental groups were described in section 4.2.7.1 - 4.2.7.3.

4.2.8.1 Interviews on students' understanding

The interviewing question focused on lesson learned from the STS-based unit, the interview started with the impact of pesticides on human and environment. Before the intervention, students thought that pesticides harmed only vegetables and fruits, and their residue remained on the plants after spraying. After the intervention, they understood that pesticides were also harmful to the environments and human as well. Excerpts from the students are as follows:

"*I think that the pesticides were harmful to water, soil and my life, so we must not use these agricultural substances*."

"*In the past, I thought that the pesticides affected only the plantation (residue on the plant). After participating in this activity, I realized that pesticides are the important problems for human life and the environment.*"

"*Now, I believe that the pesticides can harm my health and the environment.*"

Regarding the biocontrol concept, before the intervention, the students have little knowledge about biocontrol. Most students thought that biocontrol is the method to control the plant just by using natural extraction such as Neem. After the intervention, they extended their prior knowledge that biocontrol concerned with the use of certain types of living things to suppress growth of other types of living things. The following are excerpts from the students:

"*Biocontrol is the method to control plant diseases and insect pests by using microorganism, predators. This method does not utilize pesticides*."

"*Biocontrol can inhibit the insect pests and plant disease without chemical contamination*."

"*I just know that yeast, bacteria, and fungi can be used to control the plant disease*."

"*Biocontrol is like the organic agriculture but biocontrol uses living things to control other living things, for example, some birds eat the rice's worm.*"

"*I realize that insect pests have both advantages and disadvantages and some insects can control each other*."

4.2.8.2 Students' science process skills

The interview question focused on the students' scientific inquiry skills acquired during their learning in the STS-based unit. It was found that almost all students performed according to the process of scientific inquiry. Excerpts from the students are as follows:

"*After this unit, I could design and conduct experiments for my science project. I formulated my hypothesis based on the problem. I could also identify and control variables*. "

"I could set problems to conduct science project. I understood why we have to conduct the experiment. After I observed plant diseases in the field, I thought I knew how to solve the problems. "

Regarding the students' ability to transfer science process skills to their daily life and community, examples of students' statements are as follows:

"*I brought my knowledge to identify the problems in my community. When I know exactly what the problem is, I can find the way to solve it.*"

"*I can exploit the skills in various ways such as solving the waste water problems and solving the agricultural problems.*"

4.2.8.3 Students' attitude toward natural environment

The interview is related to students' thought on conservation of natural environment from pesticides. All students felt that agriculturists and farmers should use biocontrol method, organic agriculture, and extraction from herb instead of pesticides. Examples from the students' excerpts are as follows:

"*We must persuade our community to find the alternative way to replace the use of pesticides, for example, use biocontrol method, and use predators (natural enemies) to control insect pests*."

"*I must suggest my father not to kill the spiders and birds in the rice fields and the farms*."

Regarding the students' ideas on conserving the environment and natural resources, all students realized that pesticides might cause problems in their community. They would like to protect their families from the toxic substances.

This included the use of pesticide to control mosquitoes, cockroaches, or mice. Some excerpts from the interview are as follows:

“*All agriculturists in Thailand should use biocontrol method instead of chemical agents*.”

“*I think that the agricultural land in most areas of the country should be reformed. The soil and water resources should be protected from pesticides or harmful substances.*”

To the question as to whether the biocontrol of insect pest would have an impact on the environment and human. The interview results revealed that the biocontrol method helps balance the environment. Some excerpts from the interviews are as follows:

“*In biocontrol method, the natural enemies can help control insect pests. Natural enemies themselves also control each others*.”

“*All living things are a part of food chains. They can manage each other along the food chains.*”

Moreover, almost all students would like to help in solving the agricultural problems in their local area by not using chemical agents. Some students have already conveyed these messages to their parents, relatives and neighbors. However, some students still felt that the biocontrol method might not be as effective as chemical methods, despite the knowledge that biological agents would be more appropriate in terms of safety. Excerpts from the students are as follows:

“My local area has environmental problems such as contamination by pesticides and agricultural chemicals. I would like to solve these problems because these substances may affect our livings.”

“With my efforts, my parent is going to use biological agents such as Neem and Clove to control vegetables and fruits in my farm.”

“I think that biocontrol is a good method but it is not as fast as chemical control.”

Concerning the responsibility of local people to solve problems in their local area, almost all students voiced that every one in the community should help each other to conserve the local environment. The village headman or government officer should pay more attention in the natural resources and environment. Following are excerpts from the students:

"I would like to solve the problems in my local community, but the village headman must help me and other people."

"I think that all schools in the country must teach this issue in the class because only my school can't request everybody to conserve the environment."

"All people must help conserve the local environment because only a few people can't do anything, and the government must support the community in this aspect."

The most important point of the STS-based learning unit focused on application of students' knowledge to solve the problems in local community. The interviewing results revealed that after participating in the learning unit, the students transferred the knowledge learned to their families. Their parents and relative started to use herbs and microorganism in their local area for protection plants' disease and insect pests. Examples of students' statement are as follows:

"My father started to use farmyard manure instead of chemical fertilizer."

"My parent used biocontrol method to control vegetables and fruits in my field. Neem and Clove were used to replace chemical agents."

"I am using yeast to protect guavas' disease."

"My family has the mango trees plantation. We have started use the extracts from Holy basil to replace methyl eugenol."

The results from the interviews indicated that the students became more aware to solve the problem in their local area because they had the opportunity to learn and explore in the real-life situations. They observed the plant diseases, insect pests, and the insect enemies by themselves. The students were encouraged to participate in various activities related to environmental problems in their community. These results showed that the biocontrol unit using an STS approach has increased students' knowledge and attitude to the impact of pesticides and effectiveness of biocontrol on society. The students learned how to solve the authentic problems by conducting their science projects on their farms, and fruits and vegetables plantation with the help of local experts.

4.2.9 Students' perception on the STS-based learning unit

The students' perception toward the learning unit of both control and experimental groups were also collected by using a 12-item questionnaire. The positive questions were scored from 1 for strongly disagree to 5 for strongly agree, while the negative questions were scored from 1 for strongly agree to 5 for strongly disagree. The results in Table 4-48 clearly showed that the students learned with the STS approach had more satisfaction in the learning unit compared with the control group that learned in the traditional type

Table 4-48 Students' perception of the learning unit

No.	Items	Control group (*n* = 183)				Experimental group (*n* = 174)			
		Min.	Max.	mean	SD	Min.	Max.	mean	SD
1	Survey of plant and insect from local farm is very interesting.	1.00	4.00	2.78	0.80	4.00	5.00	4.82	0.38
2	I like to learn from local sages	1.00	4.00	3.08	0.73	4.00	5.00	4.74	0.44
3	I gain more knowledge from participating in activities of local community.	1.00	5.00	3.33	0.81	3.00	5.00	4.65	0.50
4	Knowledge from local sages can be used in real life.	1.00	3.00	2.79	0.52	3.00	5.00	4.71	0.49
5	Laboratory experiment is not interesting.	1.00	4.00	2.97	0.69	3.00	5.00	4.33	0.76
6	To design my own experiment made me know its objectives.	2.00	4.00	3.09	0.66	3.00	5.00	4.32	0.59
7	I want to search for more information after conducting the experiment.	1.00	5.00	3.31	0.63	3.00	5.00	4.40	0.59
8	To give opportunity for student to conduct laboratory experiment is a waste of time.	1.00	5.00	3.06	0.62	3.00	5.00	4.51	0.59
9	Knowledge gained from laboratory experiment cannot be used in real life.	1.00	4.00	3.13	0.52	3.00	5.00	4.69	0.48
10	Knowledge on biocontrol helps realize the importance of using biological method to control plant diseases.	3.00	5.00	4.32	0.65	3.00	5.00	4.56	0.52
11	Knowledge on biocontrol cannot be used in solving local environmental problems.	3.00	5.00	3.82	0.76	3.00	5.00	4.66	0.52
12	Knowledge on biocontrol made me realize that scientific knowledge can help solving agricultural and environmental problems.	3.00	5.00	4.26	0.71	4.00	5.00	4.90	0.29
	Total (60)	26.00	49.00	39.94	3.64	45.00	60.00	55.29	3.24

The results in Table 4-49 summarized the mean scores of students' perception in three main topics: STS activities, laboratory experiment and science project, and biocontrol issues. Mean scores of the students from experimental group were significantly higher than those of the traditional group in all the three topics.

Table 4-49 Mean scores of students' satisfaction from five schools

Topic	**Mean±SD**	
	Trad (*n* = 183)	**Expt (*n* = 174)**
Learning activities (20)	11.99±1.79	18.93±1.17
	$t = 43.43^{***}$	
Biocontrol experiment/science project (25)	15.54±2.03	22.25±2.05
	$t = 31.03^{***}$	
Biocontrol issues (15)	12.38±1.50	14.11±0.89
	$t = 13.29^{***}$	
Total (60)	39.92±3.64	55.29±2.24
	$t = 42.01^{***}$	

***Significant difference ($p<0.001$)

The results in Table 4-49 show that the students from experimental groups have higher satisfaction scores than those from the control groups. They realized that the bicontrol knowledge (as gained from the learning unit) helped solve the agricultural and environmental problems. The students in control group after learning through the traditional method also agreed that such activities (as stated in the questionnaire) were useful in solving the environmental problems. Nevertheless, the experimental group participated in the STS-based learning activity and thus resulting in higher satisfaction scores, when compared to those in the control group.

4.2.10 Teachers' attitude on the STS-based learning unit

The five teachers who implemented the learning unit in the five schools were asked for their attitude on the learning unit by using four open-ended questions and a 13-item questionnaire. The response to each item was measure by using 5-point

Likert scale. The results in Table 4-50 show the mean scores of teachers' attitude in the development and implementation of the learning unit.

Table 4-50 The teachers' perceptions of the learning unit from five schools (*N* = 5)

Item	Min.	Max.	Mean	SD
Development of the learning unit on biocontrol 1. Teachers realize the importance of using the topic on biocontrol in the learning unit.	4	5	4.80	0.45
2. Teachers should be trained for better understanding of the learning unit.	4	5	4.80	0.45
3. Teacher participated in the setting goal and lesson plan.	5	5	5.00	0.00
4. Time allocated in the unit corroborate with the specified learning unit structure.	3	5	4.00	0.71
5. The lesson plan integrates knowledge from other subjects	4	5	4.40	0.55
6. The lesson plan covers important points in standard curriculum.	4	5	4.60	0.55
7. Teachers provide learning sources to serve students' need.	4	5	4.80	0.45
Implementation of the learning unit on biocontrol 8. The lesson plan is suitable for the students.	4	5	4.80	0.45
9. Learning activity focuses mainly on students.	5	5	5.00	0.00
10. Community (e.g. local sages, community people) participate in designing the learning unit.	4	5	4.80	0.45
11. Various assessment tools are used.	5	5	5.00	0.00
12. Students play active role in all the learning activities and evaluation.	4	5	4.60	0.55
13. Students could learn from learning resources in their local community.	4	5	4.80	0.45

The results in Table 4-50 clearly showed that the teachers have positive perception toward the STS-based learning unit. Scores of these items ranged from 4 to 5 with mean values from 4.6 to 5.0. The only item that has score 4 is in the time allocated. The teachers thought that more time should be given.

After completing the STS-based learning unit, the teachers reflected on what they have received from the learning process. Their writings were categorized and reported as percentage of teachers covering the refection points as shown in Table 4-51.

Table 4-51 Teachers' reflection after participating in the STS-based learning process

Item	Teachers' reflection	% teachers covering the refection points*
Appropriateness of the STS approach in the teaching-learning process.	- The STS-based learning unit helped students learn in authentic context with authentic problems. - The STS-based learning unit encouraged students to solve the local problems. - The STS-based learning unit could improve science process skills for students. - The STS-based learning unit helped students to construct their own knowledge.	80% 80% 60% 60%
Using biocontrol as scientific content for the learning unit	- The STS-based learning unit helped students aware the local problems on plant diseases and danger of pesticides. - The STS-based learning unit encouraged students to conduct science projects. - The STS-based learning unit allowed students to apply scientific knowledge to community. - The STS-based learning unit is suitable for the local curriculum on environmental issues.	80% 60% 60% 40%
Knowledge gained from the workshop and from the teaching-learning process	- The learning theory of an STS approach, guided inquiry, and cooperative learning. - Various assessment methods - How to write proper lesson plan - Knowledge on biocontrol - How to conduct proper science projects - Experimental skills	100% 80% 40% 40% 40% 20%
Problems and obstacles in implementation of the learning unit	- Students lacked the experimental skills - Time was not adequate. - The scientific content on biocontrol was rather difficult. - The apparatus used in the experiment was difficult to find.	60% 60% 40% 20%

* number of teachers = 5 (one school each)

In Tables 4-51, most teachers agreed that an STS-based learning unit was suitable in motivating and encouraging students to learn because it is relevant to real-life situation. As a result, the students could construct their own knowledge, acquired science process skills and had positive attitude in trying to solve local problem. They thought that the STS-based learning unit is suitable to be used as local curriculum. The unit allowed students to apply and transfer knowledge to the community. The teachers reflected that they have gained all the necessary knowledge needed for implementing the learning unit from the given workshop. However, they had some problems in the implementation such as the students seemed to lack experimental skills and the biocontrol content was rather difficult. Some school had problems in finding the apparatuses for the laboratory experiment. Additionally, the time allocated was not enough. These recommendation and suggestion should be taken into consideration for improvement in the future.

CHAPTER V
DISCUSSION

Overview

This chapter aims to present the interpretation and discussion of the research findings. Evidence for promoting the learning outcome of the students enrolled in the STS-based learning unit was discussed. This chapter explains how an STS-based learning unit with authentic problems on plant diseases and insect pests help them not only in conceptualization of the knowledge on biocontrol, but also transferring the scientific knowledge to society.

5.1 Effectiveness of an STS-Based Learning Unit on Biocontrol on Students' Conceptual Knowledge

The results from this study clearly indicated that an STS-based learning unit on biocontrol promoted students' scientific literacy and enhanced students' learning outcome. They showed better conceptual understanding of biocontrol, improvement in science process skills, and were more aware of their local environmental problems. Most importantly, not only had positive perception toward the learning unit, they also transferred the knowledge learned to their communities.

Evidence for better understandings in conceptual knowledge on biocontrol of the students in the STS-learning unit are from the significantly higher posttest scores compared to those received in the traditional type of learning. Additionally, ability of the students to draw an exemplary concept maps that relevant to the authentic problem are indicator for their conceptualization. Other assessment tools i.e., experimental skill test, along with students' reflection, and classroom observation are evidences for students' improvement in science process skills.

Activities in the learning unit that allowed the students to expose to real-life situation greatly helped them to conceptualize the main principle of biocontrol. The success of the STS learning environment was due to the students' opportunity in visiting farms and discussing local problems with agriculturists, teachers, and their peers. They had the chance to identify agricultural problems in their community that most plant diseases were due to infection by fungi or other microorganism. They learned that most agriculturists have used pesticides for protection plant damages. They also realized that local problems such as water pollution, air pollution, and soil contamination were caused by pesticides. They asked farmers about the effects that pesticides might have on humans' health after spraying pesticides. This out-of-classroom activity helped students to understand and realize the problems in real-life situation. They could thus develop their own understanding about plant diseases, insect pests, and pest problems as well as advantages and disadvantages of pesticides.

As a consequence, the students were able to exactly identify their local problem. The teacher used this strategy to lead the students to a biocontrol laboratory experiment, in which they have to practice the biocontrol technique to be used in controlling plant diseases of their own choices. The guided inquiry instruction encouraged the students to design their own experiment on using biocontrol agents like yeast *(Saccharomyces cerevisae)* and fungus *(Trichoderma reesei)* as well as natural products (e.g. Neem) to protect the plants' disease (e.g. anthracnose disease in tomato, eggplant, and other plants of their own choices). In addition to the first activity on plant diseases, the students showed interest and enjoyed another out-of-classroom activity in the rice field. To have opportunity to observe and discuss with farmers, the students understood the interrelationship between insect pests, preys, predators, and natural enemies in the rice field.

After exposing to the authentic problems in the field trips, the students were able to set the hypothesis for their science projects. The results of these science projects although are not that great due to lacking of experience in scientific techniques, these activities motivate the students to learn meaningfully and purposefully. This is because it is relevant to their life. The students expressed their willingness to conduct their own science project to solve problems in their local area with supports from local sages. The students gained a better understanding, felt ownership of their community related project, and were more aware of their environmental problem. The students were keen to bring the biocontrol knowledge learned from school to their community. This study is in agreement with that of Chanchichaovivat, Panijpan, and Ruenwongsa (2008) who developed a hands-on experiment on using yeast biocontrol to protect anthracnose disease in red chili fruit caused by the fungus. These activities enhanced students' understanding on biocontrol concept as well as on environmental conservation that chemical agents should be avoided. This study is similar in principle to that of To-im and Ruenwongsa (2009) that the students observed and conducted experiment on the local environments and developed their own understanding of the ecosystem. This result agreed with that of Lester, Ma, Lee, and Lambert (2006) who employed the STS approach to teach students global warming issues. They encouraged students to conduct an interview about changes in the weather over his or her lifetime and explored the relationship between carbon dioxide in the atmosphere and the planet's surface temperature and found that students gained better science knowledge after the instruction. They believed that STS instruction should begin with real-world problems having science and technology components that supported students to investigate, analyze, and apply science concepts and process in solving problems. Lazarowitz and Bloch (2005) suggested that the teacher should bring societal issues in open discussion to teach students at all levels. Learning science related to societal issues is one of the conditions that support students to learn. Dass and Deal (2007) suggested that the learning in the form of real situation can bring positive achievements.

The benefit part of the learning unit based on STS approach in this study was in the fieldtrip activity that took students outside the classroom so that they had opportunity to observe, investigate and learn from local wisdom in their own environment. The students thus learned by interacting with their society with the technology learned both from the classroom and from local knowledgeable adults. This research work is similar to several other studies that have reported an enhancement of students' understanding in the subject matter and positive attitude in learning as well as increasing interaction with their society (Havu-Nuutinen & Keinonen, 2009; Keinonen, Ismail, & Havu-Nuutinen, 2008). The students stated that the fieldtrip activities increased the local science knowledge and supported meaningful learning. This is in accordance with Tal (2001) that the outdoor education such as fieldtrips support students in learning important experiences in the real world. Additionally, Havu-Nuutinen & Keinonen (2009) created a learning unit that allowed students to visit the electronic shop and interview the shopkeepers. Through visiting and interviewing, the students clearly gained the knowledge about everyday use of electricity. Fieldtrip has been shown to be one of the strategies available for teaching-learning science and environment (Tal, 2001). The learning process which incorporates the outside of the classroom can bridge the gaps between classroom and everyday life through school activities (Dori & Tal, 2000; Hofstein & Rosenfeld, 1996). In another similar study, Tripp, Wijeratne, and Piyadasa (2005) transferred hands-on scientific research results on biocontrol of insect pests to community. However, they focused on providing farmers with on-the-job training in environmentally friendly plant protection. One of the key success factors in this study is that the learning environments allow the students to learn in authentic contexts that have meaning for students. This is in consensus with several research works. For example, Tal (2001) and De Corte (2000) suggested that activities in the real situation have an important and positive influence on students. In addition, Nielsen, Nashon, and Aderson (2009) believed that activities from the out-of-school context enabled the students to develop an understanding of scientific concepts. The out-of-school contexts provide a rich environment for experiential learning and thus allow the students to learn with both their body and mind.

5.2 Effectiveness of an STS-Based Learning Unit on Biocontrol on Students' Science Process Skills

This research showed that the learning unit was successful in turning students to behave like young scientists in their scientific inquiry and thereby their scientific skills were also enhanced. We found that students involved in an STS-based learning unit on biocontrol had indeed shown significant improvement in scientific inquiry: they could use the science process skills to solve problems, ask questions, formulate hypotheses, identify variables, and reach conclusions with their peers. Most importantly they were able to exploit the scientific method to identify and solve agricultural problems in their local community through the science project of their design. Success in promoting scientific skills through the STS approach is in agreement with several other reports. For example, Yager, Choi, Yager, and Akcay (2009) found that students taught with an STS approach had significantly higher science process skills, creativity, attitude, and ability to apply concepts in a new context, when compared to those taught by a directed approach. Dass and Deal (2007) found that students in an STS project gained scientific skills; i.e. taking specific action, designing, conducting and reporting experiments. Additionally, Akcay and Yager (2010) used an STS approach for improving students' ability to apply major science concepts and process skills in new situations. Students were well able to use the scientific method to conduct their science projects relevant to their community.

This study is in accordance with that of Dori, Tal, and Tsauahu (2003) who developed a biotechnology module, by using the STS approach, to investigate nonscience major students' ability to use various thinking skills in analyzing environmental and moral problems presented through case studies. They encouraged students to debate about the use of biotechnology and the use of genetic engineering for manipulating human trait and found that this activity increased not only students' conceptual understanding but also thinking ability. Therefore, the modern society citizens should be encouraged to examine information and seek applications of science and technology knowledge.

The key success in this study is in the activities in the learning unit that encouraged students to learn science process skills that help them think while they were discovering new things scientifically. In the STS classroom, the students were encouraged to identify their local agricultural problems and explore appropriate ways to solve them. They had the opportunity to observe and ask questions about the existing problems with local sages in their community. These activities encouraged them to learn and use scientific inquiry in situations that are close to real life. The findings that the STS approach calls for students to use the scientific method to learn and apply to their community is similar to those of Dass and Deal (2007) who employed STS approach to teach students through environmental projects, and found that students in STS projects could implement original action plan within the local community. Yager, Choi, Yager, and Akcay (2009) also reported that science project in STS approach improved students' ability to solve problems identified in schools and the local communities. In our studies, the students had opportunity to work in the laboratory to practice the experimental skills needed for the subsequent science projects on real agricultural problems in their community. As a result, the students could apply the knowledge learned in designing and conducting the science projects on local problems. The activities in the science project helped promote science inquiry skills for students. They had to ask good questions, formulate hypotheses and design the methodology by themselves, collect and analyze data, discuss and conclude with their peers as scientists do. Results from evaluation of the science project as well as from classroom observation and semi-structured interview indicated that the students were able to act out the scientific method and possessed scientific inquiry skills. The finding in this study is in accordance with Roth and Roychoudhury (1993) that authentic contexts supported the scientific process skills. We can conclude that STS instruction provides the students with the ability to identify problems, seek scientific knowledge to solve real-life problems, and promote process skills in problem solving, as stated in National Science Teachers Association [NSTA] (2007).

Most importantly, although some groups' science project results were not promising for lack of experience in handling aseptic technique in biocontrol experiment, most students could transfer knowledge and ideas (on using biocontrol instead of chemical methods) to their community, as evidenced from the interview. The results suggested that the students could apply the knowledge learned to help solve problems in their communities.

5.3 Effects of STS-Based Learning Unit on Biocontrol on Attitude of the Students and Teachers

This STS-based learning unit promoted students' achievement not only on biocontrol concept and science process skills but also on their environmental attitude.

During this study, the students got knowledge and skills from local knowledgeable adults who have authentic experiences in biocontrol method to protect the environment by trying to replace chemical agents with those of biological agents. The students realize that they should have been involved in solving these problems and they are eager to receive the real experience from local experts. Similar to other studies, these activities not only help them to enjoy learning and receiving valuable knowledge but also help to enhance their critical thinking skill and communication skill (Chanchichaovivat, Panijpan, & Ruenwongsa, 2008; Havu-Nuutinen & Keinonen, 2009). Students in the STS approach this study often discussed, shared, and communicated with teacher, friends and other people in their community. Most of the students enjoyed learning from informal communication with knowledgeable adults, when compared to communicating with their teachers.

Besides, the students would like to conserve the natural resources for the long run. This study agrees with Ajiboye and Silo (2008) in that such informal intervention in civic and environmental issues promoted students' positive attitudes toward the community and the environment. The results are also in consensus with those of Prokop, Tuncer, and Kvasnićâk (2007) that encouraging students to visit three different ecosystems, i.e., freshwater, meadow and woods, resulting in a more positive attitude of students toward biology and natural environment.

Concerning students' perception toward the learning unit, they expressed high satisfaction in all activities of the learning unit, namely STS-activities, experimental activities, and biocontrol issues. It should be noticed that the students in the traditional group had much lower satisfaction scores. This is because they did not have opportunity to discuss with local sages nor conducting the science project, although the teacher gave them all information that the experimental group had. The results suggest that the real-life situation plays important role in motivating students learning.

Regarding the transfer of knowledge to community, ability of the students to learn more effectively in authentic context made them connect what they have learned in the class to problems in their community. The STS-based learning unit not only encouraged the students to apply the knowledge of biocontrol to their real life, but they were able to debate and justify the positive and negative impacts of biocontrol on the society, as evidenced from the interview. Certain groups of the students conveyed their knowledge to the community with as little negative impact on the environment and humans as possible. For example, they used results from their science project to control worms in the rice field by using dragon flies and spiders. Moreover, the students extended their capability in applying the biocontrol concepts to solve insect pest problems. They debated the advantages and disadvantages of biocontrol, not only with their peers and teachers, but with agriculturists and local experts. This study confirms that the STS-learning environment helps students to understand the impact that technology and science has on the environment and human life, and thereby transfer the message to community. For example, the science project results of students in school B in that the Holy basil (which had methyl eugenol) can be used to protect the plant from fruit fly instead of chemical method that utilize methyl eugenol. The students' family was persuaded to use Holy basil in controlling the fruit fly in their mango farm. Moreover, the results from science project of group of students in school E that employed Effective Microorganisms (EM) in controlling plant diseases has been transferred to their own schools.

The students and teacher helped each other to propose and conduct the project on clean environment in school by employing EM in toilet cleaning, in vegetable plantation and also in making organic fertilizer from vegetable wastes. This project won the prize from the district and has now been transferred to temple and the nearby village. The credit for this success was also due to the contribution of the local sages and knowledgeable adults in the community.

Not only the students that had good perception toward the STS-based learning unit, the teacher agreed that it has great benefits for the students. Even the low achievers still showed a lot of improvement in terms of knowledge, skills and attitude. It also promoted good relationship between school and community, including local sages, students' family. The scientific knowledge learned from school could help solve the community environmental problem. However, the teachers stated that their success in the teaching-learning process came mainly from the researcher's workshop at the beginning. The training activity that helped them is the principle of STS-approach, brainstorming on the lesson plan and assessment as well as the laboratory technique. They admitted that the science part is somewhat difficult to them too.

Therefore, they suggest that if this STS-based learning unit on biocontrol were to be used in other schools, those teachers should be trained as well. The lesson plan has to be modified to be appropriate for students with different background. Nevertheless, the teachers from the five schools said that in their next course they will use the STS approach in other subjects for benefits of the students. They are confident that they can develop the new curriculum on their own and they would like to convince their friends to do so.

From brainstorming with the teachers, the different in results obtained from each of the five schools may be due to several factors, including teachers and students themselves. Students in each school, although were in agricultural area, they have different background as well as different achievement (as judged from their prior knowledge). Among the five schools, students in school A with higher prior knowledge are the top in conceptual knowledge and experimental skills, but not in attitude toward natural environment nor knowledge transferred. School E students with the lowest prior knowledge although still showed the lowest scores in conceptual knowledge and they had highest ability in transferring the knowledge learned to their community.

Students from schools C and D with rather low prior knowledge have gained medium achievement in conceptual knowledge. They have higher scores in questionnaire on attitude to natural environment but did not show a good piece of work in bringing knowledge to their community compared to school E students. Students from school B was the second best from school A in knowledge and skill, but they were more keen to apply the resulting knowledge to the local community. It should be noticed that the success of these students was also dependent on other factors such as the ability of teacher to guide students, the teachers' extra time available for the students, the school environment in facilitating students' activity, and the background of students' family. This is the first time that the students learned based on the STS-based teaching process. Better outcome might be obtained in the subsequent studies.

CHAPTER VI

CONCLUSION

Overview

This chapter summarizes the interpretation and discussion of research findings of the STS-based learning unit on biocontrol. The effectiveness of the STS-based learning unit and students’ outcome are described. The implications, limitations of the study and recommendations for further study and further development are described.

6.1 The Effectiveness of the STS-Based Learning Unit on Students’ Outcome

A learning unit based on an STS approach on biocontrol has been shown to enhance students’ conceptual knowledge of biocontrol, science process skills, and increase their environmental attitude. The learning activity that included discussion with local sages in the community helped the students to integrate the local wisdom to the scientific knowledge from the classroom. As a result, the students were able to create many practical science projects that can be used in real-life situation in their own community.

The STS-based learning unit encouraged the students to learn about biocontrol of plant diseases. In this activity, students had opportunity to learn the relationships among three organisms (local fruits, yeasts or fungus, and fungal pathogen). The students could understand the importance and characteristic of biocontrol. In addition to cognitive learning, the laboratory experiment provided scientific skills for further use in the subsequence science projects.

Moreover, this relevant learning unit helped students to learn the relationship between insect pests and their natural enemies in the classroom. Almost all of the students in the STS-learning unit were able to analyze the impact of pesticides and the impact of biocontrol on humans and the environment. They recognized that the use of pesticides and chemical agents in agriculture can harm humans and the environment. They realized that the pesticides could move from the application site and spread to the soil, water, and air. It seemed that these students understood that pesticides as a product of technology not only contaminated agricultural produce and products, but also affected all living things in the community. Most students recognized that insects posed both benefits and dangers.

The STS-based learning unit has been shown to enhance students' science process skills. The learning activity that included discussion with local experts in the field trip helped the students to integrate local wisdom with scientific knowledge from the classroom, resulting in students' abilities to create practical science projects that could actually be used in their local community. The students could apply the scientific method to solve problems in new situations, they used their knowledge and skills to design and conduct useful science projects on their local agricultural problems by themselves. The STS-based learning unit also supported students' decision making, communication and problem solving.

Moreover, the findings showed that the students' attitude on local environmental problem changed positively due to their authentic experiences from the learning process. All students were more aware of the importance of the environment than in the past. In addition, the students felt they did not need pesticides because organisms could control each other. The students had meaningful experiences that were relevant to their real life in the community. They could develop a new idea to be utilized in their real situation rather than just learning to pass the tests.

For the community, this activity has changed the relationship between schools and local society in a positive way. The learning process occurred between community, teachers and students resulting in strengthening of schools and community in supporting the students' learning.

6.2 Implications of the Study

In this research study, an STS approach was appropriately used to frame the instructional units for better teaching and learning in the topic on biocontrol. The results that the newly developed instructional units enhanced students' conceptual knowledge, improved science process skills, and promoted students' attitude toward natural environment should enable school teachers to adopt this learning unit to use in teaching various science topics. For example, the topic "Life and Environment" (2nd standard Sc.2.1 and 2.2) of Thai Science National Curriculum. The learning unit on biocontrol can be extended to all level of student; however, science teacher should modify the activity according to student levels and achievements. Moreover, this learning unit can be applied in other situations/problems, such as waste treatment, water pollution, and etc., depending on the area of the school or their own interested issues. The important point is that the teachers should encourage students to identify the problems in their own communities.

The lesson learned from this learning unit that way benefit teacher is that students would be more enthusiastic to involve in the learning process if they were provided with authentic activities. This research results should be a guideline for teachers or educators in finding a proper way to help students develop their achievement and conceptual understanding correctly or even construct their own knowledge. Based on the successful of the implementation of the instructional units on biocontrol, it is important to note that not only the secondary students that should use this instructional unit on biocontrol, but other levels could use these instructional units to enhance their students' achievement. Moreover, for the students to develop their knowledge, they should be encouraged to work collaboratively so that they can share and discuss ideas with groups. The teacher should provide students with the following activity: (1) to identify the problems in their communities (2) to learn the science issues that are relevant to their real life in their communities, (3) to apply the scientific knowledge to their communities, (4) to apply science process skills to solve local problems, and (5) to identify the ways that science and technology are likely to impact in the future.

6.3 Limitations of the Study

Although the STS-based learning unit on biocontrol was successful in promoting students’ understanding and improving their science process skills, there are still many limitations. The participants in this study were from five schools of different prior knowledge. Therefore, the results from each school had to be analyzed separately. Results should be reconfirmed with other groups of students with similar prior knowledge in different school settings. Moreover, the students in this study lack experimental skills are familiar with the traditionally learning process that based on textbooks, laboratory manuals, and handouts rather than activities that support scientific skills. So, they had hard time in formulating hypothesis, identifying the variables, and designing experiment.

Teacher had to put a lot of effort in encouraging them and give them more guidance. The developed STS-based learning unit on biocontrol was intended for the students in the agricultural area and might not be appropriate for the students in the big city. Although the topic on biocontrol seemed to be well known to a wide range of people, the activity of the learning process might not be appropriate for students who have no agricultural background. The teachers involved in this study have been trained in both science content (biocontrol) and the STS approach and other supports learning process, resulting in rather good outcome. Teachers in any other schools that may not have enough background may have difficulty in implementing the unit. The laboratory on plant disease although is not difficult for students, however, aseptic technique must be used to conduct experiment. This may also cause problems for inexperienced teacher. Some schools had problems on lack or not enough the apparatuses for biocontrol experiment. This might affect students’ learning, and longer time was used in conducting the experiment. Additionally, the learning unit needed extra-time for some activity such as field trips and for conducting the science project. This could be limitation for some schools that cannot provide extra time.

6.4 Recommendations

The recommendations for this study are divided into two parts: recommendations for further study, and for further development.

6.4.1 Recommendations for further study

For generalizability, the researcher needed to analyze the context of the learning process and students' background in more details. The STS-based learning unit should be tried out with other groups of students in different agricultural areas. It should also be implemented with larger number of students with similar prior knowledge and achievement. Students with different levels of achievement should also be used to prove the effectiveness of the learning unit. Before implementing, teacher should inform the students about the whole learning process and prepared students for the new type of learning process that the students were not familiar. The students should be informed how to work cooperatively.

The students may have to be trained in certain scientific technique or certain type of assessment such as concept mapping. Moreover, before conducting the experiment they should be trained on certain scientific skills, for example formulating hypothesis, identifying variables, designing experiment, and collecting data. They should also be trained on certain scientific technique, such as how to use microscope and how to carry out aseptic technique. For successful implementation, the teacher should prepare all necessary apparatuses for students. Importantly, the researcher should make the handbook to be used with the STS-based leaning unit for science teacher. The handbook should consist of the STS learning process, the biocontrol concept, the method for conducting the biocontrol experiment, necessary apparatuses, and assessment tools. Finally, the allocated time should be modified to balance with the given activities. The teachers may have to extend the time in case the students need more time for adapting to the new learning process and activity.

6.4.2 Recommendations for further development

The results that students with low prior knowledge cannot be brought the same level in their conceptual understanding and science process skills suggested for further improvement of the learning unit. From the lesson learned, the learning unit should be redesign to be suitable for the student background. For example, the laboratory technique, such as the aseptic technique may not be appropriate for certain schools with no facilities. The experiment should be simplified so that both teacher and students can easier handle. The learning process should also be adapted in accordance to students’ ability. In this study, the principle of guided-inquiry was used in conjunction with the STS approach; however, some group of students needed more guidance than others. Thus a more flexible learning unit should be redesigned to be suitable for a wide range of participants with different achievement levels. Additionally, it seems that the teacher also needs guidance. Thus a guided-protocol should also be made for the teacher. The strategy of this STS-based learning unit on biocontrol can be modified to be used in other topics appropriate to the user.

Based on the research findings, it could be suggested that the Thai science curriculum for secondary students should be revised by placing more real-life laboratory experiment in the environment topic. Concerning the students’ skills, teachers should provide the various activities to practice them because science curriculum aims to improve scientific skills for students such as critical thinking, solving problem, and creative thinking.

Moreover, the strategy of the learning process in this study enables student to learn based on authentic problem. Teachers should design the assessments that corroborate the learning activity. Formative assessment to follow students’ progress during the learning process should be considered as important as the final examination.

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APPENDICES

APPENDIX A
CONCEPTUAL KNOWLEDGE TEST

1. Some microorganisms can be employed to control plant diseases

   ☐ True ☐ False ☐ I don’t know the answer

   Reason:

   a. Microorganisms compete for food from the living organism that they live in another organism and eat it for food.
   b. Microorganisms are parasite that can decompose other living things.
   c. Microorganisms grow on the plants’ surface to protect the plant diseases.
   d. Microorganisms cause plant diseases rather than protect the plants.

2. Biocontrol method uses both living organisms and pesticides to control plant diseases

   ☐ True **☐ False** ☐ I don’t know the answer

   Reason:

   a. Biocontrol is to use micro-pathogens to control plant diseases and insect pests.
   b. Biocontrol is to use plant extraction to control plant diseases.
   c. Biocontrol is to use living organisms and micro-pathogens to control plant diseases.
   d. Biocontrol is to use micro-pathogens and plant extraction to control plant diseases.

3. Pesticides do not harm agriculturists, consumers, and the environment.

   ☐ True **☐ False** ☐ I don’t know the answer

   Reason:

   a. Chemical substances used for controlling plant diseases and insect pests harm only plant pathogen.
   b. Plants have mechanism to destroy the pesticides.
   c. Chemical substances for controlling plant diseases do not effect human and animal, if we don’t use them so often.
   d. Often use of chemical substances for controlling plant diseases and insect pests would be harmful to human and the environment.

4. Microorganisms can be used to kill insect pests.

   ☐ **True** ☐ False ☐ I don’t know the answer

   Reason:

   a. Microorganisms cause the diseases in the insect pests.
   b. Only natural enemies can be used to control insect pests.
   c. Only the chemical substances can be used to kill insect pests.
   d. Microorganisms can decompose organic substances, so it can be used to decompose insect pests.

5. Agriculturists use microorganisms to control plant diseases, so they got pathogen from microorganisms.

   ☐ True ☐ **False** ☐ I don’t know the answer

   Reason:

   a. All microorganisms cause diseases to humans
   b. Some microorganisms cause diseases to humans, animals, and the agricultural products.
   c. Microorganisms that used to control plant deceases have no impact on human.
   d. Microorganisms used for controlling plant diseases destroy only plant pathogen, and are not harmful to human.

6. The extraction from plants can protect and kill the fungal pathogen.

   ☐ **True** ☐ False ☐ I don’t know the answer

   Reason:

   a. Plant extractions can control plant disease, but it takes time.
   b. Plant extractions are the chemical substances. It can effect human, if it is over used.
   c. Plant extractions are not dangerous, so it can be used to control fungal pathogen.
   d. **Plant extractions are not toxic to the environment**.

7. Using chemical substances for controlling insect pests have impact on surface, ground water, and air.

   ☐ True ☐ **False** ☐ I don’t know the answer

   Reason:

   a. Chemical substances cannot be decomposed, if we over use.
   b. Chemical substances, persistent organic pollutants, affect soil, water, and air.
   c. Chemical substances were extracted from plants, so they do not affect the environment.
   d. All types of pollutions arise from nature, and humans.

8. Microorganisms have their own mechanism to control plant diseases.

   ☐ **True** ☐ False ☐ I don’t know the answer

   Reason:

   a. Microorganisms produce toxin, and inhibit the fungal pathogen.
   b. Microorganisms no have effect on the micro pathogen.
   c. Microorganisms compete for food and destroy the fungal pathogen.
   d. Microorganisms use hypha to penetrate the surface of fungal pathogen, produce toxin inhibit the fungal pathogen, and kill them.

9. To use microorganisms for controlling plant diseases and insect pests would reduce the using of pesticides.

   ☐ **True** ☐ False ☐ I don’t know the answer

   Reason:

   a. Microorganisms can destroy plant diseases and insect pests, so agriculturists do not need to use chemical substances.
   b. All living things including microorganisms can control each other, so agriculturists do not need chemical substances.
   c. Chemical substances are safe for humans, animals, and plants, if agriculturists use them appropriately.
   d. Using microorganisms for controlling plant diseases and insect pests induce the amount of pathogen and insect pests, so agriculturists need to increase the amount pesticides.

10. Prolonged use of fermentations and pesticides would leave residue in the environment.

    ☐ **True** ☐ False ☐ I don’t know the answer

    Reason:

    a. Fermentations and pesticides are benefit; they help the plant grow and safe from insect pests.
    b. Fermentations and pesticides are produced in laboratory, so they are difficult to disintegrate.
    c. Fermentations and pesticides can disintegrate, so these will be no residue in the environment, although they are over used.
    d. Fermentations and pesticides are produced in laboratory, if agriculturists do not over use; they have no effect on environment.

11. Pesticides kill not only fungal pathogen, but also destroy antagonistic microorganisms.

☐ **True** ☐ False ☐ I don't know the answer

Reason:

a. Pesticides destroy both micro pathogens and insect pests.

b. Pesticides are very dangerous and have concentrated acid and base, so they can destroy all living things.

c. Pesticides kill only insect pests.

d. Pesticides are produced to kill all living things.

12. Yeasts are more suitable for post harvest control of fruit diseases than fungi and bacteria.

☐ **True** ☐ False ☐ I don't know the answer

Reason:

a. Yeasts can protect fruit diseases and are resistant to food deprivation.

b. Yeasts use hypha to cover the surface of fruits, so fruits can be kept for a long time.

c. Yeasts are microorganisms that the consumers are familiar with.

d. Yeasts can live in dry condition, and grow by using mold on fruits' surfaces.

13. "Tuaham" is predator.

☐ **True** ☐ False ☐ I don't know the answer

Reason:

a. "Tuaham" resides in insect pests and eat them.

b. "Tuaham" destroys all insects by eating them.

c. "Tuaham" eats only insect pests.

d. "Tuaham" eats smaller animals.

14. "Tuabean" is insect pests.

☐ True ☐ **False** ☐ I don't know the answer

Reason:

a. "Tuabean" produces toxin which cause disease in plants.

b. "Tuabean" is insect's baby that destroys insect pests.

c. Some "Tuabean" is a worm which eats insect pests for food.

d. "Tuabean" eats insect pests.

15. “Tuaham” and “Tuabean” can be used to control the insect pests in the plantation.

☐ **True** ☐ False ☐ I don’t know the answer

Reason:

a. “Tuaham” and “Tuabean” are eaten by insect pests.
b. “Tuaham” and “Tuabean” eat all insects for food.
c. “Tuaham” and “Tuabean” eat worms and insects.
d. “Tuaham” and “Tuabean” eat insect pests which destroy the vegetable plantation.

16. Environmental problems are caused by humans only.

☐ True ☐ **False** ☐ I don’t know the answer

Reason:

a. Both the danger from nature and humans destroy the environment.
b. Natural disasters not affect environment and natural resources.
c. Humans abuse the natural resource and therefore destroy the environment.
d. Natural disasters, animals, and diseases destroy the environment and natural resource.

17. Everyone should be responsible environmental conservation.

☐ **True** ☐ False ☐ I don’t know the answer

Reason:

a. Only one person cannot conserve the local environment.
b. Everyone use natural resources and would receive direct impact.
c. Local government should be responsible for environmental conservation in their local communities.
d. The prime minister should play important role in environmental conservation.

18. The ecosystem is not balanced due to the using of pesticides.

☐ **True** ☐ False ☐ I don’t know the answer

Reason:

a. Pesticides help balance the ecosystem.
b. Agriculturists use pesticides to increase the agricultural product.
c. Pesticides are difficult to disintegrate, so some animals receive the toxin from these substances.
d. Pesticides are dangerous for living things in the ecosystem.

19. Biocontrol is one of the alternative ways balance the ecosystem.

☐ **True** ☐ False ☐ I don’t know the answer

Reason:

a. Pesticides are dangerous for all living things in ecosystem.

b. Biocontrol is not a natural way.

c. Biocontrol does not destroy the food web.

d. Biocontrol is the method that all living things control each other.

20. Only “humans” destroy the environment and natural resource.

☐ **True** ☐ False ☐ I don’t know the answer

Reason:

a. The birth rate of human increases.

b. Humans can control and manage problems in environment and natural resources.

c. Humans continue to use modern technology to facilitate themselves.

d. Natural disasters also destroy the environment.

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APPENDIX B
EXPERIMENTAL SKILL TEST

1. Mr. A planted the ten guava trees and he found that the fruit flies destroyed the guava fruits. Mr. A would like to kill these insects, so he studied the appropriate way to control them. He found that Neem and some plants can control the fruit flies. Mr. A would like to know which plants can control fruit flies. How would Mr. A plan to do the experiment?

1.1 Pose the problem

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1.2 Formulate the hypothesis

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1.3 Variable related to experiment

- Independent variable (Variable to be tested)

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- Dependent variable (Variable to be affected)

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- Control variables (Variable to be controlled)

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1.4 Design experiment

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1.5 Collect data

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2. Mr. Dum used chemical fermentations, pesticides, and fungicides to control the diseases, insect pests, and pests in his rice field. After prolonged use, he found that the soil was destroyed. He consulted with agricultural researchers and learned that microorganisms from natural environment can help improve the soil. How would Mr. Dum plan to do the experiment to confirm this knowledge?

2.1 Pose the problem

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2.2 Formulate the hypothesis

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2.3 Variable related to experiment

- Independent variable (Variable to be tested)

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- Dependent variable (Variable to be affected)

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- Control variables (Variable to be controlled)

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2.4 Design experiment

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2.5 Collect data

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3. Mr. Dang would like to know whether the bio fermentations which he produced could protect insect pests. How would Mr. Dang plan to do experiment?

3.1 Pose the problem

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3.2 Formulate the hypothesis

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3.3 Variable related to experiment

- Independent variable (Variable to be tested)

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- Dependent variable (Variable to be affected)

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- Control variables (Variable to be controlled)

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3.4 Design experiment

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3.5 Collect data

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APPENDIX C

QUESTIONNAIRE ON ATTITUDE TOWARD NATIONAL ENVIRONMENT

Please marks (X) for answer that best describe your opinion on the following items.

Item	**Checklists**	**Level of your opinion**				
		Strongly agree	**Agree**	**Undecided**	**Disagree**	**Strongly disagree**
1	Pesticides destroy the environment					
2	Increasing use pesticides do not affect consumers.					
3	You have not need to conserve the local environment.					
4	Using boiocontrol is better than using pesticides in environmental conservation.					
5	Biocontrol is not as effective as pesticides.					
6	Using fermentations has benefits for the plant, but they can be left in soil.					
7	Pesticides do not harm humans and animals.					
8	Using pesticides cause no harms to consumers.					
9	The pollutants are important, so everyone must solve these problems.					
10	Using the extractions from plants is good.					
11	Using microorganisms cause no harm to human and environment.					
12	Using pesticides have effects					

Item	Checklists	Level of your opinion				
		Strongly agree	Agree	Undecided	Disagree	Strongly disagree
	on the water, air and soil.					
13	Thailand has so many natural resources, so we do not need to conserve them.					
14	Pesticides destroy the ecosystem.					
15	You are interested in solving the problem in local environment.					
16	Everybody should solve environmental problems in their communities.					
17	Biocontrol can balance the ecosystem.					
18	Biocontrol does not harm the environment and humans' health.					
19	If you are agriculturist, you will choose biocontrol method to control plant diseases and insect pests.					
20	You would like to transfer the biocontrol knowledge to community because biocontrol has benefit for agriculturists and consumers.					

BIOGRAPHY

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