DEVELOPMENT OF LEARNING PACKAGES TO PROMOTE KNOWLEDGE AND PERCEPTIONS ON LOCAL ECOSYSTEMS OF LOWER SECONDARY SCHOOL STUDENTS

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Thesis
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Jongdee To-im

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DEVELOPMENT OF LEARNING PACKAGES TO PROMOTE KNOWLEDGE AND PERCEPTIONS ON LOCAL ECOSYSTEMS OF LOWER SECONDARY SCHOOL STUDENTS

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ABSTRACT

This study aimed to develop three learning packages: (i) a guided inquiry learning unit on the aquatic ecosystems, (ii) a learning unit on scientific investigation of bottle ecosystems, and (iii) a community-based learning package on local ecosystems. Their objectives were to promote conceptual understanding, to develop a more caring/positive attitude toward ecosystems, and to improve the behaviors. These three learning packages were given to lower secondary school students. A mixed-methods approach was used for data collection and analysis. The data were gathered from questionnaires, interviews, written documents, and classroom observations.

The results of the guided inquiry learning unit implementation showed that students gradually accumulated conceptual understanding through designed learning activities, and both students and teachers had a positive attitude toward the learning unit.

The results of the learning unit on the bottle ecosystems indicated that students achieved significantly higher scores on the post-test compared to the pre-test. The results from interviews, students' diaries, and students' concept maps demonstrated a shift in their conceptual understanding of ecosystems from simple to complex explanations. Students' detailed observations on bottle ecosystems also became more quantifiable over time. The results suggested that these simple and inexpensive activities helped enhance the participating students' conceptual understanding of ecosystems.

The results of the learning package on local ecosystems demonstrated a significant difference between the pre- and post-test questionnaire in regards to for the students' conceptual understanding, perceptions towards ecosystems, and self-reported behaviors toward ecosystems. The qualitative data revealed that students' perceptions toward their local environment also changed for the better.

KEY WORDS: COMMUNITY-BASED/ ECOSYSTEMS/ INQUIRY APPROACH/ LEARNING PACKAGES/ PERCEPTIONS

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การพัฒนาชุดการเรียนการสอน เพื่อพัฒนาความรู้และเจตคติต่อระบบนิเวศในท้องถิ่น สำหรับนักเรียนช่วงชั้นที่สอง

DEVELOPMENT OF LEARNING PACKAGES TO PROMOTE KNOWLEDGE AND PERCEPTIONS ON LOCAL ECOSYSTEMS OF LOWER SECONDARY SCHOOL STUDENTS

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บทคัดย่อ

การศึกษาครั้งนี้มีเป้าหมายเพื่อพัฒนาชุดการเรียนการสอนทั้งหมด 3 ชุด เพื่อใช้ส่งเสริมให้นักเรียนในระดับช่วงชั้นที่ 3 มีความรู้ความเข้าใจเกี่ยวกับระบบนิเวศ เสริมสร้างเจตคติที่ดีและปรับเปลี่ยนพฤติกรรมต่อระบบนิเวศในท้องถิ่น ชุดการเรียนการสอนที่ได้พัฒนาขึ้นประกอบด้วย 1) หน่วยการเรียนรู้แบบสืบเสาะหาความรู้เกี่ยวกับระบบนิเวศ 2) หน่วยการเรียนรู้แบบการทดลองเชิงวิทยาศาสตร์ของระบบนิเวศจำลองในขวดพลาสติก 3) ชุดการเรียนรู้เกี่ยวกับระบบนิเวศในท้องถิ่น หลังจากพัฒนาชุดการเรียนการสอนทั้งหมดแล้ว ได้นำไปใช้สอนในโรงเรียน กับนักเรียนในช่วงชั้นที่ 3

กระบวนการที่หลากหลายที่ผสมผสานระหว่างวิธีเชิงคุณภาพและวิธีเชิงปริมาณ ได้นำมาใช้ในกระบวนการเก็บและการวิเคราะห์ข้อมูล โดยใช้เครื่องมือที่หลากหลายได้แก่ แบบสอบถาม การสัมภาษณ์ ผลงานของนักเรียน การสังเกตการณ์ในห้องเรียน เพื่อประเมินประสิทธิภาพของชุดการเรียนการสอน

ผลของการประเมินประสิทธิภาพของหน่วยการเรียนรู้แบบสืบเสาะหาความรู้เกี่ยวกับระบบนิเวศ พบว่า นักเรียนมีการพัฒนาความรู้ความเข้าใจเกี่ยวกับระบบนิเวศผ่านกิจกรรมการเรียนรู้ต่างๆ ที่ได้ ออกแบบไว้ นักเรียนและครูมีความคิดเห็นในเชิงบวก ต่อหน่วยการเรียนรู้แบบสืบเสาะหาความรู้เกี่ยวกับระบบนิเวศ

ผลของการประเมินประสิทธิภาพของหน่วยการเรียนรู้แบบการทดลองเชิงวิทยาศาสตร์ของระบบนิเวศจำลองในขวดพลาสติก พบว่า นักเรียนมีคะแนนความรู้ความเข้าใจเรื่องระบบนิเวศหลังเรียนสูงกว่าก่อนเรียนอย่างมีนัยสำคัญทางสถิติ จากการวิเคราะห์ข้อมูลจากการสัมภาษณ์ สมุดบันทึก และแผนผังมโนทัศน์ พบว่านักเรียนมีความรู้ความเข้าใจเปลี่ยนแปลงไป โดยมีความสามารถสร้างคำอธิบายที่ง่าย ไปสู่การพัฒนาคำอธิบายที่ซับซ้อนและละเอียดมากขึ้น การบันทึกข้อมูลจากการสังเกตของนักเรียน แสดงให้เห็นถึงการพัฒนาอย่างชัดเจน ผลการประเมินโดยภาพรวมชี้ให้เห็นว่าหน่วยการเรียนรู้ที่ได้พัฒนาขึ้นสามารถช่วยพัฒนาความรู้ความเข้าใจเกี่ยวกับระบบนิเวศได้

ผลของการประเมินประสิทธิภาพของชุดการเรียนรู้เกี่ยวกับระบบนิเวศในท้องถิ่น พบว่า คะแนนความรู้ เจตคติ และพฤติกรรมต่อระบบนิเวศในท้องถิ่น หลังเรียน มีค่าสูงกว่า ก่อนเรียน อย่างมีนัยสำคัญทางสถิติ ข้อมูลเชิงคุณภาพแสดงให้เห็นถึงการเปลี่ยนแปลงของเจตคติต่อระบบนิเวศท้องถิ่นไปในทางที่ดีขึ้น

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CHAPTER I
INTRODUCTION

1.1 Overview

The first parts of this chapter provide the background and rationale for the problem of this study. The purposes of this study as well as the research questions that help to delimit the breadth and the depth of the study are described. Finally, an overview of each chapter is given.

1.2 Background and Justification for the Study

Education deals with what students know and can do, how they interact with others and what they will face in the world (Drake, 1998). Science teaching is intended to encourage students to interpret what happens in the world according to scientific theories. Interpretations should not only be theoretical but should also allow guidance from a teacher (Izquierdo et al., 2001). These latter factors can make it difficult for students to observe phenomena directly and to construct explanations about what they do observe (Buckley, 2000).

Ecology is a major component of biology instruction, and ecosystem is the central concept in ecology. The British Ecological Society states that ecosystems rank number one on a list of the 50 most important ecological concepts (Cherrett, 1989). In the United States, ecosystems recommended by the American Association for the Advancement of Science (AAAS, 2005) as a topic for middle school students (grades 5–8). In addition, ecosystems relationships are stated as a necessary content area in the lower secondary curriculum standards in several countries. The expected learning outcomes at this grade level include abilities to explore, explain, and diagram the relationships between internal elements in ecosystems as suggested by the Center for Science, Mathematics, and Engineering Education (CSMEE, 2000).

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Although, ecosystems are recognized as an important topic in a science curriculum in several countries, including Thailand, it is often not taught as a distinct subject in the secondary school curriculum. A frequent problem in ecology education is the students' lack of interest in the topic because they are not familiar with the organisms or examples given in ecological textbooks (Magro et al., 2001). Most textbooks do not describe ecosystems relationships in depth, and no clear-cut examples are given. There appear to be very few or no examples associated with experiments that would help students consider, explore, and explain a phenomenon, regardless of the fact that ecosystems cannot be easily understood by just reading text and looking at pictures or photos (Balster et al., 2001; Weimer, 1997; Magro et al., 2001). Thus, there is a clear need for hands-on experience through field work and/or direct observations. However, this is difficult for schools due to time constraints, inadequate budgets, and shortage of staffs (Papapanagou et al., 2005; Magntorn and Hellden, 2007). To solve the problems created by such constraints, especially in schools of low economic status, a new learning–teaching approach is needed.

In light of the above, learning packages on ecosystems were developed to encourage students to learn through the scientific inquiry process: asking questions, analyzing data, reasoning, and formulating evidenced-based explanations. These learning packages were designed to accommodate the practical limitations of time and cost. Aquatic ecosystem was chosen as a model in this study because it is not easily to understand without participation in real-life situations. These learning packages focused on developing scientific skills in data manipulation and interpretation, and aimed at enhancing students' conceptual understanding of ecological topics as reported by Novak (1998). For examples, in a learning package on scientific investigation of bottle ecosystems reported in one part of this study, it is important to make clear to both the students and teachers that learning science and assigning meaning will not follow from data collection alone. Children can construct meaning from all sources of personal experiences through observing, talking, writing, and discussion.

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Environmental education (EE) is one field to which observation applies. Although this is an effective means of influencing levels of environmental knowledge (Brothers, 1990), it is not generally successful in influencing environmental action (Finger, 1993). Learning about environment has been implemented in schools' curricula during the past three decades with many different forms and varieties of teaching strategies. Most learning activities for K-12 students occur in the classroom. Teachers and curriculum designers often neglect the outdoor learning setting (Martin, 2003; Orion & Hofstein, 1994). Researchers have shown that participation in outdoor learning experiences is a promising technique for improving children's environmental attitudes and knowledge (Bogner, 1998; Crompton & Sellar, 1981; Lisowski & Disinger, 1991; Manzanal et al., 1999; Orion & Hofstein, 1991, 1994). However, field trips to new environments such as parks, museums, and nature centers may be poor settings for imposed learning tasks when compared to the environments that are familiar to students (Martin et al., 1981). It is obvious that teachers are the ones who select the ways in which learning about environment goals and objectives are met; they decide whether or not to use settings outside the classroom to teach environment. Results from research work have suggested that teachers use available educational resources unevenly. Consequently, it becomes imperative that teachers' perceptions about various environmental opportunities, and choices about the design of their environmental education programs, be more fully understood (Simmons, 1998).

Many research works reveal that learning about environment is still inadequate, relatively inconsistent, and scattered across the school curricula (Hungerford & Volk, 2003; Hungerford, 2006; Orr, 1992). Orr (1992) has also addressed that it will be ineffective in advancing its own goal of creating an environmentally or ecologically literate citizenry if it continues to discipline itself within the norms of general education. Therefore, environmental education should take place in many venues apart from the formal school curriculum i.e., non-formal education for children, youth and adults. One of the most recent changes is an increasing interest in environmental education. For example, educators are being asked to pay attention to the quality of the local fields and rivers when dealing with a sense of place or environmental sensitivity (Hungerford, 2006). Previous studies consistently have shown close associations between various environmental education programs and

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students' outcomes (Fortner & Mayer, 1991; Keen, 1991; Newhouse, 1990; Simmons, 1998; Neumann et al., 1999; Fisman, 2005; Michie, 1998; Tung et al., 2002; Overholt & MacKenzie, 2005; Smith-Sebasto & Walker, 2005; Barnett et al., 2006). However, these studies did not address the possible impacts of community based program development on environmental education programs.

There are several reasons for even though changes are now possible and becoming more common, the goals, are not being met. One reason is that environmental education is not taught as a primary subject. It is almost only taught as it can be integrated into the primary topics. This results in a limited and fragmented curriculum. In many Asian countries including Thailand, environmental education is not taught as a distinct subject in the curriculum but is incorporated into other subjects such as science, social studies, geography, civics, life experience, and moral education (Bhandari & Abe, 2000). Therefore, environmental education is undergoing a reorientation away from learning in classroom toward outside the classroom. The most efficient and effective way of solving environmental problems is to raise awareness, especially among the young. The environmental awareness is raised when one is learning in practice about environmental conservation and protection (Bureekul & Brown, 2003). Schools can improve their environmental performance by working with all members of the school community (Beazley, 1995; Ingleton, 1995; Smyth, 1995). During the process of developing children's environmental awareness, the teacher plays a vital role in promoting environmental interests. A good balance of environmental information, adequate qualifications, and interest in the environment: determines whether teachers develop the skills and attitudes necessary to understand children's knowledge, clarify and assimilate concepts recognize values and promote positive action regarding the environment.

The second reason is that the instruction is primarily "chalk and talk". The instruction is not student-centered and does not engage students to the necessary extent. In Thailand, the pedagogy is mostly the "chalk-and-talk" method, and learning is based on the rote method and spoon-feeding (Bhandari & Abe, 2000). As a result, students are encouraged to memorize rather than examine the problems critically. Similarly, Bureekul and Brown (2003) stated that environmental education in Thailand

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has been conducted by using traditional top-down approach e.g. teacher-centered. Thus there is a need for more appropriate teaching-learning method.

The third reason is that the instruction is almost wholly separated from the students' environment and their community. During the last two decades, several research works on the connections between schooling and the global ecological crisis were reported (e.g., Bowers, 1992; Hutchison, 1998; Orr, 1994; Smith & Williams, 1999). These topics focused on philosophical issues, concerning the purpose of education, alternative curricular and pedagogical strategies, the link between school and community, and the importance of local knowledge and trans-generational communication. The connection between environmental perceptions and behaviors and the EE programs in school system is a primary motivation for conducting this study.

Finally, the teachers who decide when and where and how students are to be taught about the environment often do not know how they can do in such a way that can be optimally effective. Several studies have shown connections between schooling and the global ecological crisis. The researcher hereby would like to develop effective learning packages to support teaching-learning process in environmental education. The learning packages at the core of this study addresses the four challenges stated above: curriculum fragmentation, non-student centered instruction, the separation of environmental education from the students' environment and community, and the limited capabilities of teachers in this subject area.

In response to the four challenges as mentioned above, this study aimed at developing the learning packages to promote knowledge and perceptions on local ecosystems for lower secondary school students. These learning packages are based on the inquiry approach, scientific investigation, and community-based principle. This study also concerned the impacts of the newly developed learning packages on pedagogic practices and students' performance.

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1.3 The Purposes of this Study

This study aimed at to develop learning packages on local ecosystems to enhance conceptual understanding on ecosystems, promote environmental awareness, and promote scientific skills. These learning packages were developed for schools with economic and time constraints. An inquiry approach (NRC, 1996; 2000) is applied in the learning packages' development and implementation. These are the learning packages to learn about, in, and for environment, as suggested by Lucas (1979). These learning packages integrate the knowledge learned from school together with the knowledge gained from outside school. Through these learning packages, students will hopefully develop the suitable actions for their ecosystems.

This study seems to be the first attempt in developing learning packages based on both the principle of inquiry approaches and the collaboration of community of learners. Such a community included supervisors, local teachers, community members, local sages, environmental educators, scientists, and science educators from university. In the learning packages the students should experience a diversity of instructional activities including participating in a community of learners both within and outside their schools.

The expected outcomes from this learning are (a) enhanced knowledge by which students can learn to balance environmental science concepts and practice in the community, (b) awareness of the local environmental situations, and (c) ability to take actions in conserving the environment.

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1.4 Objectives

This study has four principal objectives

1. To develop a guided inquiry learning package on aquatic ecosystems for lower secondary school students to help students understanding basic ecological principles involved in relationships among physical, chemical, and biological components in aquatic ecosystems.
2. To develop a learning package on scientific investigation of bottle ecosystems for lower secondary school students to enhance students' conceptual understanding of ecosystems and scientific skills.
3. To develop a community-based learning package on local ecosystems for lower secondary school to improve students' conceptual understanding on ecosystems, perceptions, and self-reported behaviors toward their local ecosystems.
4. To investigate the effectiveness of the three learning packages on students' achievement and perceptions.

1.5 Research Questions

This study will address the following research questions.

1. Can the newly developed learning packages promote lower secondary school students' conceptual understanding on ecosystems?
2. How do lower secondary students perceive the learning packages based on their experiences of the educational activities?
3. Have the students become more aware of the environment after implementation of the learning packages?
4. How do teachers perceive the developed learning packages?

1.6 Research Methods

This study was carried out after permission to conduct the study was ensured. The three separate learning packages with different approaches were developed. The first one employed the inquiry approach to develop students' conceptual understanding. The second one focused on the use of scientific investigation to

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promote students scientific skills as well as knowledge on ecosystems. The third one was a semester-long community-based learning package which involved the collaborative efforts of supervisors, local teachers, community members, local sages, and science educators from Mahidol University. These learning packages for lower secondary school students were implemented through a variety of hands-on activities, extra-time exercises, and field trips.

The researcher employed the mixed-methods research paradigm (Johnson & Onwuegbuzie, 2004) to gather data to answer the research questions. Various data collection methods (triangulation) were used as an attempt to capture the complexity of the educational study (Metz, 2000).

Needing the theoretical concepts of mixed-methods and triangulation, the researcher employed four qualitative and quantitative data collection strategies to gather data for the present study. These included (1) classroom observations, (2) interviews, (3) written documents, and (4) questionnaire (Patton, 1990).

During the semester-long implementation of the learning packages, the researcher scheduled and conducted pre-test and post-test questionnaires. Then, the researcher conducted classroom observations. The written documents including course syllabus, teaching materials, fieldtrip reports, and student's works were collected. The interviews were also conducted. The Statistical Package for the Social Sciences (SPSS for Windows Version 13.0) was employed to analyze quantitative data collected from a questionnaire. The gathered data were analyzed with Strauss and Corbin's (1990; 1998) open and axial coding techniques. Finally, the analyzed data were categorized to describe context of developed learning packages in school, the students' knowledge and perceptions toward local ecosystems.

1.7 Timeframe of the Study

The timeframe for this study was during March 2005-May 2007. The initiation of the study was staggered over the six months, with the literature review being first, followed by defining the study site and participants, and asking for permission to conduct the study in the school. In developing a community-based learning package, the teacher training workshops were conducted in the first month after permission was ensured. The focus group discussions were organized for learning packages

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development. The questionnaire (pre-test) was given to students at the first day of program implementation. The data collection was undertaken in second semester of 2005 school year. At the end of semester all written documents were collected as well as the questionnaires (post-test). The other two learning packages based on inquiry approach and scientific investigation were developed by the researcher during year 2006 and implemented in the second semester of academic year 2006. The findings of these studies were synthesized, revised, and reviewed for the feedbacks and comments.

1.8 Overview of Thesis

The thesis is presented in six chapters. The first chapter delineates the background of the problem, states the research questions which informs the study and specifies the objectives of the study.

The second chapter explains the literature related to the scope of the present study: learning theories, theoretical frameworks, environmental education, and inquiry-based in environmental education. Summaries of the relevant literature supporting the environmental education program and those student outcomes are also described.

The third chapter describes the materials and methodologies of the study, a description of the participants and population, the mode of inquiry or paradigm the researcher employed to seek answers to the research questions. Data collection and analysis are presented in this chapter.

The fourth chapter reports the findings of the empirical study conducted for this thesis which related to research questions.

The fifth chapter draws together the many threads that have emerged from the findings in the previous chapters and provides answers to the research questions. The discussion of the results of this study is identified in this chapter. The limitations of the study, implications for environmental education, and suggestions for further studies are also discussed and recommended.

The sixth chapter presents the summary of the overall findings.

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CHAPTER II
LITERATURE REVIEW

2.1 Overview

The purpose of this chapter is to provide a literature review concerning environmental education related to the scope of the study. The first part is the learning theories. Many learning theories reviewed in this chapter explain learning styles concerning sociology, psychology, and education. Several theories which can be applied to the environmental education program were also reviewed. The second part describes the theoretical basis grounded for this particular study. The third part highlights the meaning and objectives of environmental education in response to the educational challenges. The fourth part presents inquiry-based instruction on environmental education. Inquiry-based learning unit have been proposed to enhance students' knowledge, understanding and to link theories to practices. Guided-inquiry and scientific investigation whose focus is to teach ecology also has reviewed. The fifth part describes research on environmental education with a special emphasis on students' outcomes. Definition of environmental education and historical of environmental education were reviewed. The implications and action competence toward environmental education has an epistemological focus. Finally, the last part reveals research on assessment of environmental education programs conducted both inside and outside the classroom.

2.2 Learning Theories

Learning composes the acquiring of knowledge through systematic study in a field such as that in schools as well as behavior acquired through interaction with individual's environment (Bandura, 1977). The difference between the two approaches is that the first is structured while the other is experiential. For both types, the act of learning is a social phenomenon and it is mediated through social agents such as teachers, parents, classmates, community, and others (Greenall-Gough, 1993).

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Knowledge can be broadly defined as the mental components of an individual that results from all processes, whether innately or experientially acquired. For enhancing the knowledge, the body of information processed by the person, or, by extension, by a group of people, or a culture (Reber, 1995). Value in turn, are considered to be the beliefs derived from physical, emotional, and intellectual needs, which influence attitudes and behavior (Gilbert, 1996; Rokeach, 1973). Attitudes are more specific evaluative statements or beliefs about the objects, such as opinions or ideas, and as such are more numerous and varied than values (Fishbein and Ajzen, 1975). Values are important because they mediate attitudes as they are cause, the underlying reason why we form attitudes and they transcend objects and situations, and as results of value are more abstract and difficult to assess. Attitudes are more specific and concrete, and often more situations related, and they can be measured with carefully constructed questionnaire (Kuo, 1994). Values and attitudes comprised of three components: cognitive (knowledge and intellectual components); affective (feeling attached to the attitude or values, awareness); and behavioral (the aspects leading to action). Motivations are more specific reason that underlie, guide, and influence behaviors (Maslow, 1954). Motivations are the reason ‘why’ and individual interested in an area, or willing to participate in an activity.

Hatwell (2000) argues that there is an inconsistency between behavioral intention and actual behaviors. Individuals with high positive environmental attitudes who indicate they intend to participate or complete a particular activity, often report a lower level of actual behavior than they intended (Andrich and Styles, 1998). While links exist between levels of attitude, knowledge, and behavior, an increasing in one does not by consequence result in an increase in another (Styles, 1993). Moreover, attitude taken from a different perspective having a positive attitude to an issue does not translate into positive behaviors, if there are significant external, and, or internal barriers to complete the behaviors (Andrich and Styles, 1998; Styles, 1993). However, whenever possible education can help tendencies to act.

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Various learning styles and categories are summarized in Table 2.1. Schmeck (1988) indicated two basic types of learning styles. One is global-holist/field dependent/right brained, the other is focus-detailed/field independent/left brained. Shemeck also asserted that both styles are equally good for problems solving. Each style is likely to be associated with greater efficiency in specific tasks. The most effective problem solvers should practice strategies connected with both styles. Styles and Lawrence (1986) defined six major strands of learning in psychology: behaviorist, cognitivist, social learning theory, humanistic psychological, self-regulation of learning, socio-cultural theories of learning (Table 2.1).

Table 2.1 Theoretical perspectives on learning processes

Major Theory Identities	**Interpretation of Learning Phenomena**	**Empirical Focus of Theorizing and Research**
Behaviorist Pavlov, Hull, Skinner, Watson	All behavior is learned and conditioned and modified by reinforcement learning via stimulus-response bonding.	Overt, observable, measurable, countable, manipulable pieces of behavior.
Cognitivist Developmental Piaget, Bruner, Kohlberg	Learning determined by the level of cognitive structural organization, via processes of assimilation and accommodation, cognition develops with age and interaction with the world.	Solution to problem tasks assumed to reflect cognitive organization. Inferences from examples of thinking to underlying structure of intellect.
Cognitivist Human Information Processing Newell and Simon, Polya	Learning acquired and applied in procedures for storing information in memory and applying the problems.	Solutions to problems tasks, computational simulations, processing models of mental processes.
Humanistic Psychological Rogers, Maslow	Learning is self-motivated natural orientation to growth and self actualization.	Clinical and observational explanations.
Social Learning Theory Bandura	Learning is influenced by social influences via observational learning and reinforcement.	Modeling, social inferences to explain social behavior and personality.
Vygotskian Theory Vygotsky	Learners are active constructors of knowledge, but dependent on others in their society for learning from inter-individual to intra-individual as learner internalizes concepts/skills etc.	Social interaction, collaborative.
Self-regulation of Learning Brown, Paris, Zimmerman	Learners are active participants in their own learning. Self-regulated learners adapt to self, task, and context characteristics.	Learning strategies to plan, monitor, evaluate, and regulate learning, knowledge about learning.

Source: Styles and Lawrence (1986)

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There are some issues which may be concerned with each learning approach described above and each provides partial and possible solution in the environmental education. The three learning theories: cognitive, social learning, and Vygotskian theory have been used to ground the framework of this study.

The cognitive approach to learning depends on internal or intrinsic motivation. Intrinsic motivation is dependent on factors which are internal and are usually derived from feelings of satisfaction rather than external rewards. The primary reason that cognitivist learning has difficulty in changing people's behavior, especially in the environmental field, is that it fails to account for the multiple barriers that exist in real life (McKenzie-Mohr and Smith, 1999).

Social learning, learners are more active in the learning process. They are not only acquire facts and information but also involved in the social interaction (Bandura, 1977). This theory comprises knowledge, interaction, and the observation of the behavior of others. Educators play role as learning facilitators. The contents are expected to learn by being exposed to information as in the cognitivist approach, but additionally, an interface and in some cases as role models. In this particular learning, individual is not a learner in isolation but enters in a dynamic relationship with leader. Leader is a role model where modeling involves demonstrating a desired behavior in which role models are important instruments in achieving social change (Burn, 1991).

Vygotsky's theory sees learners as active agents who construct their own formulation of the knowledge (Vygotsky, 1978). They use collaborative strategies by dependence on other social actors in the society for learning. Learning is a joint effort between leader and learners. The educators facilitate learning by providing challenge and problems for the learners to solve and additionally provide supports in the learning process. This is student-centered model of learning where emphasis is placed on the actual learning, rather than learning how to learn. The key to intellectual growth is effective teaching that leads to intellectual development (Connell & Russo, 1980). Collaboration implies appropriate feedback mechanism to test learning and teaching effectiveness. The challenges provided to students that form the backbone of learning process, are individual teacher dependent. This is problematic in terms of consistency and reproducibility.

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Beyond the learning theories as discussed above, two fundamental assumptions underlie the formal education system (i) whether students gain knowledge and skills they acquire in school; and (ii) whether students can apply those knowledge and skills in situations outside the school. This leads to the development of an alternative educational program for students to extend knowledge, bear on the relationship between knowledge, beliefs, and actions, and provide opportunities for students to apply their potential to effectively translate beliefs to actions. Today, the ideas of experiential and naturalistic education are integrated to the curricula, and the ideas of environmental education have found a new context for instruction beyond the four walls of the classroom-the communities of practice (learning in, with, and for community).

2.3 Theoretical Basis

2.3.1 Theories of Constructivism

Constructivism is connected with experiential learning and related to some of the ideas of Jean Piaget. Learning in the view of constructivism is a constructive process in which the learner builds an internal illustration of knowledge and a personal interpretation of experience (Chapman, 1988). Learning is an active process in which meaning is accomplished on the basis of experience. This learning relies on the fact that knowledge cannot reject the existence of the real world.

The fundamental of constructivism motivates the learning control over from teachers to students. The constructivists have said that the nature of learning e.g. situated, interactive as well as nature of knowledge is important This learning must be placed in the context that reflects the real world for the constructive process which happens and transfers from environments to schools and classrooms (Jones, 1995).

The constructivists suggest that teachers should design the sequence of series of teaching/learning that relates to the experiential learning model of Kolb (1984). This model consists of four modes, i.e., concrete experience, observation and reflection, the formation of concepts, and testing in new situations. These modes deal with the processes that knowledge can be gained through the experience, which may begin at any one of the four modes and it is a continuous cycle. Through experience learners integrate their observations into the logic. After making decisions and solving

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the problems, the learners can utilize the components of learning and apply their experiences with the real world (Kolb & Fry, 1975).

2.3.2 Theories of Experiential Learning

Experiential education is a process through which a learner constructs knowledge, skills, and values from direct experiences. The concept of experiential learning is very close to the constructivism. It is based on the concepts of “learning by doing” which aims to encourage learners to feel learning as well as to think, and to let them "try on" new behaviors and new emotional and cognitive responses (Kolb, 1984). The learning by doing is first attributed by Dewey (1938) who emphasizes the importance of experiential learning (Kolb, 1984). In addition, Kolb (1984) has stated that education is becoming more accessible to all learners and there has been a corresponding need for curricula to translate abstract ideas into practical realities in human life. The experiential learning theory combines experience, perception, cognition, and behavior. It revolves around any experience that can be incorporated into the curriculum or program, which is complemented by a debriefing or reflection component. Moreover, Kolb (1984) indicated the learning cycle which composes of four modes: concrete experience (feeling), reflective observer (watching), abstract conceptualization (thinking), and active experimentation (doing). This learning cycle deals with the processes that knowledge can be gained through the experience which may begin at any point of the four mode continuous cycle.

Experiential learning is a process whereby knowledge is created through the transformation of experience. Kolb (1984) has stated that education is becoming more accessible to all learners and there has been a corresponding need for curricula to translate abstract ideas into concrete practical realities in human life. The experiential learning theory combines experience, perception, cognition, and behavior. Experiential learning revolves an experience that can be incorporated into the curriculum or program, which is complemented by a debriefing or reflection component.

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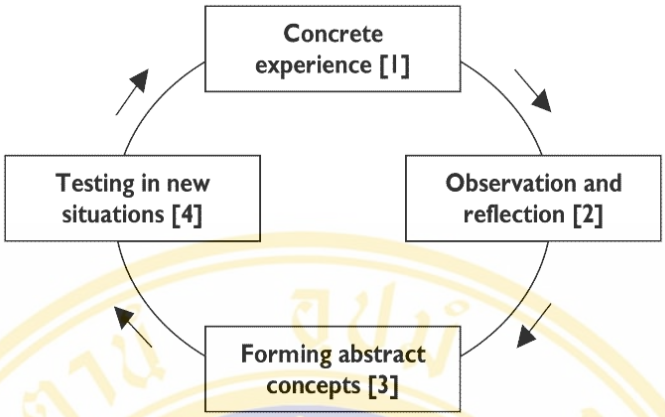

Figure 2-1 Experiential learning cycle (Kolb and Fry, 1975)

In a socio-ecological model of a child's outdoor experiences (Moore & Young, 1978), it is proposed that a child lives simultaneously in three independent realms of experiences: physiological-psychological environmental of body/mind, the sociological environment of interpersonal relations and cultural values, and the physiographic landscape of spaces, objects, persons, and natural and built elements. The freedom of the outdoor environment serves as a balance to a child's supervised indoor environment.

2.3.3 Theories of Intelligence

Intelligence is identified in the reference to a socially recognized and valued role that appears to rely heavily on a particular intellectual capacity (Gardner, 1999). According to Gardner, there are at least eight intelligences, namely, linguistic, musical, logical-mathematical, spatial, bodily kinesthetic, interpersonal and intrapersonal. Only two-logical-mathematical and linguistic intelligence have been considered importance in schools. The latest addition to the seven intelligences, the naturalist intelligence is defined as the person's ability to recognize and classify his or her natural environment. Gardner (1999) claimed that when the method of instruction is geared toward all different types of intelligence, a learner can be said to have learned more completely, having an opportunity to use his or her different learning styles.

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2.3.4 Developmental Theories

A number of developmental psychologists have attempted to study children's relationships with nature and whether an innate sense of kinship with nature manifests by time (Cobb, 1969; Tuan, 1978). Tuan (1978) suggested that children have to be taught by adults about the natural environment, as "nature is an inarticulate teacher." Children show a natural curiosity about the world but this curiosity may be easily repressed if adults fail to nurture it.

2.3.5 Theories of Social-cultural

Predominant in Vygotskian work is the attempt to link the social and individual level of cognition. These dimensions are underpinned by the two famous propositions concerning the named "zone of proximal development" (Vygotsky, 1978) and the "genetic law of cultural development" (Vygotsky, 1981).

First, the concept of the zone of proximal development (ZPD), has been defined as the distance between the child's "actual development level as determined by independent problem solving" and the higher level of "potential development as determined through problem solving" under adult guidance or in collaboration with more capable peers (Vygotsky, 1978). The concept of the ZPD generally exemplifies Vygotsky's concernment with the role of assistance or instruction and also of assessment. His interest would be in assessing how learners make progress. The focus would be on the historical process as well as the product in assessment. Vygotsky viewed that it was more important to assess the learners' potential level rather than their current level.

Second, the "general genetic law of cultural development" theorizes the social in connection with the psychological. Basically, this law lies at the heart of the Vygotskian thesis of the social formation of the mind.

The cultural law can be used in a setting within the ZPD, where the social and the individual are brought together. It is in the ZPD that the so-called "psychological tools" (particularly speech) and signs have a mediational function. It is in the use of "psychological tools" that distinguish man from animals. Just as tying a knot with a handkerchief around one's finger serves as a psychological tool and stimulus, such a mediational process is known as an "instrumental act." Vygotsky saw these

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rudimentary sign that means evidence of the historical transition from natural to culturally mediated forms of behavior, forms of behavior in which man himself determines his behavior with the help of an artificially created stimulus means.

In order to explain the historical and ontogentic development of mediated or instrumental forms of behavior, Vygotsky turned to the primary function of speech as a means of social interaction and communication. Vygotsky argued that the higher voluntary forms of human behavior have their roots in social interaction and communication, in the individual's participation in social behaviors that are mediated by speech. It is in social interaction, in behavior that is being carried out by more than one individual that signs first function as psychological tools in behavior. The individual participates in social activity mediated by speech, by psychological tools that others use to influence his or her behavior and that he or she uses to influence the behavior of others. Subsequently, the individual begins to apply to himself the same forms of behavior that were initially applied to him by others.

Vygotsky claimed that in the process of development the child not only masters the items of cultural experience but also the habits and forms of cultural behavior, the cultural methods of reasoning. Therefore, there is a need to distinguish the main lines in the development of the child's behavior. First, there is the line of natural development of behavior which is closely bound up with the processes of general organic growth and the maturation of the child. Second, there is the line of cultural improvement of the psychological functions, the working out of new methods of reasoning, the mastering of the cultural methods of behavior. Usually the two lines of psychological development (the natural and the cultural) merge into each other in such a way that it is difficult to distinguish them and follow the course of each of them separately.

The most essential feature distinguishing the psychological tools from the technical tool, is that it directs the mind and behavior whereas the technical tool, which is also inserted as an intermediate link between human activity and the external object, is directed toward producing one or other sets of changes in the object itself (Vygotsky, 1981). Thus, Vygotsky claimed that humans are able master their actions and even themselves from the "outside" through symbolic, cultural systems. Within these systems, meanings are embedded which form the basis of 'psychological tools'.

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Based on Vygotskian thought, meanings, tools, and goals all necessarily relate the individual and the social world of which the individual is part, for they are all formed in the socio-cultural context. Understanding the use of tools (psychological or physical) is jointly constructed by the developing child and by the culture in which the child is developing, with the assistance of those who are already more competent in the use of those tools and in culturally appropriate goals.

The socio-cultural theories of learning (Bruner, 1996; Lave & Wenger, 1991; Vygotsky, 1978; Wenger, 1998) were used as a theoretical base for this present study. In socio-cultural theories of learning, the learning and practicing takes place within social aggregates that share a common practice. Knowledge emerges by discursive assignment of meaning and social identification. Therefore, the learning packages as a part of environmental education program are used here as concepts to describe processes of collective and collaborative learning, which are based on socio-cultural learning concepts and focus on the role of group membership or community participation for (collective and individual) learning.

2.3.6 Theories of Communities of Practice

In socio-cultural theories of learning, communities of practice are social aggregate in which learning and innovation take place. Knowledge emerges by discursive assignment and social identification (Lave & Wenger, 1991; Wenger, 1998). The key to the development of skills of this nature is practicing authentic contexts (Berliner, 1988) in order to learn to interpret situations and to deal with them effectively. This is not derived from high-order knowledge but rather, by using complex situational understanding and practiced dexterity which comes from the breath and depth of experience (Berliner, 1988). The key to the development of skills of this nature is practice in authentic contexts. It is only the authentic contexts that novice practitioners can learn to interpret situations and to deal with them effectively.

Lave and Wenger (1991) has underpinned the central place of this type of exposure and also pointed out that becoming proficient is much to do with joining a culture of practitioners. Lave and Wenger also emphasized that learning in practice is a matter of acculturation, of joining a community of practice, rather than the application of skills or principles which operate independently of social contexts.

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One of the features of learning in a practice context is that experts are able to guide novices through the complexities of practice. Brown et al. (1988) have further developed the concept of the situated learning by analyzing the way in which novices learn from experts. Modeling involves the demonstration of particular aspects of practice by the experts. They make their situated knowledge explicit as they coach the learners. Coaching involves the provision of feedback on the learner's performance, often making use of Vygotskian (Tharp & Gallimore, 1988) notions of scaffolding and fading by which novices are supported in the completion to tasks which they would be unable to achieve without help.

This model of learning emphasizes the inherently socially negotiated quality of meaning and claims that learning and knowing are embedded in the relations and interactions of people engaged in activities within their socially and culturally structured world. Learning becomes a social practice in a world of jointly constructed meaning and knowledge. The model of learning also sees learning as a transformation of newcomer to old-timer rather than a process of transmission of skills from teachers to students. In addition, it alters the normal Piagean conceptualization of learning from something that takes place in the individual mind, as an accommodation of new mental models and structures, to something that takes place in participation framework. Learning is, within this model, distributed among co-participants, not a meeting at the crossroad.

As Lave and Wenger (1998) state in their contribution to Leach and Moon's book, 'Learners and Pedagogy', if the novice does not learn directly from the expert but from peers and the rest of the community then knowledge can be considered not to reside in an individual but to reside within the community as a whole - mastery resides not with the master but in the organization of the community of practice of which the master is a part. One of the features of learning in a practice context is that experts are able to guide novices through the complexities of practice. Brown et al. (1988) have further developed the concept of the situated learning by analyzing the way in which novices learn from experts. Modeling involves the demonstration of particular aspects of practice by the experts. They make their situated knowledge explicit as they coach the learners. The coaching involves the provision of feedback on the learner's performance. This often makes use of Vygotskian notions of scaffolding and fading by

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which novices are supported in the completion to tasks which they would be unable to achieve without help (Tharp & Gallimore, 1988). This learning process moves the focus of the learning away from pedagogy and the skills of the master to the efficacy of the community's learning resources. Thus the problems for the school teachers are not those of pedagogy – how best to teach – but problems of how the community of practice involved can be replicated within the confines of the school's learning environment.

This study based on the theory "communities of practice" (Lave & Wenger, 1991; Wenger, 1998) which was notion from the constructivist theory. Social constructivism (Vygotsky, 1978) is the key process at work. Social constructivism broadens Piaget's view of individuals constructing knowledge and poses the question, is the 'mind' located in the head or in social action (Cobb, 1969). If the mind resides in our heads then we can think of learning as acquiring knowledge; if the mind is influenced and shaped by society, social action and social responses - as in a community of practice - then we can think of learning as participating in knowledge held jointly by the community (Cobb, 1969). As learning as participating in knowledge held jointly by the community then this concept has been proposed.

Communities of practice are not merely a community of interest. It brings together practitioners who are involved in doing something. Over time, they accumulate practical knowledge in their domain, which makes a difference to their ability to act individually and collectively.

In this model, learning and knowing are embedded in the relations and interactions among people engaged in activities within their socially and culturally structured world. Learning becomes a social practice in a world jointly constructed meaning and knowledge. Learning is viewed as a transformation of newcomer to old-timer rather than a process of transmission of skills from teachers to students. In addition, learning is distributed among co-participants, not a meeting at crossroads.

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2.4 Inquiry-based Instructions

In the past 20 years, our understanding of how people learn has changed. Not long ago, many people believed that students' brains were like empty vessels waiting to be filled with knowledge imparted by a teacher. But advances in cognitive research and developmental psychology, combined with today's urgency to educate all students in an increasingly diverse society, have transformed the way we think about teaching mathematics and science. Today, educators and researchers understand that most people learn more effectively through personal experience and by connecting new information to their prior knowledge and believe. Listening to a teacher lecture and reading textbooks are not enough to gain depth of knowledge. Students need to personally construct their own understanding by posing their own questions, designing and conducting investigations, and analyzing and communicating their findings. Students need to have opportunities to progress from concrete to abstract ideas, rethink their hypotheses, and adapt and retry their investigations and problem-solving efforts. In short, students construct their own understanding by taking an active role in their learning—one of the primary tenets of inquiry (NRC, 1996; 2000). In fact, national and state reform measures in science and mathematics education call for inquiry teaching methods that enable students to contribute their own ideas and to pursue their own investigations.

A classroom based on inquiry is more than a "gathering of individual learners brought together for reasons of economy." Rather, it is a community of inquiry (Schifter, 1996). In this community, students and teachers share responsibility for learning and collaborate on constructing understanding. Students offer their input into many aspects of their learning: how the classroom is set up, how time is structured, which resources are used, which topics are explored, how investigations will proceed, and how findings are reported. No longer are teachers sole surveyors of knowledge and students passive receptacles.

Inquiry guides a learner's explorations into the workings of the world. Along the way, he or she gains wisdom founded on knowledge. Ann Rosebery (Exploratorium Institute for Inquiry, 1996) stated: “Inquiry is a way of being in the world. It is a stance about one’s relationship to the world, to people, to one’s work, to knowledge. This path to wisdom requires an attentive and curious explorer, someone

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who actively makes connections between ideas and observed phenomena; one who can focus on an idea as well as, at times, to follow her curiosity and make unexpected connections. Scientific inquiry—the active construction of ideas and explanations—informs this adventure. As Dewey (1916) noted, inquiry helps us consider our past understandings in light of what we're learning, illuminating possibilities and helping us to choose which path to venture down next.

Ultimately, the central meaning of scientific inquiry revolves around two big ideas (i) inquiry as the essence of scientific enterprise, and (ii) inquiry as a strategy for teaching and learning science.

Thus, the fundamental nature of science is embedded in inquiry-based learning. Inquiry can be a very effective mechanism for better understanding the essence of science, its technical and reasoning processes, and the attitudes that accompany these processes. This is rather like using our brain to study our brain. For example, in order to understand the neurology or physiology of our brain, we use our brain's technical and reasoning abilities, as well as certain attitudes, to carry out and report our research. When we finish, we have a better understanding of our brain because we followed the rules by which it operates, using its precision and logic to build our understanding of it.

Several researchers and educators have shaped the definition and procedures of the inquiry approach in teaching. These researchers and educators such as from the National Research Council ([NRC], 1996; 2000) states, "inquiry into authentic questions generated from student experiences is the central strategy for teaching science." National standards emphasize the investigative nature of science and the importance of students' active engagement in the construction of scientific ways of knowing and doing (NRC, 1996; AAAS, 1993; 2001).

The Standards produced by the National Research Council (1996; 2000) defined ‘inquiry’ as: a multifaceted activity that involves making observations, posing questions, examining books and other sources of information to see what is already known, planning investigations, reviewing what is already known in the light of experimental evidence, using tools to gather, analyze and interpret data, proposing answers, explanations and predictions, and communicating the results. Inquiry requires

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the identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations (p. 23).

The National Research Council (NRC) (1996; 2000) argues that students do not come to understand inquiry simply by learning words, such as 'hypothesis', or by memorizing procedures, such as steps of the so-called 'scientific method'. Developing students' ability to understand and engage in inquiry-based learning activities then requires direct experiences and continues practice with the processes of inquiry. The literature suggests teachers the need to attempt to introduce students to the methods of science, and in particular to see how to design experimental investigations. In order to develop their understanding on inquiry, students must experience inquiry directly to gain a deep understanding of scientific characteristics, because experience and understanding go together (Cohen & Manion, 1995). The science teachers have to assist students to understand the inquiry processes in which they are engaged.

Research suggests that inquiry-type learning experiences are more effective if conducted in the context of the conceptual development of the topic taught. Thus it is argued that students should be presented with inquiry-based learning experiences in the subject of interest. Hofstein and Walberg (1995) said that in inquiry-type practical classes, students should be involved in the process of scientific inquiry for seeking understanding of science phenomena, and that this process should be integrated with other complementary activities, such as the development of scientific concepts, related scientific skills and experiences. Moreover, Hofstein and Lunetta (2004) suggested that laboratory activities offer important experiences in science teaching and learning; further commenting that teachers should provide students with experiences in methods of scientific enquiry and reasoning, and in the application of scientific knowledge with everyday life.

As pointed out in the Standards, a characteristic of inquiry is that learning science is an active process. An active process here refers to the teaching and learning strategy that the teacher uses inquiry to enable students to understand scientific concepts through an active learning method and students as inquirers or seekers of information are encouraged to ask questions, generate hypotheses, analyze data, solve problems, and draw conclusions (NRC, 1996). Students should be able to design and conduct scientific investigations in practical classes. Therefore, because students have

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to learn the procedural skills of scientists, and understand the nature of science and they could understand and retain the concepts that they have learnt (NRC, 2000). For example, students should have opportunities to conduct an investigation; for example, changing a single variable that might affect the rate of a reaction.

Therefore, inquiry teaching and learning pose a challenge to science teachers and their students to understand scientific inquiry in practical classes.

The engagement in inquiry-typed experiments in the chemistry laboratory, students can improve their ability to ask high-level and better questions, to hypothesize for further experimental investigations. The student written documentation can be used for promoting student learning in science, because writing, traditionally considered, is one of formal modes in the assessment of student understanding. For example, Keys et al. (1999) determined an important role in engaging student cognitive skills, such as scientific thinking and scientific skills, in investigating personal construction of meaning in the science laboratory.

Many science educators believe that inquiry-based laboratory can provide students to experience authentic scientific inquiries. For example, Hofstein and Lunetta (2004) believed that inquiry laboratories have potential to enhance student constructive learning, conceptual understanding and understanding of the nature of science. These laboratories involve that students are provided experiences to formulate hypothesis, design experiments, gather and analyze data, and draw conclusions about scientific problems or natural phenomena, with the development of scientific concepts and processes. Inquiry-based experiences are especially effective if conducted in the context of the conceptual development of the topic taught.

Scientific inquiry is a complex skill in science and becomes as an important element of the classroom. Science teachers believe that students can be able to understand the nature of scientific inquiry by engaging in inquiry. Scientific inquiry can help students develop the conceptions of the nature of science. In addition to knowledge of the scientific inquiry and the nature of science, the science teachers have to understand the processes that scientific knowledge is created to incorporate inquiry-based laboratory. Student knowledge about scientific inquiry and the nature of science does not occur by accident. Students do not develop an understanding simply through

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experiencing inquiry any more, so science teachers should allow students to come to the laboratory and to learn with their own experiences (Schwartz et al., 2004).

The trend in the educational reform around the world is to provide choices and alternative approaches for learners where teachers have the knowledge and skills to decide which approaches should be adopted when and for what reasons. It is understandable why the reform leaders in Thailand adopted student-centered learning as the main focus of change in the teaching and learning approach.

2.5 Environmental Education (EE)

Environmental education highlights the importance between experience-based and information-based approaches. Environmental education provides an important link for a study that looks into the possible disjunction between theories and practices in transition such as what which can occur between students as learners. EE should be an approach which provides the appropriate actions on knowledge of the world.

2.5.1 Definition of Environmental Education

In the field of EE, several researchers and educators have shaped the definition and goals of EE. These researchers and educators such as Stapp (1969), International Union for Conservation of Nature and Natural Resources [IUCN] (1970), UNESCO (1992; 1997), Hungerford et al. (1980), Orr (1994), and Ramsey (2001) defined EE as the process, interdisciplinary nature, application to all school subject area, and the challenges to educators in formal and non-formal setting.

Stapp (1969), at the University of Michigan published the first definition of EE. His definition extends the concept of conservation education by including components of citizen responsibility and involvement in decision concerning environment. He described EE as follows:

> *"[E]nvironmental education is aimed at producing a citizenry that is knowledgeable concerning the biophysical environment and its associated problems, aware of how to help solve these problems, and motivated to work toward their solution."* (p. 31)

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IUCN (1970) identified the definition of EE as,

"EE is the process of recognizing values and clarifying concepts in order to develop skills & attributes necessary to understand and appreciate the interrelatedness among man, his culture and his biophysical surroundings. EE also entails practice in decision making & self-formulation of a code of behavior about issues concerning environmental quality." (IUCN, 1970)

At an international level, EE gained importance during the 1972 Stockholm Conference on the Environment. Recommendation 96 of this conference recommended EE as a critical means to address the world's environmental crisis. This recommendation was addressed at the 1975 International Environmental Workshop in Belgrade, Yugoslavia, resulting a document that defines the goals and objectives of EE. The Belgrade Charter was further refined at the Intergovernmental Conference on EE in Tbilisi, Republic of Georgia in 1977. Similarly, UNESCO (1997) described that EE as a lifelong learning. Particularly, UNESCO identified aims of EE as to change, prepare, understanding the problems of the world as follow:

"EE, properly understood, should constitute a comprehensive lifelong education, one responsive to changes in a rapidly changing world. It should prepare the individual for life through an understanding of the major problems of the contemporary world, and the provision of skills and attributes needed to play a productive role towards improving life and protecting the environment with due regard given to ethical values." (p.24)

In response to this lack of coordination, Hungerford et al. (1980) suggested that the goal of EE should be considered. He maintained the following as the superordinate goals of EE:

"To aid citizens in becoming environmentally knowledgeable and, above all, skilled and dedicated citizens who are willing to work, individually and collectively, toward achieving and/or maintaining a dynamic equilibrium between quality of life and quality of the environment." (p.44)

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Orr (1990) presented seven propositions for EE as follows:

"All education is environmental education. …Environmental issues are complex and cannot be understood through single discipline or department. …The way education occurs is as important as its contents. …Experience in the natural world is both essential part of understanding the environment and conductive to good thinking." (p.48-53)

Similarly, Ramsey (2001) stated the important of EE preparation and mentioned the preparation of EE as follows:

"EE must prepare individuals to be responsive to a rapidly changing technological world, to understand contemporary world problems, and to provide the skills needed to play an effective role in improvement and maintenance the environment." (p.110)

In responding to those researchers and educators statements, it is necessary for people to be informed, take control and solve the environmental problems. However, the best way is to solve the problems. Therefore, as a global and national people much become more efficient in using their environmental and natural resources. Moreover, the 1992 Dublin Statement on Water and Sustainable Development, a hundred countries and representatives of eighty international, intergovernmental and non-governmental organizations, addressed concerns about the knowledge-based and capacity building on water and sustainable development. In addition, water resource management was stated as an important issue that people have to learn and study.

In Dublin Statement, education of environment issues and investigation those issues are considered to be necessary for people in all levels. EE is one strategy that may make people understand more clearly about environmental and resources management and result in changes in their behaviors. Children at a very young age can become environmentally aware and thereby be motivated to take action for their environmental and natural resources.

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Youths are needed to experience in a multi-perspective approach. In contrary, the effective education for young people to have the fundamental knowledge, skills, and values on their lives and the environment are the challenge. They need to experience for going beyond the classroom to realize their environment. Moreover, they need to realize that communities are built with participation. Therefore, public education is needed to consider the communities' identity as separated, contained institution within the society, and evolve into a new identity with evolving relationships in which they conduct their activities (Wheeler & Bijur, 2000).

2.5.2 History of Environmental Education

Over the past three decades, EE has been and is now implemented in the schools' curriculum. EE still has a largely inadequate, relatively inconsistent, and scattered presence in curriculum (Hungerford & Volk, 2003). EE takes place in many venues apart from the formal school curriculum i.e., non-formal education which children, youth and adults, its institutionalization versus formal schooling shapes the practice of EE both in and outside the schools. EE will be ineffective in advancing its own goal of creating an environmentally or ecologically literate citizenry as long as it continues to discipline itself within the norms of general education (Orr, 1992). The EE tends to neglect the social, economic, political, and deeper cultural aspects of the ecological problem. Moreover, EE works to legitimize and reinforce problematic trends in general education when it consorts with school as an adjectival educational discourse (Martin, 1996).

Since EE's widespread appearance in the 1970, its goals have been continuously contested. Many researches focused on individualistic skills and outcomes, and for EE failure to male explicit and develop a critical agenda for deep social transformation (Huckel & Sterling, 1996). On the other hand, other researches are concerned that the politicization of EE, whether radical or conservative, limits opportunities for people to develop the empathetic and the spiritual connections with the natural world on which political may depend (Miller, 1990; Sobel, 1996). Most researches agree for example, that the purpose of EE is to provide people with the experience and knowledge needed to care their environments. However, what counts

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as knowledge and the experience, what constitutes care, and even the meaning of environmental can differ widely among those with diverse political and personal commitments.

2.5.3 Educational System in Thailand

Thailand has gone through a truly comprehensive reform in education in accordance with the 1997 Constitution and 1999 National Educational Act. Thailand had educational reform in 1999 for many reasons. The framework of education included the 1997 Constitution that provided challenging guidelines for educational reform in several provisions, and the 1999 National Education Act which served as the major legislation on education in the country and which placed the holistic reform of education on Thailand's national agenda. The Thai educational system focuses on lifelong learning as one of the principles and ultimate goals. Lifelong learning is promoted through the transfer of learning outcomes and the validation of experiences. In this regard, learners transfer their learning outcomes between all types of education such as formal, non-formal and informal education while workers are encouraged to have their experiences validated.

The framework of education in Thailand is based on the 1997 Constitution and the 1999 National Education Act. They provide principles and challenging guidelines for the provision and development of Thai educational system in order to prepare all Thai people for a learned society. The Constitution has greatly increased the rights of Thai people to participate in political activities and the right to voice public opinion on major problems while the National Education Act has introduced new initiatives and provide principles and guidelines for the comprehensive reform in Thailand. The reform measures embrace equity and quality in education and aim to increase the quality of life of Thai citizens. The 1997 Constitution of the Kingdom of Thailand mentions participation of local people and communities in the educational system which will make education both relevant to the needs of the people and responsive to changing environments, demands and opportunities at the local level. The challenging guidelines mandated by the 1997 Constitution have been promulgated for implementation through the enactment of the national education law since 1999.

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The National Education Act is a 15 –year National Education Plan (1999). It was prepared by OEC (Office of Education Council), Ministry of Education. The National Education Plan focuses on the integration of all aspects of the quality of life. It emphasizes human-centered development and an integrated and holistic scheme of education, religion, art and culture. Thai people shall attain full development in terms of physical and spiritual health, intellect, morality and integrity as well as a desirable way of life that focuses on living in harmony with other people.

The National Education Plan has three objectives 1) lead to a knowledge –based economy and society; 2) promote continuous learning; 3) involve all segments of society in designing and decision making concerning public activities. It is also expected that the National Education Plan will empower Thai people so that they will be able to adjust to world trends and events while maintaining their Thai identity as well as develop desirable characteristics including virtue, competency, happiness and self-reliance.

Undoubtedly, educational reform cannot succeed without the reform of learning, a key issue in educational reform that directly benefits all people and can be implemented without any required regulation. In this regard, reform curricula, reform of learning process and establishment and development of lifelong learning sources, play a vital role. The problems that teachers faced after educational reform in 1999 were that teachers could not develop their own curricula, which had to relate to community problems and status. Teachers did not have enough knowledge about lifelong learning and student-centered learning to accomplish this goal of the Plan.

2.5.4 Environmental Education in Thailand

Environmental education has been included in Thai educational system for the past twenty-five years, influenced by international organizations, the country's intensified environmental problems and increasing environmental awareness among government, non-government, private sectors, and communities. USAID supported the Thai Ministry of Education's First Master Plan on Environmental Education (1991-6). This master plan consisted of a set of goals, strategies, rationale, work plan, and activities aimed for promoting awareness about conserving natural resources and the environment among all students and population. In addition, National Plans (5^{th}, 6^{th},

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and 7th) emphasized environmental education through, the development of environmentally related curricula and training of environmentally related personnel. Several environmental subjects were introduced into primary, secondary, and tertiary level. However, EE was not taught as a distinct subject in the curriculum but is incorporated into other subjects such as science, social studies, geography, civics, live experience, and moral education. The 1999 Educational Act stated that it is the duty of the responsible sectors to provide education. Emphasis is on decentralization, the community involvements are encouraged.

Environmental education should not be limited only in schools. The activities to promote and raise awareness of environmental conservation are also considered as means to educate the public. At present, EE in Thailand is undergoing a reorientation away from learning in classroom toward learning by doing outside classrooms. This is due to the perception that the most efficient and effective way of solving environmental problems is to raise awareness, especially among the young. Environmental awareness is raised when one is learning in practice about environmental conservation and protection (Bureekul & Brown, 2003).

EE in Thailand has been conducted mostly by using traditional method which is teacher-centered and top-down approaches (Bureekul & Brown, 2003). It is well established that learning by doing and participating in real situation and environment will lead to recognition of the importance of the environment and community (Ramsey, 2001; Wheeler & Bijur, 2000; Orr, 1992; Huckel & Sterling, 1996). This also enable students to track problems and to find ways and means to solve the problems. However, the concept of communities of practice is concentrating more on the students as a center of an interactive learning and teaching processes. Then, we need to look at the Wenger's theory which mentions how community involves in the learning.

2.5.5 Implications of Environmental Education in Schools

High-level policy and curriculum changes in many countries in mid- and late-1990s seemed to acknowledge a global re-orientation towards the sustainable environmental education. However, concerns were raised that implications of these changes for policy, curriculum, teaching and learning, and practice in the school sector

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were still not in well combination (Tilbury, 1995). Four key components of the reoriented environmental education are (1) sustainable development issues; (2) socially critical education; (3) participatory processes; and (4) partnerships for change (Tilbury, 2001).

There is a widespread view that these concepts have generally failed to take root in most environmental education in schools (Benedict, 1999; Rauch, 2002; Scott *et. al.*, 1998; Scott & Reid, 1998; Sterling, 2001; Tilbury, 2001). It has been argued that the goals and aims of EE are incompatible with existing structures of schooling (Stevenson, 1987), or at the least, challenge deep-seated concepts of knowledge, learning, and the disciplines (Benedict, 1999). By the same taken, environmental education has been identified as a potential breeding ground for innovation and educational reform in schools (Elliot, 1999; Rauch, 2002).

2.5.6 Issues for Curriculum and Pedagogy

The re-oriented environmental education certainly poses significant challenges to curriculum and pedagogy in schools. Tilbury (1995) defines the "new", environmental education for a sustainable future, as being: relevant; holistic; values-orientated; issues-based; action-orientated; and critical education.

The "action-orientated" aspect is perhaps the most widely accepted of these six characteristics. It is often stated that EE comprises three dimensions: education in the environment, education about the environment, and education for the environment. The "in-about-for" classification was Lucas' (1979) attempt to categorize the different meanings that had been given to the term "environmental education". The concept was picked up readily within the environmental education literature, and it is often asserted that genuine environmental education only takes place when the real intention is education for the environment (Fien & Gough, 1996).

Education for the environment denotes an action-oriented approach where students work towards the resolution of environmental questions, issues, and problems (Fien & Gough, 1996). Fien (1994) locates this kind of EE within the critical theory tradition of education. Critical theory directs analysis of environmental problems towards identifying social interests and forces which contribute to, or sustain, the degradation of the environment. Critical theory is in the sense that it seeks to enable

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teachers and students to identify and critique the social structures which influence their own and others' thoughts and actions, so that they might make choices that are not constrained by these influences.

A socially critical approach sees EE as having a transformative function. Through socially critical environmental education practice, students and teachers may begin to identify and challenge existing structures which contribute to the creation or perpetuation of environmental problems. The critical theory/critical pedagogy approach has widely supported in the environmental education literature, although it is not without its critics. Walker (1997) argued that, in the case of environmental education, critical theory is more useful as a way of critiquing practice than changing practice. "Educational researchers have carefully portrayed cases of exemplary practice, theorised about how practice could be improved, and worked with practitioners to implement EE in their schools. The key issue, then, is why has research in EE had so little influence on the learning and teaching of environmental education in schools?" (Walker, 1997).

Walker (1997) argued that critical theory research approaches in environmental education are inadequate as tools for changing teaching practice because they do not take teachers' own theories about teaching, learning, and curriculum into account, nor do they adequately recognise and accommodate the conditions and constraints of teaching practice. As a result, Walker suggested that socially critical environmental education will only be implemented in schools where there is already a coherence between practitioners' constraint structures including their theories about learning and curriculum, and socially critical environmental education theory. Where there is no such coherence, Walker predicted that socially critical environmental education will fail to be implemented, because socially critical theory did not provide a mechanism for practitioners to change their theories and practice. Whether or not Walker's argument is robust, the literature certainly supports the claim that implementing EE in schools requires significant changes for teachers, learners, and other partners in the school education. Before reviewing some models that have been proposed to support these changes, it is useful to look further at how contemporary theorists have defined the educational goals of EE. Two areas of note are the concept of "action competence", and the growing emphasis on pluralistic views in EE.

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2.5.7 The Instructional Vision of Environmental Education

Environmental education is a comprehensive and cohesive whole that both draws on and advances broader educational goals and instructional methods. EE is an integrative undertaking. Instructors teach across disciplines, linking the methods and content of natural and social sciences, art, mathematics, and humanities to help learners fully understand and address complex environmental issues. Environmental educators need the ability and the commitment to keep the whole picture in mind as they facilitate students toward environmental literacy."

The learner is an active participant in EE. If learning is to become a natural, valued part of life beyond school, instruction should engage the learner in the process of building knowledge and skills and be guided in part by the student's interests. Environmental issues are complex and multi-faceted. They can especially prompt deep feelings and strong opinions. Educators must take a balanced approach to instruction. Educators incorporate differing perspectives and points of view even–handedly and respectfully and present information with intellectual honesty. They involve learners in critical evaluation of data, results, models, conclusions, and opinions. Fairness and accuracy are watchwords for instruction.

Three important ideas that shape the instructional vision of environmental educators are systems, interdependence, and the importance of where one lives. The idea of systems helps make sense of a large and complex world. A system has parts that can be understood separately, but the whole cannot be understood completely without recognizing the relationships among its parts. Environmental educators are challenged to recognize the ramifications of our interdependence. EE begins close to home, encouraging learners to explore and understand their immediate surroundings. The sensitivity, knowledge, and skills gained by forging this local connection provide a base for moving out into larger systems, broader issues, and a lifetime of learning about causes, connections and consequences.

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Environmental education works both in and outside the classroom. Instructors foster learners' innate curiosity and enthusiasm, providing them with early and continuing opportunities to explore the environment. Experiences outside classroom are an important instructional strategy for engaging students in direct discovery of the world around them. This awareness of their local community can prompt a personal commitment to apply skills and knowledge in pursuit of environmental quality and quality of life.

Finally, environmental education provides opportunities for learners to enhance their capacity for independent thinking and effective, responsible action. Engaging in individual and group experiences helps learners develop these capacities independently and in collaborative situations that anticipate the way in which problem-solving happens in the community, on the job and in the family. A strong emphasis on developing communication skills helps learners demonstrate and disseminate their knowledge.

2.5.8 Action Competence in Environmental Education

The new environmental education view as named "action competence" means students' abilities to act with the reference to environmental concerns has articulated a widely concept (Breiting & Mogensen, 1999; Jensen & Schnack, 1997). This view is underpinned by the view that environmental problems are structurally fasten in society, and therefore have to be understood as community issues with the conflicting interests at the all levels including individual, social, and structural. Moreover, EE can help students to identify, expose, and analyze all three levels which address the causes of environmental issues (Breiting & Mogensen, 1999).

Action competence supports the purpose of EE that it is not simply to modify students' behaviour (Jensen & Schnack, 1997). Jensen and Schnack argued that it cannot be a task of the school to improve the world with the help of students' activities. But the school should try to influence the students' behaviours in a previously determined direction, without allowing students to consciously choose whether or how to make a behavioural change. The environmental education programs have to be concerned with educational value according to educational standards rather than pure environment. The participation approach has been included by a democratic

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view of education. The members decide for themselves in what and when they will be involved (Jensen & Schnack, 1997).

For the “action competence”, EE programs must aim at involving students as active participants in all aspects of the environmental education experience. Students must be supported to identify problems, determine solutions, and take action in a way that empowers them to become competent, completed, and willing participants in future actions that contribute to the solution or prevention of environmental problems (Wals, 1994).

The model “action-taking” has been developed by Wals et al. (1997) to support the implementation of environmental education programs as action research and community problem-solving model. This model involves teachers, environmental educators, and students in a research triangle as each group engages in a process of inquiry and reflection that relevance by members of the school community (Wals et al., 1997).

Wals stated that “…this means that students investigate a local environmental issue of their own interest (e.g. water quality, school beautification, school violence and safety), teachers investigate ways to improve their own teaching (e.g. working in groups, utilising community resources, conflict management), and outside facilitators who co-ordinate the research triangle, investigate contemporary issues in EE research (e.g. students’ perceptions of nature, student empowerment, curriculum design)” (Wals, 1994, p.140).

The model of action-taking was applied in schools in the United States and the Netherlands. The results showed that it was successful but the process required much time, energy, and commitment from those involved.

2.5.9 Others Views in Environmental Education

Those who involved in environmental education should be allowed participating in discussion, communication, sharing their opinions, and reflect on their roles and identities throughout the environmental education programs. Many studies found that EE must be seen as a developing process rather than fixed goal (Tilbury, 2001a; Scott et al., 1998).

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The environmental education is not be only implemented in formal education system, but also discourses through many ways that the environment can be viewed because environment is a nature, a problem to be solved or a resource to be managed, or a system to understand and learn, or a community project to study (Gough, 1997). As Sauvé mentioned that it is an essential dimension of basic education focused on a sphere of interaction that lies at the root of personal and social development: the sphere of relationships with our environment (Sauvé, 2002, p. 1).

In the field of EE, several researchers and educators have shaped the definition and goals of EE. These researchers and educators such as Stapp (1969), IUCN (1970), UNESCO (1977), Hungerford (1980), Orr (1990), and Ramsey (2001) defined EE as the process, interdisciplinary nature, application to all school subject area, and the challenges to educators in formal and non-formal setting. This particular study offers a context for integrated learning. An integrated curriculum is often associated with real-life problems in contrast with a traditional subject-based curriculum. This provides a mean for higher order thinking as students are challenged to move beyond memorization to see patterns and relationships and pursue a topic in depth. They are engaged in constructing knowledge rather than accumulating information and they also develop analysis and synthesis skills (Drake, 1998).

This has significance for EE in the knowledge students have of the subject area. For this reason, the exploration of the environmental education program to enhance student's knowledge, perceptions toward water resources management, and self-reported behaviors toward water resources management can shed light on the science education research and on society generally.

2.6 Research on Environmental Education

A number of the literature indicates that sustained contact with a given place can best cultivate children's environmental knowledge and concern (Hart, 1997; Sobel, 1996; Vaske & Kobrin, 2001). Nevertheless, current EE practices may not be the most effective pedagogical approach to creating genuine environmental concern. In a recent study, Haluza-Delay (2001) found that EE built around wilderness experiences might actually diminish environmentally responsible behaviors among suburban participants because these programs tend to reinforce the separation of pristine nature and the

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students' home environments. This finding implies that teaching children about the positive aspects of their local environment would build their sense of caring and connection to the place where they live.

Fisman (2005) has examined the effects of an urban environmental education program (open spaces as learning slaces) on children’s awareness of their local biophysical environment. The results suggested significant changes on the students' maps in four of the five variables: scope, natural features, tree, and built features. The analysis of the interview data brings to light some plausible hypotheses that may explain the mechanism behind the observed relationship. This study resulted in a number of interesting findings that deserve further research. Some of the questions that are highlighted by this work include in the following questions. Would an action/service learning component increase elementary students' environmental awareness within their own neighborhood? Is action-oriented learning more effective in reaching children living in economically depressed neighborhoods than simply giving them the opportunity to experience nature? Do the neighborhood characteristics that seem to impede the development of awareness mediate other types of learning? Answering these questions will provide valuable guidance on the design of more effective curricular materials and will ultimately allow educators, planners, and policy makers to offer programs that will lay the foundation for the development of a generation of knowledgeable, engaged, compassionate community stewards.

DiEnno and Hilton (2005) applied constructivist learning theory to environmental education to explore knowledge gains, student attitudes, and engagement among high school students exposed to a week-long unit on nonnative plant species. Constructivist and traditional teaching methods were compared. Each class was given a pretest and a posttest. The constructivist group gained an increase in knowledge and attitudes, whereas the traditional group did not. The two groups did not differ significantly on engagement. The results of this study indicate that application of a teaching method based on the constructivist learning theory is a beneficial method for EE about nonnative plant species. The short exposure to an EE experience may not be a good indicator of lasting attitudes toward the environment. These short experiences may not be enough to produce fundamental change in an individual's disposition and attitudes toward environmental issues (Hart & Nolan, 1999). It may be

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necessary to spend more time in order to influence the affective realm (Tung et al., 2002). However, in order to bring EE into school systems, short-term programs may be a way to at least begin the process. Students will be exposed to new material and have the opportunity to learn. Benefits may be limited but still meaningful, in terms of the long-term hope of creating a community that values EE in schools.

There are increasing numbers of schools that attempt to integrate hands-on, inquiry-oriented activities in their classrooms to offer students an opportunity to experience major concepts in science (Krapfel, 1999). The National Science Education Standards (NRC, 1996) encourage teachers to help students develop their own problem-solving skills (Pate, Thompson, & Keyes, 2001). An integrated stream study can provide a learning environment that connects previous knowledge, personal experiences, and trips to the margins and maintains curiosity (American Association for the Advancement of Science [AAAS], 2001).

Stream studies have been integrated successfully into classrooms across the United States (Anderson, 2000; Bouillion & Gomez, 2001; Friday, 1997; Juhl, Yearsley, & Silva, 1997; Kimmel, 1996; Middleton, 2001; Randall, 1997; Steckelberg et al., 2000; Talsma, 2001). Stream monitoring and river studies provide a unique opportunity for students to investigate real-world problems associated with water quality. In addition, outdoor education programs, such as stream monitoring, provide frequent trips to the margins of the classroom (Haley-Oliphant, 1994; Palmberg & Kuru, 2000). Margins are places in the curriculum where students and teachers explore concepts, ideas, and questions that give everyone the chance to take risks, to wonder, and to maintain curiosity and creativity. Stream monitoring provides students with an integrated, holistic approach to learning. For example, the Chicago River Project was an interdisciplinary activity that integrated language arts, social studies, science, and math and provided a well-rounded view of the ways in which concepts and skills learned in school can be transferred to their lives outside of school (Bouillion & Gomez, 2001). Stream studies address the National Science Education Standards in several ways. Students are immersed in inquiry activities where the answer is unknown. They are asked to find explanations for problems in their community. They learn about how science works by designing their own experiments and collecting data using techniques and skills practiced by scientists. In addition, they experience the

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nature of science when the answer is not clear, and they integrate new information. Stream studies have the potential to add a new dimension to the science classroom because they are inquiry based and focus on real-world situations. Conducting stream studies provides students with an education that empowers them, gives them a reason to learn, and makes science come alive.

Overholt and MacKenzie (2005) surveyed fifteen secondary school teachers in five states on how they designed and implemented a long-term stream monitoring in their classrooms and the problems and benefits they encountered. The researchers surveyed the students involved in the stream monitoring projects to obtain their perspective. Teachers reported that stream monitoring provided real-world application of concepts discussed during class and offered an interdisciplinary learning experience for students. In the present study, it seems clear that there was no specific set of steps that teachers followed to design and execute this type of project. Teachers secured funding from a variety of sources, depending on their needs and their ability to interact with local, state, and national sources. Most teachers did not have any difficulty gaining support from their school district.

Smith-Sebasto and Walker (2005) presented the findings of a study that explored student perceptions of the residential environmental education (EE) program at the New Jersey School of Conservation. The researchers administered a 3-item instrument that was based on the minute paper/muddiest point techniques to 2,779 students from 31 schools. A qualitative methodology with a grounded theory approach was used to discover which areas of the program were most meaningful, most confusing, and most interesting to the students. The findings revealed that students found social, personal, and wilderness survival sessions to be very meaningful. They thought environmental science sessions were confusing. They were interested in learning more about many subjects, but they have less interest in social topics than environmental science, safety, or recreation topics. A grounded theory for effective residential environmental education has been offered.

Recent science education reform proponents explicitly put forward the idea that all students, regardless of culture, gender, race, or socioeconomic status, should be capable of understanding and doing science. Students often report that what they learn in science lacks relevance to their lives (Nieto, 1994). It is unfortunate that this

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perception is rather pronounced in the field of environmental education (EE). For example, Connell et al. (1999) found that most Australian high school students did not believe that environmental issues affected them and that there was very little they could do to improve the environmental conditions where they lived. These findings are indicative of a more generalized perception that traditional school science experiences do not facilitate in developing the belief that students can be caretakers of the environment (Gough, 2002; Hudson, 2001; Legault & Pelletier, 2000; Tran et al., 2002; Worsley & Skrzypiec, 1998). Barnett et al. (2006) have developed and implemented a field-based urban ecology science program to engage the traditionally underrepresented groups, such as minorities and women in real-world science to address this need. The researchers described the components of the program and discussed why the program has been successful in providing opportunities for all students to engage and learn science. Using mixed methods to evaluate the program, they found that it improves student interest in science, and supports students in developing a better understanding of scientific methodologies, and improves students' sense of environmental stewardship when compared with students experiencing traditional science instruction over the course of an academic year.

Fien et al. (2002) explored similarities and differences in the knowledge, beliefs and actions that comprise the environmental attitudes of senior secondary school students in Australia and Brunei. Utilizing the data from a wider international study in Asia and Pacific (Yencken et al., 2000a), the paper uses findings from these two countries to illustrate the pervasiveness of global environmental concerns over local cultural influences in the construction of youth environmental attitudes in Australia and Brunei. Thus, young people in these countries, as they do in all parts of the Asian-Pacific region, have very similar levels of environmental awareness and knowledge, sources of environmental, beliefs, systems or world views about the environment, and levels of perceived control over environmental trends. They also have a shared desire for schools to do more in the areas of environmental education. The paper concludes that much more effort is needed in certain areas. The first is to encourage teachers and others who have influence over young people to develop their own knowledge and skills to be able to teach environmental education effectively. The second is in the area of curriculum and pedagogical reform so that young people

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explore the many possible ways in which current systems can change to support sustainability, in which current lifestyles reflect these systems, and in which their own actions can contribute to a sustainable future.

Simmons (1998) studied the teachers' perceive on benefits and barriers using natural settings for environmental education. Questionnaire (83 items) and open-ended interviews were used for data gathering. The results show that the teachers viewed the four natural settings quite distinctly. Deep woods and rivers, ponds, and marshes were seen as being significantly more appropriate for teaching EE than urban nature was. On the other hand, they were also seen as presenting significantly more hazards than either county park or urban nature settings. A close look at the results suggests particular areas of concern for each of the settings and, consequently, particular topics that need to be addressed through training programs or materials development. For the rivers, ponds, and marshes setting, planners of training programs need to help teachers gain the necessary background to teach about these watery environments. In addition, planners need to help teachers develop the necessary skills and resources that address perceives of the safety issues. Finally, planners need to understand why so many teachers believed that it would be difficult to arrange a trip to this type of setting. Although teachers' perceptions of each setting varied, there were certain commonalities. An examination of the results across all of the settings provides some insight into how the teachers perceive natural areas. In general, the teachers believed that it was important to provide nature experiences as part of the curriculum, which their students would enjoy these experiences, and that participation in programs at natural areas would be educationally worthwhile. But with their strong endorsement came a concern over their own preparation. Compared with their sense of the importance of providing EE, the teachers were less certain about whether they would feel comfortable teaching in the settings. Likewise, they did not believe that they were particularly well trained to teach in natural areas. They expressed a desire for more training and felt they would require more training before they took their students to places like these. In contrast, teachers expressed a great deal of confidence in knowing what to do with their students and knowing what teaching techniques to use in each setting. Similarly, teachers were not particularly worried about not knowing the answers to students' questions. They were concerned, however, about students' safety,

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exposure to poisonous plants, and the possibility of getting lost. In addition, they seemed to believe that their classes were too large to manage and that they lacked the necessary background to teach in natural areas. The results describe teachers who are enthusiastic and somewhat confident, yet apprehensive, about teaching in natural areas. When training programs are developed they need to address these multifaceted views. Although some focus on teaching methods may be welcomed, the teachers may find sessions and support materials that directly confront their fears most beneficial.

According to a review of environmentally educational researches and science educational researches, a perspective of developing environmental education program becomes a matter of engaging student into the real situations and creating the activities which students cane actively participate.

In response to what researchers, educators, and environmental educators contended, this study intends to conduct the study documenting and revealing the developed environmental education program in the lower secondary school context and depicting how this developed program impacted the student' performances. This study employed the processes of collective and collaborative learning, which are based on socio-cultural learning concepts and focus on the role of group membership or community participation for (collective and individual) learning (Bruner, 1996; Lave & Wenger, 1991; Vygotsky, 1978; Wenger, 1998).

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CHAPTER III
METHODOLOGY

3.1 Overview

The chapter begins with theoretical framework of this particular study. The ethical concerns in this study are also presented. The next section describes the data collection. The descriptions of how the data were analyzed and interpreted are presented. Research design for this study is described.

3.2 Theoretical Framework of the Present Study

This part provides the theoretical framework involving in this study. The socio-cultural theories of learning that underpin this study, as well as an experiential education and constructivists as theoretical framework of this study are described. The theoretical framework for this study is summarized in Figure 3-1.

The socio-cultural theories of learning (Bruner, 1996; Lave & Wenger, 1991; Vygotsky, 1978; Wenger, 1998) served as theoretical framework for this study. As mentioned in section 2.3.5, socio-cultural theories of learning comprise the learning and practicing which take place within social aggregates that share a common practice. Knowledge can be emerged by discursive assignment of meaning and social identification. Therefore, learning packages were used here as a concept to describe processes of collective and collaborative learning. This serves as one of the framework of this study, as shown in the left part of Figure 3-1. The researcher concerns that students are purposeful in their learning and practicing in places within social interactions that share experiences, rather than act as spoon-receiving. The development of knowledge on ecology is not only constrained by empirical data, but is also socially interaction validated by community of learners and goes beyond practicing in the natural world. Learning is an active process in which meaning is accomplished on the basis of experience. These theories of learning belief that knowledge cannot reject the existence of the real world (Chapman, 1988). Moreover,

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scientific knowledge cannot, therefore, be learnt from sensory experience alone (Leach & Scott, 2003).

Due to the complex nature of social settings in which knowledge is enacted, it is critical to understand the various aspects that contribute to the formation of the socio-technical conditions for stakeholders to accomplish their work, instead of focusing solely on the knowledge-transferring problem. The theoretical framework of this study is based on the concepts of distributed cognition, social networks, and more importantly focuses on the role of human agency in enabling the work to get accomplished in the context of a real-world situation.

Therefore, communities of practice may help students to learn and practice by emerges by discursive assignment and social identification (Lave & Wenger, 1991; Wenger, 1998). Since many research studies indicate the key of the skill, development of nature is practicing authentic contexts in order to learn to interpret situations and to deal with them effectively. These learning packages bring together learners involved in doing something. Over time, they accumulate practical knowledge in their domain, which makes a difference to their ability to act individually and collectively. In these newly developed learning packages, learning and knowing are embedded in the relations and interactions among people engaged in activities within their socially and culturally structured world. Learning becomes a social practice in a world of jointly constructed meaning and knowledge.

In these learning packages, learning and knowing are embedded in the relations and interactions among people engaged in activities within their socially and culturally structured world (Lave & Wenger, 1991; Wenger, 1998). Learning becomes a social practice in a world of jointly constructed meaning and knowledge. Learning is viewed as a transformation of newcomer to old-timer rather than a process of transmission of skills from teachers to students. In addition, learning is distributed among co-participants, not a meeting at the crossroads.

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In this process, the focus of the learning is moving away from pedagogy and the skills of the teacher to the efficacy of the community learning resources. In addition, these learning packages will be added in the context that reflects the real world for the constructive process which happens and transfers from environments to schools and classrooms.

Due to the complex nature of social settings in which knowledge is enacted, it is critical to understand the various aspects that contribute to the formation of the socio-technical conditions for stakeholders to accomplish their work, instead of focusing solely on the knowledge-transferring problem. Theoretical framework of this study is based on the concepts of distributed cognition, social networks, and more importantly focuses on the role of human agency in enabling the work to get accomplished in the context of a real-world situation by promoting community of learners which composed of educators, researchers, community people, and students.

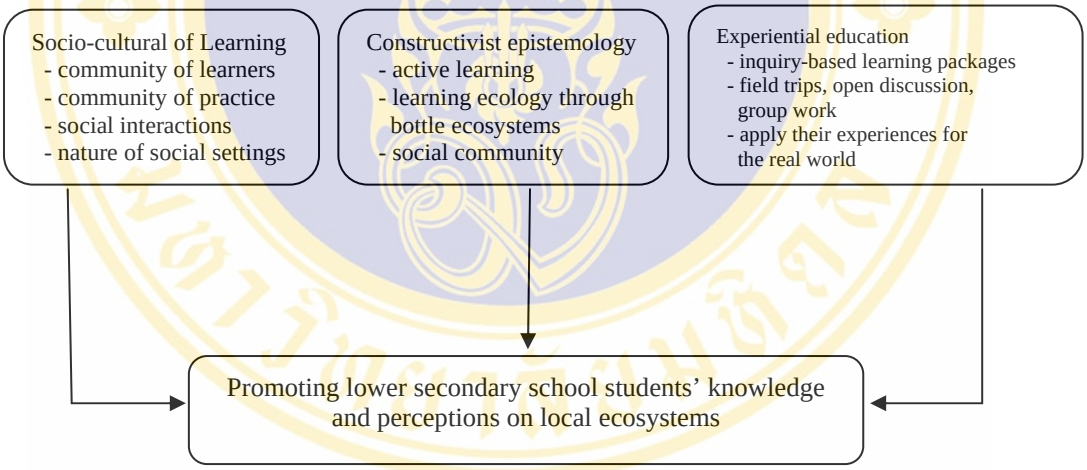

Figure 3-1 Theoretical Framework of this study

As shown in the middle part of Figure 3-1, this study was applied from the constructivist epistemology. It is a view about the nature of human knowledge and more particularly of scientific knowledge comprises a view about the origins, transmission, mechanisms, and procedures of scientific knowledge (Matthews, 1994). **Constructivism** is connected with experiential learning and related to some of the ideas of Jean Piaget (Chapman, 1988). It is theory about knowledge and learning, which describes both "what is knowing" and how one "come to know". This is based on research work in psychology, philosophy, science, biology (Fosnot, 2005), and

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related to the epistemology of learning science (Matthews, 1998). According to Sandoval (2005), the constructivist epistemology that should be emphasized on teaching and learning of science can be classified into four main themes: science as construct, diversity of scientific methods, forms of scientific knowledge, and certainty of scientific knowledge. It can be summarized that scientific knowledge is constructed rather than discovered, and is socially validated. As such, learning science concepts is an adaptive and a cognitive process. It involves introduction of new knowledge through active learning and social interaction, rather than making sense of the natural world through personal observation and thought (Abd-El-Khalick & Lederman, 2000; Schwartz et al., 2004; Fosnot & Perry, 2005).

Related to that view, **experiential education** (Dewey, 1938; Kolb, 1984) has been proposed to develop students' learning for understanding and to link theory to practice. Students construct knowledge, skill, and value from direct experiences. This concept has been proved to promote learning by doing that aims to encourage learners to feel learning as well as to think it, and to let them "try on" new behaviors and new emotional and cognitive responses. It has been a corresponding need for curricula to translate abstract ideas into practical realities in human life. According to the experiential learning theory combines experience, perception, cognition, and behavior, this theory has been proposed.

In this study, learning packages were expected to be a matter of engaging students into the real situations and creating the conditions in which students actively participate in activities that enable them to make their own individual constructions. Activities, such as open discussion, group work, and problem solving, field trips etc., were used to enhance student's individual construction. Through these learning activities, the learners should utilize the components of learning and apply their experiences for the real world as suggested in experiential learning (Kolb, 1984).

The researcher believes that the experiential education, such as described in this work, becomes a matter of engaging students into the real situations and creating the conditions in which students actively participate in activities that enable them to make their own knowledge individual constructions. Activities, such as open discussion, group work, and problem solving, field trips etc., are used to greatly enhance student's individual construction. It has been found in science educational

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research and environmental education research to be an effective method that promotes students understanding of scientific concepts and linkage to the natural world (Kolb, 1984; Moore & Young, 1978; Tuss, 1996; Martin *et al.*, 1981). The researcher also believes through this learning program, the learners will utilize the components of learning and apply their experiences for the real world according to Kolb and Fry (1975).

As shown in Figure 3-1, the researcher aims to promote student knowledge and perception on local ecosystems by applying the theoretical concepts of social-cultural theories of learning, constructivist epistemology, and experiential education to develop learning packages to be used in the science class undertaken by lower secondary school students. The learning packages were developed based on inquiry approach, as NRC (1996; 2000) defined, an 'inquiry' as: a multifaceted activity that involves (1) making observations, (2) posing questions, (3) examining books and other sources of information to see what is already known, (4) planning investigations, (5) reviewing what is already known in the light of experimental evidence, (6) using tools to gather, analyze and interpret data, (7) proposing answers, (8) explanations and predictions, and (9) communicating the results.

In this study, the researcher developed the learning packages based on inquiry approach comprising three learning packages (i) a guided inquiry learning package on aquatic ecosystems, (ii) a learning package on scientific investigation of bottle ecosystems, and (iii) a community-based learning package on local ecosystems. These learning packages were developed through collaborations of supervisors, local teachers, local sages, science educators, environmental educators, and scientists from the university, and researcher. Regarding the implementation of these learning packages, the research study not only seeks to determine the effectiveness of the learning packages, but also investigated how these packages influence students' learning. To examine such a study, the mixed-methods approach providing combine of qualitative and quantitative was employed for data collection and analysis.

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3.3 Ethical Issues

The ethical concerns are principally those of the ongoing maintenance of confidentiality with respect of data, obtaining inform consent from all participants, monitoring for potential harm throughout the study, and the methods for dealing with any concerns of participants with respect to being involved in a research.

To gain permission for the research to be conducted in the schools, a formal letter was sent to the school principal. The letter described research goals and objectives, research methodologies, the time duration required for each data collection method, name of research's advisor, and the researcher's contact address. When permission was granted, the researcher sent a letter and a consent form to every potential participant for the study. Anybody volunteering to participate in the research was required to sign a consent form and mailed it back to the researcher.

In addition, teachers and students involved in this research were given the information about the study before the research was undertaken. The aims and questions which formed the basis of the study, and the requirements of the study in terms of data collection were explained. The ethics governing the conduct of the research were clarified. These included research methodology and procedures the researcher would follow in setting up data collection as interviews and observations; ownership of the data, and data analysis by the researcher; in maintaining the confidentiality and accuracy of transcripts; in monitoring for potential harm, the methods for dealing with concerns; and the way for withdrawing from the study. The participants were also asked to sign their names as they agreed to participate in this study.

For ethical reasons and respect for human rights, the participants' have been given pseudonyms. It needs to be noted that the participants in this study were completely voluntary and anonymous. Moreover, the participants had been informed that they were free to withdraw from the study at anytime.

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3.4 Procedures Used for Data Collection and Analysis

3.4.1 Data Collection

The researcher considered that mixed-methods research paradigm (Johnson & Onwuegbuzie, 2004) is appropriate to use to gather data and analyze data. The mixed-methods technique addresses much more comprehensive research purposes than quantitative or qualitative approach alone (Creswell, 2003; Bryman, 1988, 2007; Brewer & Hunter, 1989; Green, et al., 1989; Creswell, J.W., & Plano Clark, 2007: Tashakkori & Teddlie, 2003; and Christ, 2007). So, mixed-methods technique was used in this study to maximize strengths, minimize weaknesses of the study, and collect more complete answers to posed research questions (Johnson & Onwuegbuzie, 2004).

Accordingly, researchers collect multiple types of data (Johnson & Onwuegbuzie, 2004). As described by Johnson and Christensen (2004), mixed methods approaches are effective because "*words, pictures, and narrative can be used to add meaning to numbers; number can be used to add precision to words, pictures; and narrative; can provide quantitative and qualitative strengths; can answer a broader and more complete range of research questions because the researcher is not confined to a single method or approach; the researcher can use the strengths of an additional method to overcome the weaknesses in another method by using both in a research study, and can provide stronger evidence for a conclusion through convergence and corroboration of findings* (pp. 409-414).

The researcher conducted a mixed-methods study with a triangulation design. Triangulation has been described as ". . . *a technique which provides more and better evidence from which researchers can construct meaningful propositions about the social world* (Mathison, 1988, p 15). Mathison (1988) and Merriam (1988) also argued for the use of triangulation to conduct educational research to augment the validity of findings of issues under investigation. However, understanding a social phenomenon as well as educational aspect requires its examination under variety of conditions (Denzin, 1978). Therefore, time triangulation that means investigation in the different of times was employed in this study.

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Needing the theoretical concepts of both mixed-methods and triangulation, the researcher employed four qualitative and quantitative data collection strategies to gather data for the present study. These included (1) a questionnaire, (2) interviews, (3) the collection of written documents, and (4) classroom observations (Patton, 1990). The natures of these data collection strategies will be discussed in a later section.

3.4.1.1 Questionnaire

A questionnaire is "*a self-report data-collection instrument that each research participant fills out as part of a research study*" (Johnson & Christensen, 2004: p.164). Therefore, the purpose for using a questionnaire was to obtain information about the perceptions and behavioral intentions of students. To quantify students' perceptions and self-reported behaviors, the researcher adapted Musser and Malkus's (1994) questionnaire to use in this study. A questionnaire was developed to examine the students' perceptions toward ecosystems and resources management and self-reported behaviors toward resources management. Two different types of information were gathered from a questionnaire: (1) information on students' perceptions toward ecosystems and resources management and (2) students' self-reported behaviors toward resources management (see Appendix A for a full questionnaire).

The questionnaire for the present study comprised of 5-point Likert scale 30 items ranging from strongly agree to strongly disagree for students' perceptions toward ecosystems and management (Section 1) and from always to never for self-reported behaviors toward ecosystems and management (Section 2). This questionnaire was tried out with thirty grade 8-students. The internal consistency of the questions, using Cronbach's alpha coefficient (internal consistency), of Section 1 and Section 2 were 0.85 and 0.88 in respective order. The reliability of Section 1 and Section 2 were 0.88 and 0.91. Thus, this questionnaire could be effectively used to quantify the students' perceptions toward ecosystems and resources management and self-reported behaviors toward resources management because of its internal consistency was more than 0.7 and the reliability was more than 0.8 in all sessions.

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One set of questionnaire was used to obtain information on students' perceptions toward ecosystems and resources management and self-reported behaviors toward resources management both before and after the program implementation.

3.4.1.2 Interviews

Interviews followed by the questionnaire conducting. An interview is *a data-collection method in which an interviewer (the researcher or someone working for the researcher) asks questions of an interviewee (the research participant)* (Johnson & Christensen, 2004: p.178). In this present study informal, formal, and semi-structured interviews were conducted with the participants (Cohen *et al.*, 2000). The purpose of the interviews was to gather data about the opinions, students' perceptions toward ecosystems and resources management, experiences with participating in the program, and assess students' level of understanding of ecosystems concepts. The direct verbal interaction between individuals in an interview during the interview provided the interpretative meaning and descriptions of particular themes being investigated (Cohen, Manion, and Morrison, 2000).

Before conducting the interviews, a list of open-ended questions were developed. The interviews questions had been validated by three experts from three different disciplines. Then, these interview questions were piloted with three students. The questions were modified according to the students' comments and discussion with two experts. This process was repeated two more times to obtain the effective interview protocol. After the pilot interviews, several modifications were made. Interview questions were re-arranged; some were re-worded; and some were removed with comments from these interviewees and a discussion with the researcher's thesis advisors. Finally, two more pilot interviews were conducted and the final interview protocol was completed. (see the interview questions in Appendix B).

Eight randomly selected students were interviewed. Before the interview, the researcher asked the participants for permission to take notes and tape-record the interview. The interviews were conducted both before and after the program to measure conceptual understanding of the ecosystems, perceptions toward water resources management, students self-reported behaviors toward water resources management, and students perceptions toward learning packages. The researchers asked questions in a variety of formats and compared responses as an internal check

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for self-reporting bias. Moreover, teachers were interviewed to evaluate their perceptions toward learning packages (see the interview questions in Appendix C). Each 30 minute semi-structured interview was audio-taped, noted, and transcribed for further analyses using open and axial coding techniques according to Strauss and Corbin (1998).

3.4.1.3 Written Documents

Written documents provided another source of data for this present study. Merriam (1988) described the benefits of written documents as follows.

> *Documents, on the other hand, are usually produced for reasons other than research and therefore are not subject to the same limitations. They are, in fact, a ready-made source of data easily accessible to the imaginative and resourceful investigator. (p. 104)*

The researcher, following Merriam (1988), collected various written documents containing information about the learning packages implementation throughout a semester-long data collection. The collected written documents included curricular and course descriptions, course outlines, teaching materials, projects for fieldtrips. All of written documents were analyzed to provide the description of the program. The students' works were also gathered. These written documents composed of concept maps, reports, free writing, and journals to assess students' conceptual understanding, perceptions toward ecosystems and resources, and perceptions toward learning packages.

3.4.1.4 Classroom Observations

Observations are *"the watching of behavioral patterns of people in certain situations to obtain information about the phenomenon of interest"* Johnson and Christensen (2004, p. 186). Such observations were needed to best capture natural behaviors and give a firsthand account of the situation being studied (Cohen, Manion, and Morrison, 2000). The purpose of the classroom observations was to gain first-hand experience with the activities that occurred both in and out of the class. The researcher used observations to help illustrate how various community members and agencies were involved in the teaching and learning of the learning packages.

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Prior to observations, the researcher developed an observation protocol. The observation protocol was adapted from Classroom Observation Protocol and Observation Protocol for Elementary Study (National Research Council, 2006), and contained items such as observation date and time, local context and environment, and classroom activities. The researcher piloted the observation protocol with two classes. Then, the observation protocol was revised for a final version with the assistance of the researcher's thesis advisers. (See Appendix D for the observation protocol)

During observations, the researcher took the role of observer-as-participant. That is, the researcher spent a *"limited amount of time observing group members and tells members they are being studied" (*Johnson and Christensen, 2004, *p. 190)*.

The processes of data collection used in this study are summarized in Table 3.1.

Table 3.1 The processes for collecting data in this study

Time	Type of Data	Data Collection Tools
Beginning of learning packages implementation	Student knowledge, perceptions toward ecosystems and resources	Questionnaire (Pre-test) Interview
During learning packages implementation	Student activities Student-student interaction Student-teacher interaction Teacher activities	Classroom observation Audio-recorder Video-recorder Students' works
End of learning package implementation	Student knowledge, perceptions toward ecosystems and resources	Questionnaire (Post-test) Interview Concept mapping Students' explanations Students' reports Students' diaries Students' reflection Students' journals Teacher's reflections

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3.4.2 Data Analysis

The researcher employed two approaches to analyze the gathered data. One was the quantitative approach using the Statistical Package for the Social Sciences (SPSS for Windows Version 13.0); the other was Strauss and Corbin's (1990; 1998) open and axial coding techniques for qualitative approach. Here, the approaches used to analyze data obtained from each data collection tool are described.

3.4.2.1 Analysis of Quantitative Data

The returned questionnaires were coded and entered into the Statistical Package for the Social Sciences (SPSS for Windows Version 13.0). The 5-point Likert-type scales indicated respondent's degree of agreement from score 1 (strongly disagree) to score 5 (strongly agree) and described their behaviors from score 1 (never) to score 5 (always). Descriptive statistics such as frequency, percentage, means, maximum, minimum and standard deviation were used for analyze data. Comparison of the mean difference before and after participated in community-based learning package in *Maeklong School* was analyzed by Paired t-test. Comparison of the mean difference between variables was employed to clarify how students perceived toward ecosystems and resources. The significance level for all statistical analysis was set at the level of 0.05.

3.4.2.2 Holistic Scoring Rubrics

The holistic scoring rubrics technique was applied for analysis of concept maps, reports, and interviews for conceptual understanding. The details of each analysis are as follows.

1) Holistic scoring rubrics of concept map

The concept maps were analyzed for three general concepts of the ecosystems: meaning, structure and role of organisms. Seventeen relationships and two hierarchies were set for analyzing and scoring. The examples of each specific concept given by the students were considered for analyzing and scoring as well. Scoring criteria for the concept map were set according to Novak and Gowin (1984), i.e. concept, proposition, hierarchy, and example (Table 3.2). The expected minimum and maximum total scores from the four elements were 1 and 45. Attributes for maximum quality are as follows: all relevant concepts of the ecosystems are correct with multiple connections; understanding of facts and three general concepts of the ecosystems are clearly

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demonstrated by correct links and the concept map is neat, clear, and legible, has easy-to-follow links and has no spelling errors. On the other hand, at the minimum total score of 1, the concepts are linked via the linking words but with low interrelationship between concepts and difficult to understand. Students' concept maps were analyzed according to the set criteria and then categorized into five levels of conceptual understanding: inadequate (score range 1-8), fair (score range 9-16), moderate (score range 17-25), good (score range 26-33), and excellent (score range 34-45) as shown in Table 3.3.

Table 3.2 Scoring criteria for concept map analysis (adapted from Novak and Gowin, 1984)

Elements	Score	Description
Concept	1 point for each concept	How many concepts does the map include?
Proposition	1 point for each relationship	Is the relationship between two concepts indicated by connecting link and linking word(s)? How many relationships are shown?
Hierarchy	5 points for each valid level of hierarchy	Does the map show hierarchy? How many hierarchies are shown?
Example	1 point of each example	Specific events or objects that are valid instances of those designated by the concept.

Note**:** Three concepts, seventeen relationships, two hierarchies, and fifteen examples were set. The expected maximum score of 45 are sum of the four elements.

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Table 3.3 Analysis of level of understanding for concept map of ecosystems. Holistic scoring rubrics for concept map analysis was adapted from Novak and Gowin (1984)

Level of conceptual understanding	Score range	Description of concept map analysis
Inadequate	1-8	No concept is identified. No submission.
Fair	9-16	A few relevant concepts of ecosystems are correct with no connections. Concept map is untidy and difficult to follow and has some *link errors*. Understanding of facts and concepts of ecosystems is demonstrated with some significant errors.
Moderate	17-25	Few relevant concepts of ecosystems are correct with two or more connections. Concept map is neat, *legible*, but some links are difficult to follow, and has some *link errors*. Understanding of facts and concepts of ecosystems is demonstrated but has some incorrect links.
Good	26-33	Most relevant concepts of ecosystems are correct with multiple connections. Concept map is neat, *clear*, and *legible*, has *easy-to-follow* links and has few *link errors*. Understanding of facts and concepts of ecosystems is demonstrated by a few error links.
Excellent	34-45	All relevant concepts of ecosystems are correct with multiple connections. Concept map is *neat*, *clear*, and *legible*, has *easy-to-follow* links with no *errors*. Understanding of facts and concepts of ecosystems is clearly demonstrated by correct links.

2) Holistic scoring rubrics of report

Six components of the report were chosen for scoring: title and introduction, objective(s), scope of study, materials and methods, results, and discussion. The details of holistic scoring rubrics for report analysis are shown in Table 3.4. Each component had a score range from 0 to 4 which was adopted from Schlenker and Tierney (2006). The expected minimum and maximum total scores were 0 and 24. Holistic scoring rubrics of reports were set into four categories: fair (score range 0-5), moderate (score range 6-11), good (score range 12-17), and excellent (score range 18-24).

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Table 3.4 Holistic scoring rubrics for report analysis (adapted from Schlenker and Tierney (2006)).

Components	Poor (0 point)	Fair (1 point)	Moderate (2 points)	Good (3 points)	Excellent (4 points)
Title and introduction	Title and introduction are missing.	Contain title and introduction.	Title focuses on an investigation of local ecosystems but is vague or non specific. Introduction does not give information about the significance of the report.	Title focuses on the investigation conducted but contains some vague terms. Introduction gives very little information about the significance of the report.	Title focuses on the investigation and contains no vague terms. Introduction presents the significance of the report.
Objectives	Objective is missing.	Contains objective(s).	Contains objective(s) but some are vague or unreasonable.	Most of objectives are clear and reasonable.	All of objectives are clear, reasonable, and accountable.
Scope of study	Scope of study is missing.	Contains scope of study.	Scope of study is vague.	Scope of study is clear.	Scope of study is clear, reasonable, and accountable.
Materials and methods	Materials and method section is missing.	Contains materials and methods section.	Some but not all materials and methods used are included. Quantity of materials is included. Methods of data collection and analysis are missing.	Some but not all materials and methods used are included. Quantity of materials is included. Methods of data collection and analysis are included.	All materials and methods used are included. Quantity of materials is included. Methods of data collection and analysis are included.
Results	Results section is missing.	Contains results section.	Includes all of the following: some results are included, results are not clear, results are not analyzed.	Includes all of the following: some but not all results, results are clear, results are not analyzed.	Includes all of the following: some but not all results, results are clear, results are not analyzed, only described.
Discussion	Discussion is missing.	Contains discussion section.	Results are explained but the connections with objective(s) are not clear. There is no clear connection between discussion and introduction.	Results are explained but the connections with objective(s) are not clear. There is a clear connection between discussion and introduction.	Results are explained based on the objective(s) are not clear. There is a clear connection between discussion and introduction.

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3) Holistic scoring rubrics of interviews

The interviews for conceptual understanding were conducted both before (Interview I) and after (Interview II) participation in the learning packages. Each of the ten interviewing questions was scored using the interview scoring rubric adapted from Magntorn and Helldén (2007). The concepts of ecosystems were categorized into three topics: structure and recognition of the ecosystems, relationships among ecosystem components, and roles of plants and animals in the ecosystems (Table 3.5). The scores were summarized and categorized into the four levels of conceptual understanding: poor (score range 0-10), fair (score range 11-20), good (score range 21-30), and very good (score range 31-40).

Table 3.5 Interview scoring rubric for the concepts of the ecosystems adapted from Magntorn and Helldén (2007)

Concepts	1 point	2 points	3 points	4 points
1. structure and recognition of the ecosystems	No answer for all of the questions.	Some or all answers seem to be ambiguous or incorrect in the structure and recognition of the ecosystems.	Most of the answers are clear and reasonable.	All answers are clear and accurate.
2. relationships among ecosystem components	No answer for all of the questions.	Some or all answers seem to be ambiguous or student cannot explain the interrelationship in the ecosystems.	Most of the answers are clear and reasonable.	All answers are clear and accurate.
3. roles of plants and animals in the ecosystems	No answer for all of the questions.	Some or all answers seem to be ambiguous or student cannot distinguish the roles of plants and animals in the ecosystems.	Most of the answers are clear and reasonable.	All answers are clear and accurate.

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The transcribes from the interview on perceptions toward ecosystems and resources conducted before and after participating were categorized into four levels using the scoring rubric: poor (almost all answers do not show any concerns about the water resources management), fair (some or all answers show that students seem to be aware about water resources management), good (most answers show students' concerns on water resources management), and excellent (all answers show students' concerns on water resources management). The scores were summarized and categorized into the four levels of conceptual understanding (Table 3.6): poor (score range 0-10), fair (score range 11-20), good (score range 21-30), and very good (score range 31-40).

Table 3.6 Interview scoring rubric of the perceptions toward ecosystems and management

Score (Points)	Level of perceptions	Criteria
1	Poor	Almost answers do not show any concerns about the water resources management
2	Fair	Some or all answers showed that students seem to be aware about water resources management
3	Good	Most answers showed students' concerns on water resources management
4	Excellent	All answers showed students' concerns on water resources management

Finally, the researcher brought together the analyzed data to compare, contrast, and identify themes that could be emerged from these four distinct data sources.

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3.4.2.3 Analysis of Qualitative Data

The axial coding is the second stage of coding data. Strauss and Corbin (1990) defined axial coding as *"a set of procedures whereby data are put back together in new ways after open coding, by making connections between categories. This is done by utilizing a coding paradigm involving conditions, context, action/interactional strategies and consequences"* (Strauss & Corbin, 1990, p. 96). This procedure involves relating subcategories to a category. It focuses on the discovering and relating categories in terms of "the paradigm model" (Strauss & Corbin, 1990, p. 99) that facilitated the researcher thinking systematically about data collected and related them in the complex ways.

Consistent with the requirements for using open and axial coding techniques, the data collected from classroom observations, interviews, and written documents was transcribed, perused, compared, and contrasted to develop keywords trends, categories, and classifications to depict the characteristics, the activities, and the perceptions that occurred in the program. In this instance, transcribed observation, observation field notes, transcribed interview data, and written documents were coded using open and axial coding techniques (Strauss & Corbin, 1990; 1998). Open coding was used to identify general categories of information contained in the participants' activities, the participants' responses to the interview questions, the participants' written documents, and the researcher's filed notes. Data were perused, read, and re-read to look for both similarities and differences. These data were then labeled and grouped to form tentative categories. Next, an axial coding technique was used to re-organize the tentative categories, moving from more general ones to create related and meaningful groups of data. In axial coding, these data were put back together in new ways by making connections between categories, according to Strauss and Corbin (1990).

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3.5 Research Design

This research design was divided into three main stages as described as follows.

1. Development of three learning packages for lower secondary school students, i.e., a guided inquiry learning package on aquatic ecosystems, a learning package on scientific investigation of bottle ecosystems, and a community-based learning package on local ecosystems.
2. Implementation of the learning packages to lower secondary schools students.
3. Investigation of the effects of the learning packages on the students' knowledge and perceptions on local ecosystems.

Summary of the research methodology for this present study is shown in Figure 3-2. The newly learning packages were conducted at the lower secondary schools in Samutsongkhram Province, Thailand.

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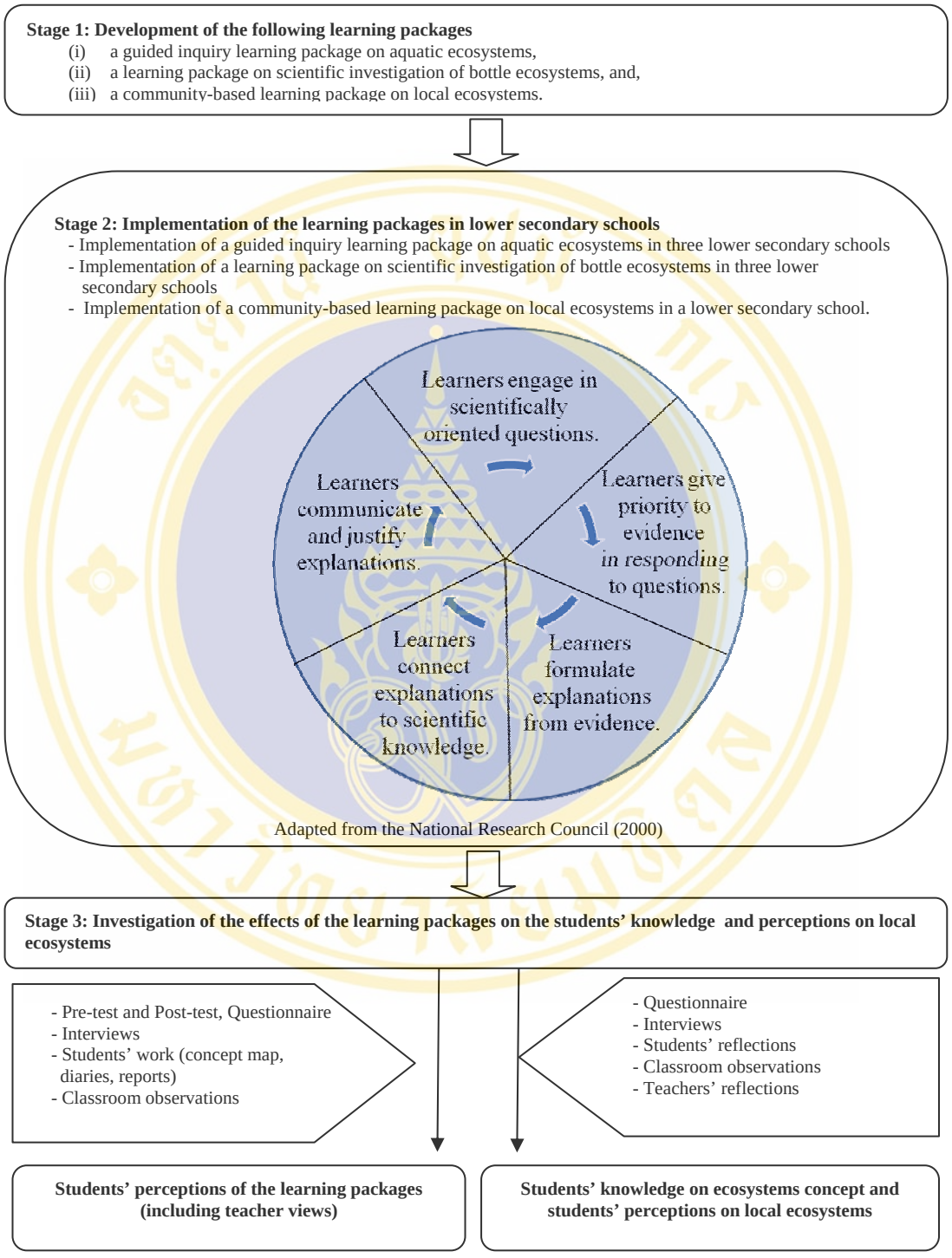

Figure 3-2 Research design of this study

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3.5.1 Development of Three Learning Packages for Lower Secondary School Students

3.5.1.1 Development of a Guided Inquiry Learning Package on Aquatic Ecosystems

1) Development of the Learning Content

A learning package on "An Investigation on the Effects of Different Light Periods on Chemical, Physical, and Biological Components in the Mini-aquaria" was designed based on an instructional development framework of learning and communicative strategies for teaching (Leach & Scott 2002; 2003) and followed a five-step process of inquiry teaching by Beyer (1979) with a slight modification. These five steps are (i) define a problem, (ii) develop a hypothesis, (iii) search for evidence, (iv) draw a conclusion, and (v) test the adequacy of the conclusion.

The purpose of this learning package was to support students in understanding ecological principles underlying the relationships among physical, chemical, and biological components in aquatic ecosystems. This was accomplished by providing experimental data for students to interpret and use to derive their own explanations.

The scope of content was based on national science educational standards (NRC, 1996; IPST, 2001). The constraints of budget, staffing, and competency of teachers in schools in low economic areas were also considered. All students, regardless of economic status, should be able to use the newly developed learning package as effectively as those in other schools to enhance their learning outcomes; specifically, being able to explore and comprehend the concept of ecosystems interrelationships.

2) Development of the Mini-Aquaria Experiment

The researcher prepared the key components for the learning package by developing a simple mini-aquaria experiment on the effects of different light periods on physical, chemical, and biological components. In this learning package, instead of conducting the experiment themselves, the students were given data to overcome the limitations of time, budget, equipment, and staffing. However, for schools that do not have these limitations, students could be encouraged to perform the experiment and collect their own data.

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The mini-aquaria experiment was modified from the techniques described by the Bottle Biology Project (1993). Three identical mini-aquaria were constructed, each containing similar numbers, sizes, and types of plants and animals (fish and snails) and the same amount of water, soil, and gravel. These three mini-aquaria were placed in three light boxes of the same size and light intensity under three different experimental conditions: (i) 24-h light period no dark period (24L:0D) for aquarium I, (ii) 16-h light period with an 8-h dark period (16L:8D) for aquarium II, (iii) 8-h light period with an 16-h dark period (8L:16D) for aquarium III. The light period in each aquarium was set by using a timer.

In this experiment, for simplicity the length of aquatic plants, fish, and snails were used as indicators for growth. In addition, the number and length of leaves were measured. Visual inspections of each mini-aquarium were conducted daily for 4 wk to note the general appearance of plants, animals, and water. Digital images were taken at different time periods. These data were indicators for changes of biological components. Data for pH, DO, and temperature were measured twice per day at the end of the light and dark periods by using PINPOINT pH, DO, and temperature meters by American Marine Inc., Ridgefield, CT USA. The nutrient data including nitrate, phosphate, and iron were measured once a week using a Pocket Colorimeter II Test Kit by Hach Company, Loveland, CO USA. At the end of the 4-wk period, the organisms in three mini-aquaria were examined, and the lengths of plants, fish, and snails were measured. All data were gathered in tables and used as key scientific data in the study's learning package. All of data on the mini-aquaria are shown in the next chapter.

3) Materials for Mini-aquaria Experiment

Materials used in this mini-aquaria experiment are recyclable, inexpensive and readily available. The mini-aquaria experiment requires recyclable soda bottles and materials available in school, office supply stores and aquarium hobby shops. A list of items include mixed calcined clay and screen topsoil, gravel red feint (No.40), 50/50 (tap water/de ionized water), aquatic plants, aquarium liquid or powdered nutrients, fish, snails, fish food.

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For generating different light period, light boxes were developed from cardboard boxes outfitted with 23 watt compact fluorescent bulbs and appliance timers.

Plants and aquatic animals from local bogs, marshes, lakes, streams, and from aquarium stores carrying live plants were used in the mini aquaria. Recommended plants species are listed in Table 3.7.

Table 3.7 Recommended aquatic plant species used for the experiment

COMMON NAME	SCIENTIFIC NAME
Duckweed	*Lemna sp.*
Bacopa	*Bacopa monniera*
Dwarf Hairgrass	*Eleocharis aciculari*
Chain sword	*Echinodorus tenellus*
Elodea	*Egeria densa*
Cryptocoryne	*Cryptocoryne walkeri*
Hornwort	*Ceratophyllum submersum*
Muskgrass	*Chara sp.*

Before developing the learning package, a mini-aquaria experiment was conducted three times to obtain reliable results. In addition a class of secondary school students was asked to perform this experiment and their data were quite comparable to these performed by the researcher. This is not only to confirm the accuracy of data, but to make sure that this mini-aquaria experiment is also working well with students, in case they need to explore data on their own. Before implementation, a pilot trial was conducted in a lower secondary school with 30 seventh grade students. The overall learning package was assessed by three experts and three teachers, and revised according to their comments.

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4) Learning Package Components

A four-period learning package (200 min total) consisted of a unit overview, learning objectives, instructional materials, and activities.

a) Unit overview

The learning package was based on mini-aquaria experimental data used to enhance students' abilities to transform data and to explore ecological concepts about the interrelationships between organisms and their environment. It emphasized particular aspects of scientific investigations, i.e., generating testable questions, analyzing data, interpreting data, posing explanations, and communicating the results and implications. The scientific content arose from the interrelationships among components in ecosystems under different light periods.

b) Learning objectives

After participating in this learning package, students were expected to be able to define research questions and develop answers to the questions (through transforming data into the appropriate forms and interpreting data), generate explanations on the effects of light period on components in aquatic ecosystems using the given evidence, and derive concepts of the interrelationships among various components in aquatic ecosystems.

c) Instructional materials

The materials comprised pictures of various ecosystems at different seasons, data of mini-aquaria experiment, and students' worksheets. Data from mini-aquaria experiments were used to save not only money but time; students did not have to wait for 4 wk to obtain the data as they would if they did the experiment themselves.

A scheme of guided inquiry learning package on aquatic ecosystems is summarized in Table 3.8. The framework on development and implementation of a guided inquiry learning package on aquatic ecosystems development and implementation are illustrated in Figure 3-3.

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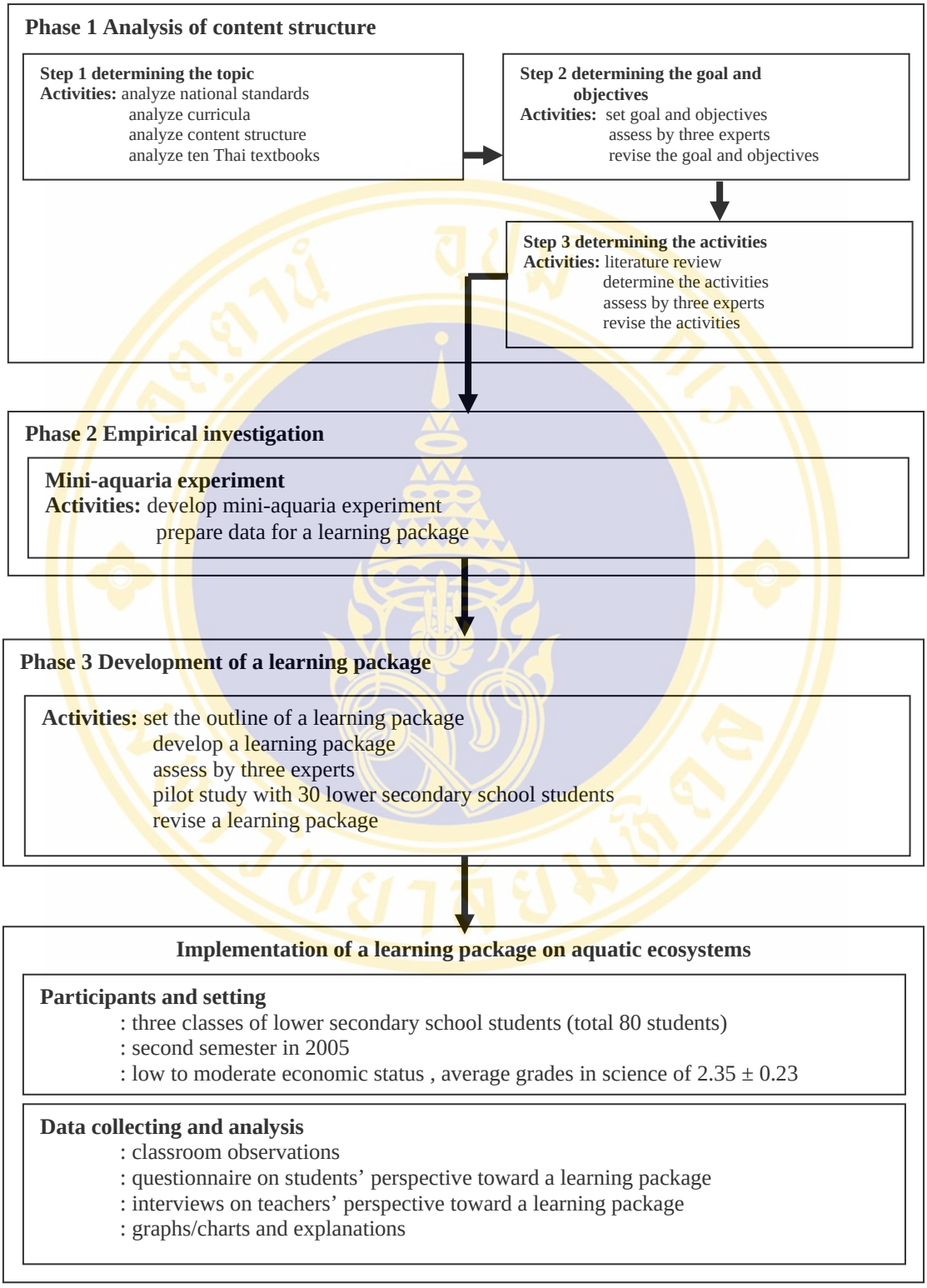

Figure 3-3 Framework of a guided inquiry learning package development and implementation

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Table 3.8 A scheme of a guided inquiry learning package on aquatic ecosystems

Activities	Time (Minutes)	Ecological ideas (E)/ Scientific Skills (S)	Outcomes
1. Engagement students with opened question "What are the different among aquatic ecosystems in different seasons?"	20		- Students' answers
2. Brainstorming on the factors making different among aquatic ecosystems in different seasons.	10	- Relationship among physical, chemical, and biological components (E)	- A list of factors given by students - Students' answers
3. Designing the experiment – teacher encourage students to think, share, and discuss on designing experiment to study the effects of light periods of aquatic ecosystems	15	- Experimental Design (S)	- A list of experiments given by students
4. Exploring the data provided by teacher on the mini-aquaria experiment to analyze the effects of light periods on chemical and biological components in mini-aquaria	25	- Data exploration (S) - Data analysis (S)	- Graphs - Charts - Diagrams
5. Small group working to explain the effects of light periods on chemical and logical components in mini-aquaria. Teacher encourages students to formulate explanations from evidence	50	- Developing explanation from the evidence (S) - Relationship among physical, chemical, and biological components (E)	- Students' explanations
6. Connecting explanations to scientific knowledge on the effects of light periods on chemical and biological components in aquatic ecosystems	50	- Elaboration concepts with the explanations (S) - Relationship among physical, chemical, and biological components (E)	- Students' answers
7. Students present and justify explanation in the class	30	- Evaluation of the explanations	- Students' presentations and discussion with class

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3.5.1.2 Development of a Learning Package on Scientific Investigation of Bottle Ecosystems

1) Development of the Learning Content

A learning package on scientific investigation of bottle ecosystems was designed based on an instructional development framework of learning and communicative strategies for teaching (Leach & Scott 2002; 2003) and followed a five-step process of inquiry teaching by Beyer (1979).

2) Learning Package Components

This learning package was developed as two-period learning package (100 min total) in class and a period of one month for students to perform their own scientific investigation using extra time. This learning package was composed of a unit overview, learning objectives, instructional materials, and planed activities.

a) Unit overview

In a learning package on scientific investigation of bottle ecosystems as reported in the present study, it is important to make clear to both the students and teachers that learning science and assigning meaning will not follow from data collection alone. Children can construct meaning from all sources of personal experiences through observing, talking, writing, and discussion.

This learning package provides students the opportunities to create their own bottle ecosystems for questioning, hypothesizing, experimenting, observing, data collecting, interpreting, and discussion. The research question in this study is whether learning through scientific investigation of bottle ecosystems encourages students to develop their own conceptual understanding of ecosystems and promote scientific skills as well.

b) Learning objectives

After participating in this learning package, students were expected to be able to develop their own conceptual understanding of ecosystems and promote scientific skills in questioning, hypothesizing, experimenting, observing, data collecting, interpreting, and discussion.

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c) Instructional materials

Materials used in this learning package are recyclable, inexpensive and readily available. Before starting the unit, teachers and students need to collect materials sufficient for four or five students per group.

1. Two or more two-liter pop bottles for each group
2. Sand, soils, topsoil, gravel,
3. Water source: canal, river, tap – water, deionized water
4. Light source which made from cardboard boxes outfitted with bulb
5. Aquatic animals: fish, water snails
6. Aquatic plants: Duckweed (*Lemna* sp.), Bacopa (*Bacopa monniera*), Dwarf Hairgrass (*Eleocharis aciculari*), Elodea (*Egeria densa*)
7. Stationery equipments: scissors, markers, ruler, glass, tape, paper
8. The measurement equipments: pH meter, thermometer, Dissolved Oxygen meter, nutrients measurement

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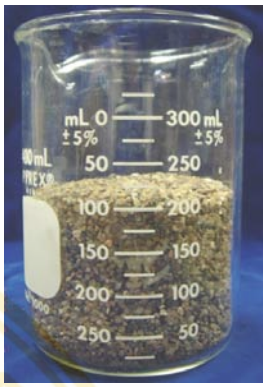
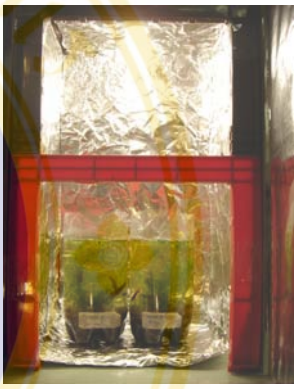
Soda Bottle

Soil


Sand

Clay

Light Source


Light Source

Elodea (*Egeria densa*)

Measurement equipments

Bacopa (*Bacopa monniera*)

Snails

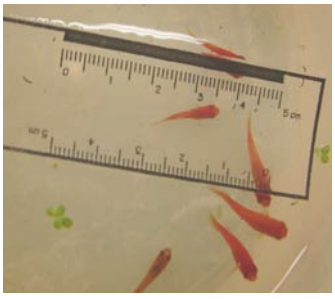

Fish

Figure 3-4 Materials for bottle ecosystems development

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d) Activity Outline

A scheme of a learning package on scientific investigation of bottle ecosystems is summarized in Table 3.3. The framework on development and implementation of this learning package development and implementation are illustrated in Figure 3-4.

Engagement (10 Minutes)

The background information is intended to provide and engage students to ecosystems. Teacher asks students on their concepts about aquatic ecosystem, components of aquatic ecosystem and relationships among components. The set of questions is as follow;

Do you know about the ponds in your community?

What does ecosystem mean?

When you think of pond, please tell me “what are living in pond?”

What are the relationships in the pond?

Exploration (40 Minutes)

Students build a classroom aquarium; students design their own using the Bottle biology: Aquatic ecosystem Procedure.

Bottle Biology: Aquatic ecosystem Procedure

1) Cut the top off one bottle, at the shoulder (where it tapers). Cut the base off another bottle and score it with holes. This is the cover.
2) Fill bottom of bottle with sand, soil and gravel as designed.
3) Add water-slowly, to minimize sand displacement--and then root three ten-centimeter aquatic plant’ stalks firmly in the soil and sand. Add more aquatic plants according to the plan. Sprinkle a small amount of duckweed onto the water's surface.
4) Let the aquaria stand overnight to let them settle, and to allow chlorine from water to dissipate (if tap water is used).
5) Add fish and snails into aquarium.

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Exploration (Four weeks – about 10 – 30 minutes per time)

During a four-week period, have the students record daily observations in their laboratory notes. Suggest certain things for them to be watching for, like plant growth or population changes. Ask for quantitative measurements (exactly how many? exactly what size? how many days?) as well as qualitative (what color? what shape? slow or quick movement?).

Explain (30 Minutes)

At the end of the four-week period, have the students discuss the information they've obtained through observation. At this time, they should write hypotheses to explain some of the things they've seen.

Evaluate (20 Minutes)

Students evaluate what they have seen and try to answer questions: are the aquaria appropriately stocked?; have they been well-maintained?; are observations recorded at regular intervals?; and are hypotheses based in fact?

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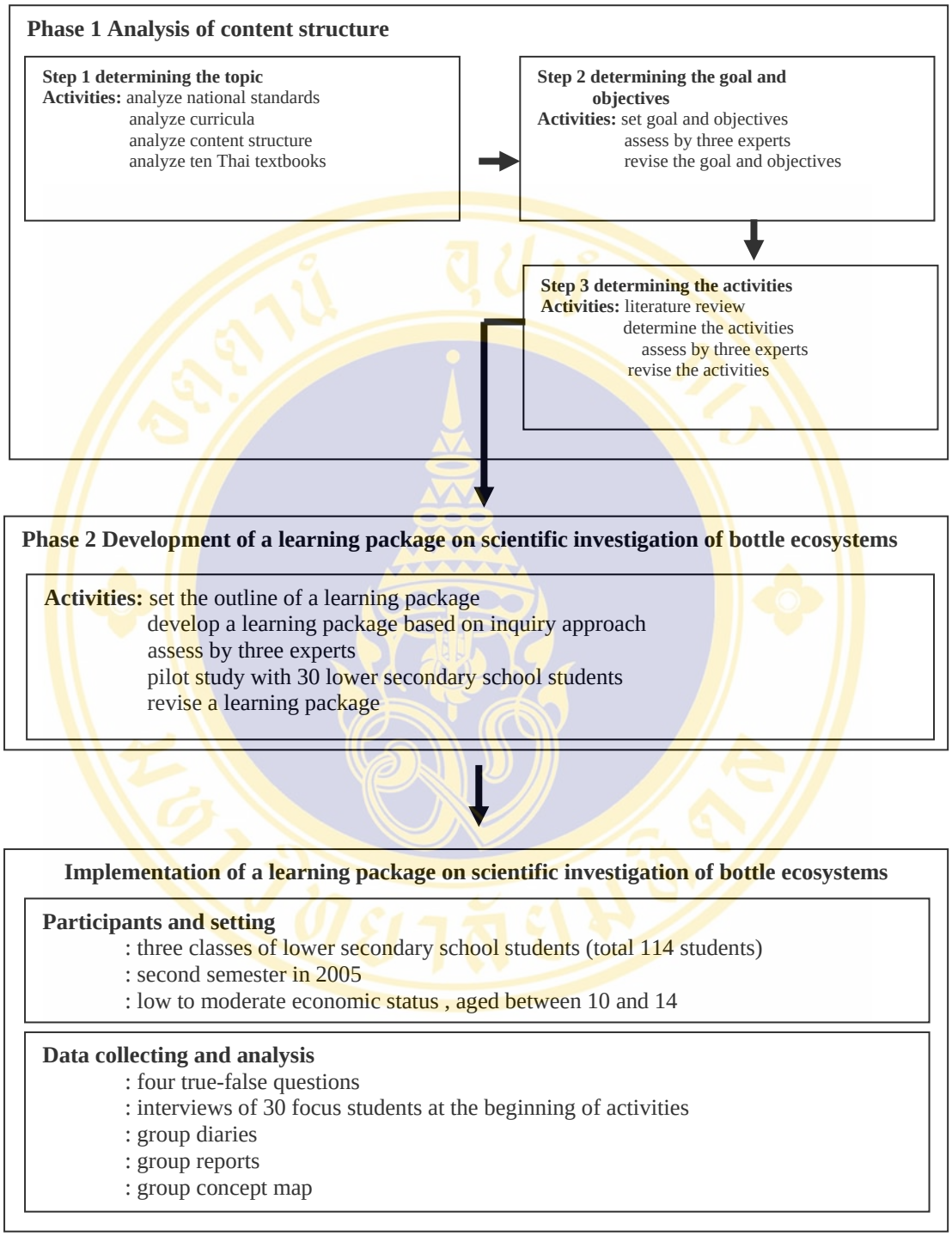

Figure 3-5 Framework of learning package on scientific investigation of bottle ecosystems development and implementation

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Table 3.9 A scheme of a learning package on scientific investigation of bottle ecosystems

Activities	Time (Minutes)	Ecological ideas (E)/ Scientific Skills (S)	Outcomes
1. Engagement: students with opened questions	10		- Students' answers
2. Exploration: students build a classroom aquarium; students design their own using the Bottle biology: Aquatic ecosystem Procedure	40	- Experimental Design (S) - Components of aquatic ecosystems (E)	- A list of aquatic ecosystems - A list of ecosystems components - Students' answers
3. Exploration: During a four-week period, have the students record daily observations in their laboratory notes. Suggest certain things for them to be watching for, like plant growth or population changes. Ask for quantitative measurements (exactly how many? exactly what size? how many days?) as well as qualitative (what color? what shape? slow or quick movement?).	10-30	- Changes in the ecosystems overtime (E), (S) - Relationship among physical, chemical, and biological components (E) - Data exploration (S) - Observation (S)	- Students' laboratory notes/diaries
4. Explain: At the end of the four-week period, have the students discussed the information they've obtained through observation. At this time, they should write hypotheses to explain some of the things they've seen.	30	- Data exploration (S) - Data analysis (S)	- Students' answers - Report - Concept map - Diaries - Students' explanations
5. Evaluate: Students evaluate what they have seen and try to answer questions: are the aquaria appropriately stocked?; have they been well-maintained?; are observations recorded at regular intervals?; and are hypotheses based in fact?	20	- Evaluation of the explanations	- Students' answers - Report - Concept map - Diaries - Students' explanations

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3.5.1.3 Development of a Community-Based Learning Package on Local Ecosystems

1) Development of the Learning Content

A community-based learning package on local ecosystems was designed based on an instructional development framework of learning and communicative strategies for teaching (Leach & Scott 2002; 2003) and followed a five-step process of inquiry teaching by Beyer (1979). This curriculum aimed to provide opportunities for teachers and students to learn, understand, and aware of their local ecosystems, and then take actions on their own ecosystems. The local aquatic ecosystems: canals in Muang District Samutsongkharm province, Thailand were used as learning sites. The development of curriculum comprised two main phases: brainstorming for contents of the program, and construction of the program.

a) Brainstorming for the contents of the instruction

The scope of the curriculum was gathered from brainstorming through three focus group discussions with the participants: two supervisors from Educational Service Area Office-Samutsongkharm (ESAO), a local school teacher, three local sages, two science educators, an environmental educator, and two scientists, including the researcher. The participants expressed their feelings, opinions, and perceptions toward the existing teaching-learning process on environment at school. They discussed the factors that supported or hindered the teaching and learning, and proposed the expected learning process with pedagogical content knowledge. The proposed content and concepts of the curriculum derived from brainstorming were designed to be consistent to the National Science Curriculum Standards (IPST, 2001: NRC, 2000). The finalized topics of a community-based learning package on local ecosystems are shown in Table 3.10.

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Table 3.10 Comparison of the scope of contents and concepts of the developed a community-based learning package on local ecosystems with the national science standards (IPST, 2001, NRC, 2000)

Scope of contents	Concepts	Science standards
1 Around Us	Meanings of environment, natural resources, and ecosystems	**Standard Sc 2.1** : The student should be able to **understand** the local environment, relationship between living things and environment, interrelationship between living things in different eco-systems, **master** the investigative processes and **possess** a scientific mind, **communicate** the acquired knowledge for positive use.
2 Local environment and natural resources	Local environment and natural resources	
3 Water and life	The water and its importance	
4 Environmental Problems and Actions	Problems solving on local ecosystems	
5-7 Explorer 1-3	Scientific process for investigating local aquatic ecosystems	
8-9 Learning with Local Sages 1-2	Local wisdom on the importance of local ecosystems, utilization, problems, and management related to local wisdom	**Standard Sc 2.2**: The student should be able to **understand** importance of natural resources, utilization of natural resources at local, national and international levels, **master** the investigative processes and **possess** a scientific mind, **communicate** the acquired knowledge for positive use and sustainable management of natural resources and local environment.
10-12 Water Detective in community	Local ecosystems: physical, chemical, and biological factors	
13-14 Data analysis and generating report	Data analysis and generating report of local ecosystems study (scientific mind)	
15 Reporting	Local ecosystems, improvement of the local ecosystems quality	
16 Exhibition	Communication skill	

b) Construction of the a community-based learning package on local ecosystems

After agreement on the content, the lesson plans for the instruction were designed and developed. These were done through four focus group meetings composed of a supervisor from ESAO, local school teacher, 2 local sages, two science educators, and an environmental educator, including the researcher. A set of lesson plans was developed with some assistance and suggestions from Association Professor Kampanad Bhaktikul from Faculty of Environment and Resource Studies, Mahidol University, Dr. Robert Bohanan and Dr. Kevin Niemi from University of Wisconsin-Madison, USA. The local teacher who involved in this study used the knowledge and

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skills acquired from teacher training workshops as well as opinions from focus group meetings to generate the lesson plans under researcher facilitation. The list of teaching-learning activities was generated after the first meeting and revised several times through the process of brainstorming to improve the quality and relate with the ad-hoc events.

2) Learning Package Components

A community-based learning package on local ecosystems was designed as a semester-long program using local ecosystems as learning resources that students learn about, in, and for their local ecosystems. The program was composed of learning objectives, instructional materials, lesson plans, teaching-learning activities, and the evaluation of students' conceptual understanding of ecosystems, perceptions toward ecosystems and management, and self-reported behaviors toward ecosystems and management. The details of the program components are described as follows:

a) Curriculum overview

The activities of community-based curriculum were designed as a 15 two-period unit. The program activities were based on the community-based education that students not only learned from and with local environment, but also for their local community. The program was composed of unit overview, learning objectives, instructional materials, activities, and assessment of students' knowledge, perceptions, and self-reported behaviors toward environment.

b) Learning objectives

After completing this curriculum, the students should be able to

1) identify, explore, and explain the local ecosystems, relationship between biological, chemical, physical components in ecosystems;

2) explore and analyze status of the local ecosystems;

3) distinguish and explain interrelationships among biological, chemical, and physical components within the ecosystems;

4) develop perceptions and awareness of the local ecosystems;

5) communicate the acquired knowledge to take actions on their own local ecosystems.

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c) Instructional materials

The instructional materials in this curriculum were textbooks, students worksheets, test kits for measuring chemical properties of water (pH, dissolved-oxygen, nitrate, ammonia), and equipments for measuring physical properties of water (turbidity meter, meter for water depth measurement, Secchi disc for water clarity, thermometer for temperature examine).

d) Lesson plans and teaching-learning activities

The lesson plans for community-based curriculum were developed through collaborative efforts of the supervisors, local teachers, local sages, science educators, environmental educators, scientists from the university, and researcher. The schedule of teaching-learning activities is described in Table 3.11. Each topic was designed based on 5E learning cycle (Bybee et al., 2006).

These activities are listed in the chronological order, which was the order of the time that it occurred and complexity. Early activities were designed to engage students into the curriculum. Then, the activities were conducted for students to develop the knowledge and perceptions on local ecosystems needed for the entire program. The teaching and learning sequence of community-based curriculum is shown in Figure 3-6.

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Table 3.11 The teaching-learning activities of the a community-based learning package on local ecosystems

Scope of contents	Teaching-learning Activities	Week	Time (hours)
1. Around Us	- Brainstorm about the meanings of environment, natural resources, and ecosystems: working in group of five or six - Discuss and present to the class - Each student construct mind map on ecosystems	1st	2
2. Local environment and natural resources	- Brainstorm about the environment and natural resources in local ecosystems: canals and river in Samutsongkharm province - Discuss about environment and natural resources in class - Discuss the topics which students are interested for further field trips	2nd	2
3. Water and life	Hands-on activity on water and its importance - Discuss on questions "how will we alive?" and "how long one can survive without water?" - Measure and compare weight of fresh fruit and dry fruit - Discuss the differences between fresh fruit and dry fruit - Make conclusion about the water and its importance	3rd	2
4. Environmental problems and actions	- Lecture by Local Sages on local ecosystems and problems - Discuss and summarize the lesson and present to the class	4th	2
5. Explorer 1	Plan and design activities - Provide objectives of the field trips by teacher - Brainstorm on the interesting factors - Divide students into group according to their interests - Each group of students plan and design the field trips and sampling areas to investigate local water resources under teacher's supports - Present their own plans to the class - Generate the schedule for field trips and report the progress	5th	2
6. Explorer 2	- Learn how to use basic equipments for water quality measurement: test kits for dissolved oxygen, pH, nitrate, ammonia, Secchi disc, and meters in class	6th	2
7. Explorer 3	- Practice the use of equipments for water quality measurement in schoolyard	7th	2
8. Learning with local sages 1	- Lecture by local sages on the importance of local ecosystems, utilization, problems, and management related to local wisdom - Minor field trip around the local sage's house	8th	2 (local community)
9. Learning with Local sages 2	- Discuss and summarize the lesson learned and present to the class	9th	2 (in school)
10-12 Water detective in community	Three field trips for investigating the local ecosystems - Each group of students observe and record: plants, birds, mollusk - Each group of students measure and record water quality parameters: DO, pH, nitrate, ammonia - Measure the physical properties of water resources (Klong) including tide, general appearance, width, depth, turbidity, and temperature	10th-12th	12 (extra time)
13-14 Data analysis and generating report	- Each group of students analyze the data, discuss, and generate group report	13th, 14th	4
15. Reporting	- Each group of students present their report to the class - Discuss for the possible actions for taking care of the local water resources	15th	2
16. Exhibition	- Students presented their results to local community	16th	2

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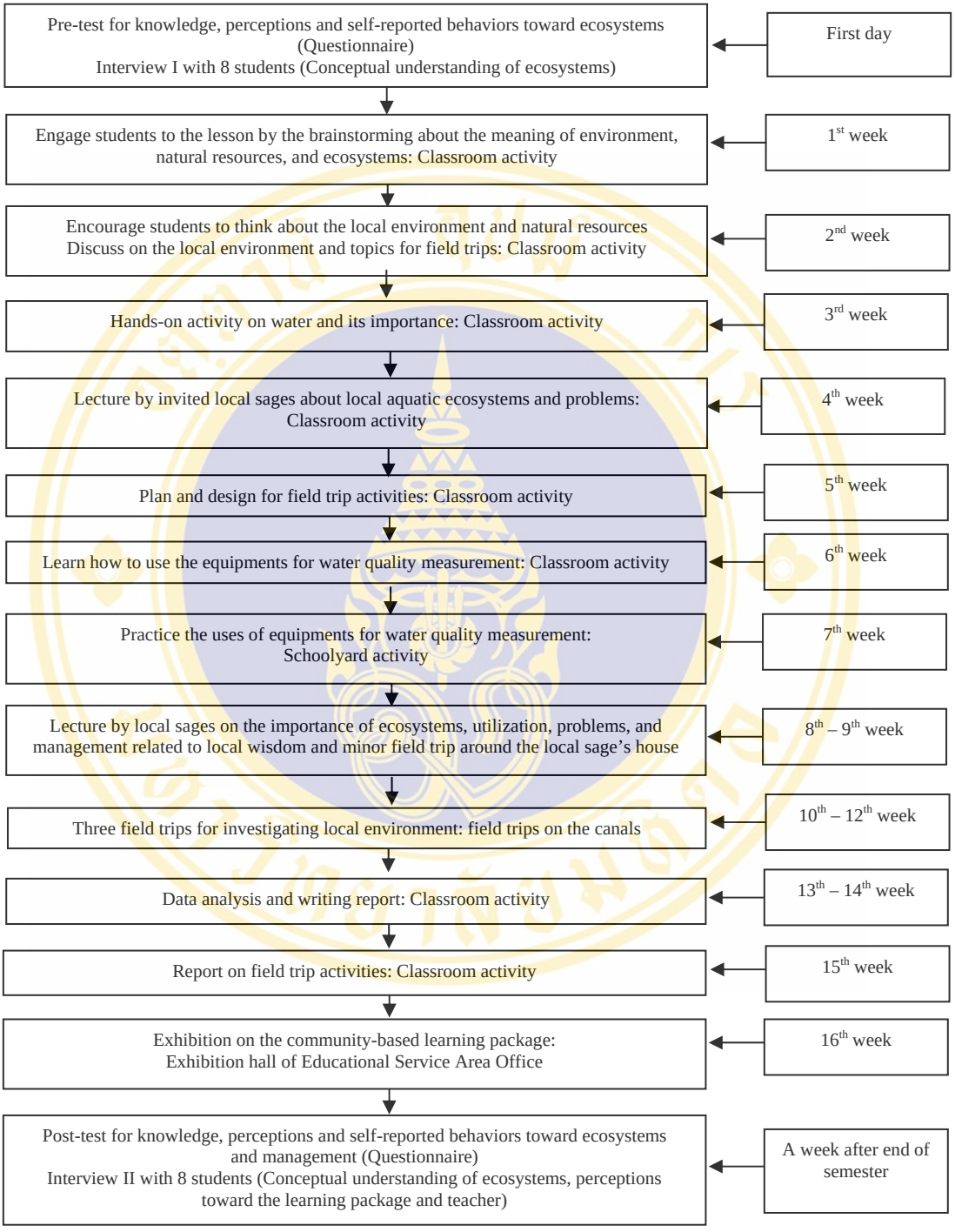

Figure 3-6 Teaching and learning sequence of community-based learning package on local ecosystems

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3.5.2 Implementation of Three Learning Packages for Lower Secondary School Students

3.5.2.1 Implementation of a Guided Inquiry Learning package on Aquatic Ecosystems

A guided inquiry learning package was implemented, as a part of the general science curriculum, in three lower secondary schools with similar curricula and facilities.

1) Participants and Context

Three lower secondary schools with similar curricula and facilities were involved in a guided inquiry learning package on aquatic ecosystems. The schools were of low to moderate economic status. There were a total of 80 students (7th grade), 45 boys and 35 girls, aged 13 to 16 yr. Each class contained 25 to 30 students with average grades in science of 2.35 ± 0.23 (on a standard 4.0 grading system). There was no significant difference in prior knowledge in environmental science and ecology among students from the three schools. These students were taught the environmental concepts and general science at primary school, and none of them had any prior experience with the mini-aquaria experiment.

Total of 80 students (from 3 classes) were divided into group of five students. Thus, there were 5-6 groups per each class which was convenience for one teacher to handle. Each group of students was asked to generate graphs and charts from the given data in their own ways for subsequent interpretation.

2) Activities

Step 1: Define a problem (20 min)

Prior to defining a problem, the teacher first engaged students with pictures of the aquatic ecosystems in different seasons and an open-ended question: “What changes occur in the aquatic ecosystems in different seasons?”

Step 2: Generate research questions and design experiment (30 min)

Each group of students discussed the effects of light period on components in ecosystems and generated plausible research questions. The following questions were given to guide their efforts: What will occur in the aquaria with different light periods? How does it occur? Students brainstormed on designing experiments to investigate the effects of light period.

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Step 3: Data exploration and analysis (50 min)

The teacher told students that due to shortage of time and equipment, they would instead be given data from a previously performed mini-aquaria experiment. The data were presented in tables with details of experimental setting and data collection. The teacher encouraged students to compare their experimental design from Step 2 to the experiment performed previously. However, in schools equipped with facilities for this mini-aquaria experiment, the students should be encouraged to do the experiment by themselves and generate their own data.

Step 4: Construct explanations from the evidence (50 min)

Each group of students used the results from their graphs and charts as evidence to draw conclusions and develop their own explanations of the effects of light periods on chemical, physical, and biological components in mini-aquaria.

Step 5: Test adequacy of the explanation (50 min)

The students were asked to review, compare and contrast, and connect their own explanations with the provided scientific knowledge provided by textbooks, handouts, and graphs from the experimental data. During this phase, the teachers posed questions about the relationships among physical, chemical, and biological components in the aquatic ecosystems.

3.5.2.2 Implementation of a Learning Package on Scientific Investigation of Bottle Ecosystems

1) Participants and Context

A learning package on scientific investigation of bottle ecosystems study was conducted in a public school in middle to low-income community in Samuthsongkhram Province, Thailand. The participants consisted of 114 students, aged between 10 and 14, from three classrooms of the 7th grade. The participants were divided into 30 groups (3-4 students/group) to represent mixed age, gender, and ability by their own teachers. The researchers did not know the background and ability of students before sampling. One from each group was chosen to make focus students using the random sampling technique. The focus students included 13 boys, 17 girls at different levels of achievement, i.e. 5 high, 10 middle, and 15 low achieving ones. The participants were taught the topics of ecosystems at 5th grade and none of them had any prior experience in the scientific investigation of the bottle ecosystems.

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2) Activities

The researcher carried out educational activities over a period of one month, i.e. scientific investigation of bottle ecosystems with students in three classes of lower secondary school students as follows:

Activity 1: Evaluation of prior knowledge

All 114 students were given a pre-test of the four true-false questions, which had been validated by three experts from three different disciplines at the beginning of activities to evaluate prior conceptual understanding. In addition, interview I of the focus students was conducted on (i) structure and recognition of the ecosystems, (ii) relationships among ecosystem components, and (iii) roles of plants and animals in the ecosystems. Each 15 minute semi-structured interview was audio-taped and noted.

Activity 2: Construction of the bottle ecosystems

Each group of students was asked to build their own bottle ecosystems that would survive for four weeks. Materials provided were soda bottles, soil, gravels, small fish, water, plants, aquatic plants, snails, and rocks. Each group chose materials that would meet their own design.

Activity 3: Observation and diary writing

Each group of students was required to keep a diary of their own bottle ecosystems over four-week periods concerning ‘what can be seen’, ‘what is going on’, ‘changes in both living and non-living things’, ‘what might be happening in the bottle’, etc. During this activity, students in each group observed, recorded, discussed, and analyzed their own data for the diary, and carried out report preparation and presentation at the end of the fourth week. Students met once a week with their teacher to report their findings, discuss, and solve problems that had arisen. Moreover, students met with their classmates for discussing and sharing of their findings once a week in the classroom.

Activity 4: Presentation

At the end of the fourth week, each group of students presented their own findings and what they had learned. The reports and concept maps were also collected for further analysis.

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Activity 5: Evaluation of conceptual understanding

Post-test of the four true-false questions as previously used for pre-test was given to all 114 students. The 30 focus students were also interviewed for fifteen minutes through a semi-structured interview with the same topics as interview I. These interviews were audio-taped and noted.

3.5.2.3 Implementation of a Community-Based Learning Package on Local Ecosystems Implementation

1) Participants and Context

The details of school selection, participants, and context for this study are presented in the following sections.

A school was selected to exemplify a community-based learning package on local ecosystems for lower secondary school. The criteria for school selection were (1) type – the school needed to be public school, (2) size – the size was to be middle to large school, (3) location – the location had to be less than 500 meters far from water resources areas, and the willingness of the principal and teachers. Once the target school was selected, the researcher contacted the principal of the school to request and obtain permission for the research to be conducted. The school has been given the pseudonym *Maeklong School*[*].

The background information about the school was gained from the school leaflet, reports, and webpage. *Maeklong School* is located in Muang Samutsongkhram, Samutsongkhram Province, Thailand. It is located about 500 meters from a middle canal. The school has total 533 students (secondary and high school) and 39 teachers (data from Education Service Area Office 1 (ESAO)- Samutsongkhram, 2005). The students' achievement was low (GPA 2.35 ± 0.23 on a standard 4.0 grading system). The school is in an economically disadvantaged community. Most of students' families are at or below the poverty line.

[*] Pseudonym is used throughout this study.

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One science teacher with two decades of teaching experience, *Wanpen*[†], volunteered to participate in this present study. This teacher taught 20 students at seven grade level. Others were also involved in the study. The researcher contacted supervisors in ESAO, local people in Samutsongkhram, science educators, an environmental educator, local sages, and scientists who agreed to be involved in the program development and implementation.

2) Activities

The teaching-learning activities were conducted following the developed lesson plans. The details of actual educational activities of a community-based learning package on local ecosystems are described in chronological order.

Engagement

The curriculum started with the engagement of students into the program by the brainstorming on the meaning of environment, natural resources, and ecosystems. Each student constructed concept map on ecosystems. Then, they discussed for their interested field trip topics. The next activity of the program was hands-on activity which was an introductory exploration on water and its importance and discussed for conclusion. Then, a lecture on local water resources and water resources problems by local sages was arranged for students.

Exploration

The exploration stage continued with planning and designing field trip activities in classroom by brainstorming. For field trip, each group of 5-6 students planned and designed for the activities and sampling areas to investigate physical, chemical, and biological components of local water resources under teacher's guidance. The topics were the study of species and number of plants in local water resources, the study of species and number of mollusks in local water resources, the study of species and number of birds in local water resources, the study of physical and chemical properties of local water resources, the study of water quality of local water resources. Students were encouraged to design their own plan for data collection and analysis. Nevertheless, they presented the plans to the class and discussed for the most appropriate schedule, with the supports from teacher as consultant.

[†] Pseudonym is used throughout this study.

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Practicing

Before field trips, students were required to practice the water quality measurement by using the test kits for pH, dissolved oxygen, nitrate, ammonia, as well as, Secchi disc, meters for measuring water depth. Students were given opportunity to go to local sage's house to attend the lecture on the importance of water resources, utilization, water problems, and water management. Students also made minor field trip on the river bank around the local wisdom's house. Then, students discussed, summarized, and presented the lesson learned to the class.

Exploration (Field Trips)

Three field trips within three months were conducted. During field trip, each group of students observed and recorded the physical, chemical, and biological components according to their interests and plans. Students measured water quality including pH, dissolved oxygen, nitrate, and ammonia by using test kits. The physical properties of water were also measured, i.e., tide, general appearance, width, depth, turbidity, temperature.

Explanation (Data Analyzing)

After the field trips, each group of students analyzed the data and prepared group report with guidance about the techniques from teacher. Students also consulted local sages, experts, and used other resources including additional books, textbooks, journals, and websites. During this activity, teacher encouraged and facilitated students to discussion and sharing of ideas among group members. The students also discussed the possible actions that should be done for taking care of the local water resources.

Evaluation

At the end of the program, students displayed their work as posters, reports etc. at the exhibition hall of ESAO. Students and teachers from other schools, local sages, district educators, and local people were invited to attend the exhibition.

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3.5.3 Investigation of Effects of Three Learning Packages for Lower Secondary School Students

The researcher employed the concept of the mixed-methods research paradigm to gather data to answer the research questions. (See Chapter I for the research questions.) This method was selected because this study is like many educational studies in that a single data collection method could not capture the complexity of the educational setting, activities and outcomes (Metz, 2000).

3.5.3.1 Effects of a Guided Inquiry Learning Package on Aquatic Ecosystems

1) Data Collection

The students' achievements were assessed by using a combination of qualitative and quantitative approaches: a questionnaire, written documents on graphs and charts and explanation, interviews, and classroom observation.

The classroom observations were conducted based on unstructured observation and complete participation in a setting (Cohen et al., 2000). The data collected were description of the range and nature of activities occurred, i.e., activities of teacher and students, engagement, cognitive demand modes, and extent of student are learning. Other relevant information on learning package implementation was also observed.

2) Data Analysis

Open coding technique (naming and categorizing of phenomena through close observation of data) and axial coding technique (putting the data back together in new ways by making connections between a category and its subcategories) as suggested by Strauss and Corbin (1990; 1998) were employed to analyze the qualitative data on written documents and interviews. The Statistical Package for the Social Sciences (SPSS for Windows Version 13.0) was used for quantitative analysis. The data were reported as means, standard deviation, frequency, and percentage.

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Analysis of graphs/charts: The written graphs/charts were analyzed for five components, i.e. title, axes, legend, description, and data validity by using scoring rubrics (adopted from Schlenker and Tierney, 2006). The holistic scoring rubrics of graph/chart were categorized into five levels of scientific skills on data transformation and data manipulation: inadequate (score range 0-4), fair (score range 5-8), moderate (score range 9-12), good (score range 13-16), and excellent (score range 17-20).

Analysis of explanation: The written documents of explanations were read and re-read for breaking down and taking apart a sentence, a paragraph, and giving each discrete incident, idea, or event, a name, something that stands for or represents a phenomenon. The explanations were read in order to categorize them as coherently as possible into key topics. Key topics composed of effects of light period with the pH, dissolved oxygen (DO), temperature, nitrate, phosphate, iron, fish, plants, snails, and water. In all analyzes, discrete written explanations were recognized as 'sentence' which was tabulated in the form of a contingency table. Descriptive statistics were used for describing the students' conceptions on the concepts and relationships among internal components in ecosystems. The holistic scoring rubrics of the written explanations were categorized into five levels of conceptual understanding on the interrelationship in ecosystems: fair (score range 1-4), moderate (score range 5-8), good (score range 9-12), and excellent (score range 13-16).

3.5.3.2 Effects of a Learning Package on Scientific Investigation of Bottle Ecosystems

1) Data Collection

The quantitative data consisted of pre-test and post-test of the four true-false questions of the 114 students. The qualitative data included an interview of 30 focus students (interview I) at the beginning of activities and interview II, group diaries, group reports, and group concept maps after the activities had been carried out. In addition, group diaries were used to assess development of conceptual understanding overtime.

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2) Data Analysis

The quantitative data, the pre-test, and the post-test on true-false questions were statistically analyzed using the paired t-test. The qualitative data on interviews, diaries, concept maps, and reports were transcribed, categorized, transformed, and analyzed both qualitatively and quantitatively.

Analysis of interviews: The concepts of ecosystems were divided into five topics as described in activity 1 (described in section 3.4.1.2). Each topic was divided into three or four categories which represented level of understanding according to Magntorn and Helldén (2007). The key concepts derived from the interviews were categorized, and then rated according to the pre-set levels of understanding. Holistic score rubrics were set to categorize overall conceptual understanding of ecosystems into three levels of understanding, i.e. fair, moderate, and good.

Analysis of diaries: The diary contents were read in order to categorize them as coherently as possible into various key topics, i.e. plants, animals, water, relationships, scientific process, and perception. In all analyses, discrete written diaries were recognized as 'sentence' which were tabulated in the form of a contingency table. For the purpose of enumeration of all that was written in the diary, a single observation, any word, reference phrase or discrete statement that met a particular criterion was counted. If more than one discrete instance of the same topic occurred within a single unpartitioned statement it was recorded once. The data were analyzed at the 1st, 2nd, 3rd, and 4th week to follow development of students' conceptual understanding. Descriptive statistics were used for describing the students' conceptual understanding over the four week period.

Analysis of concept map: Three general concepts of ecosystems, i.e. meaning, structure and role of organisms were set. Seventeen relationships and two hierarchies were set for analyzing and scoring. The examples of each specific concept given by the students were considered for analyzing and scoring as well. Scoring criteria for the concept map were set according to Novak and Gowin (1984), i.e. concept, proposition, hierarchy, and example. The expected minimum and maximum total scores from four elements were 1 and 45. Students' concept maps were analyzed according to the four elements and then categorized into five levels of conceptual understanding.

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Analysis of report: Five components of report were chosen for scoring, i.e. title, introduction, materials and methods, results, and discussion. Each component had a score range from 0 to 4 which was adopted from Schlenker and Tierney (2006). The expected minimum and maximum total scores were 0 and 20. Holistic score rubrics of reports were set for grouping them into five levels of quality, i.e. poor, fair, moderate, good, and excellent.

3.5.3.3 Effects of a Community-Based Learning Package on Local Ecosystems

The mixed-methods research paradigm (Johnson & Onwuegbuzie, 2004) was used to gather data and analyze data. The data included true-false questions and interview on conceptual understanding of ecosystems, questionnaire on perceptions and self-reported behaviors toward environmental management. The data were collected both before and after participation in the program. In addition, the written documents on concept maps, reports, and classroom observations were also used.

1) Data Collection

Questionnaire, adapted from Musser and Malkus's (1994), were used to obtain information on knowledge, perceptions, and self-reported behaviors toward ecosystems both before and after the program. The questionnaire comprised three parts: 1) 15-true-false questions, 2) 5-point Likert-scales on perceptions ranged from 1 (strongly disagree) to 5 (strongly agree) and 3) 5-point Likert-scales on self-reported behaviors ranged from 1 (never) to 5 (always). The internal consistencies of the questionnaire on perceptions and self-reported behaviors using Cronbach's alpha coefficient were 0.85 and 0.88 and the reliabilities were 0.88 and 0.91, respectively.

Eight randomly selected students were interviewed on conceptual understanding of the ecosystems and perceptions on local ecosystems both before and after program participation. The researcher asked questions in a variety of formats and compared responses as an internal check for self-reporting bias. Each 30 minute semi-structured interview was audio-taped, noted, and transcribed for further analyses using open and axial coding techniques according to Strauss and Corbin (1998).

The written documents on concept maps, field/laboratory records, drawings of local ecosystems, and reports were collected.

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2) Data Analysis

Analysis of questionnaires: The quantitative data on pre-test and post-test of the questionnaire were analyzed using the paired t-test. The Statistical Package for the Social Sciences (SPSS for Windows Version 13.0) was used for quantitative analysis. The significance at $P < 0.05$ was used for mean separation and comparing the students' perception and self-reported behaviors toward water resources management before and after participating in the program.

Analysis of interviews: The transcribes from the interview on perceptions on local ecosystems were categorized into four levels using the scoring rubric: poor (almost all answers do not show any concerns about the water resources management), fair (some or all answers show that students seem to be aware about water resources management), good (most answers show students' concerns on water resources management), and excellent (all answers show students' concerns on water resources management).

Analysis of concept maps/reports/interviews: The holistic scoring rubrics technique was applied to analyze the concept maps, reports, and interviews. They were categorized into three levels of conceptual understanding: poor, fair, and good conceptual understanding.

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CHAPTER IV
RESULTS

4.1 Overview

This chapter presents the development of three learning packages on local ecosystems. In the first two learning packages, the first part dealt with construction of scientific experiment on mini-aquaria which will be used as content to be integrated with the learning process. The first learning package is a guided inquiry-based mini-aquaria experiment on the effects of different light periods. The second learning package is the scientific investigation on bottle ecosystems. The third learning package on local ecosystems was developed by using the community-based principle. The results of perspectives toward the learning packages are shown at the end of this chapter.

4.2 Development of Three Learning Packages for Lower Secondary School Students

4.2.1 Development of Mini-Aquaria Experiment on the Effects of Different Light Periods

The mini-aquaria experiment on the effects of different light periods gave the opportunities for the students to construct their own explanation and understanding on ecosystems. The procedure and the results of the mini-aquaria experiment were revealed in this part.

The aquatic ecosystem has been chosen as a model in this study because it cannot be easily understood without participation in real situations. This scientific experiment focuses on developing scientific skills in experimental design, exploration, data manipulation, interpretation, and communication based on the evidences.

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The experiment focused on the effects of different light periods on physical, chemical and biological components in the mini-ecosystems. This experiment was designed for helping students to derive the concepts of the interrelationships in aquatic ecosystems through the investigation of data, data analysis, and discussion. The data were prepared for using as materials for developing a guided inquiry learning package on aquatic ecosystems in this study. These data were prepared for students underpin of the limitations of time consumption, budget, equipments, and manpower. For the schools that do not have the limitations as mentioned, teachers should provide students to do the experiment and collect data by their own.

The procedure for development of mini-aquaria experiment was described in previous chapter (section 3.4.1.1). The results on pH value, dissolved oxygen, and temperature of the mini-aquatic experiment under three different conditions are shown in presented in Table 4.1, 4.2, and 4.3. The details of experimental setting are shown in each table.

Dissolved oxygen (DO), pH, and temperature profiles in the three mini-aquaria over 4 weeks are shown in Figure 4-1, 4-2, and 4-3.

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Table 4.1 Mini-aquaria experimental data on pH, DO, and water temperature in the aquarium I (24-h light period with no dark period [24L:0D]).†

Day	Parameter		
	pH	DO (mg/L)	Temperature (°C)
1	8.00	10.60	25.50
2	9.02	11.00	24.89
3	9.24	11.50	24.50
4	9.31	11.70	24.61
5	10.90	13.60	25.11
6	10.70	13.80	24.89
7	10.28	11.60	24.83
8	10.24	9.90	25.11
9	10.19	10.10	24.78
10	10.32	9.30	24.78
11	10.30	9.00	24.67
12	10.31	8.60	25.11
13	8.00	10.60	25.50
14	9.02	11.00	24.89
15	9.24	11.50	24.50
16	9.31	11.70	24.61
17	10.01	7.80	25.22
18	10.31	8.70	24.67
19	10.21	12.00	24.50
20	10.17	7.70	24.39

†All parameters were measured at 0800 h daily.

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Table 4.2 Mini-aquaria experimental data on pH, DO, and water temperature in the aquarium II (16-h light period with an 8-h dark period [16L:8D]).

Day	Parameter					
	pH		DO (mg/L)		Temperature (°C)	
	End of dark period	End of light period	End of dark period	End of light period	End of dark period	End of light period
1	8.20	8.00	8.10	10.50	21.89	23.11
2	8.49	8.90	8.00	11.90	22.28	24.78
3	8.67	9.06	8.20	12.20	21.11	23.72
4	8.56	9.07	8.30	12.00	21.67	24.89
5	9.37	9.74	10.20	15.00	21.72	23.89
6	9.30	9.76	10.00	14.80	22.22	24.00
7	8.21	9.80	3.70	14.40	20.89	24.22
8	9.28	9.82	7.60	14.60	22.39	25.11
9	9.54	10.00	8.00	14.40	22.72	24.50
10	8.96	9.98	8.00	13.10	22.22	21.89
11	8.97	9.90	8.10	10.00	21.67	21.94
12	8.97	8.90	4.10	12.00	21.39	22.22
13	9.54	10.02	6.70	13.10	21.78	23.72
14	9.54	8.97	6.70	4.40	21.78	22.33
15	7.34	8.88	4.20	6.20	21.78	20.28
16	9.10	9.90	8.20	15.70	21.72	23.72
17	9.10	9.80	8.20	14.00	21.72	22.78
18	7.64	9.70	3.60	13.80	19.78	22.22
19	7.64	9.99	3.60	17.10	19.78	22.72
20	7.64	10.28	3.60	15.70	19.78	21.89

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Table 4.3 Mini-aquaria experimental data on pH, DO, and water temperature in the aquarium III (8-h light period with an 16-h dark period [8L:16D]).

Day	Parameter					
	pH		DO (mg/L)		Temperature (°C)	
	End of dark period	End of light period	End of dark period	End of light period	End of dark period	End of light period
1	8.00	8.38	6.50	10.10	21.50	22.89
2	7.80	8.37	6.70	9.80	21.89	23.72
3	7.77	8.38	5.90	10.40	20.94	23.28
4	7.80	8.40	6.30	10.50	21.61	24.44
5	7.82	8.52	6.40	11.00	21.11	24.11
6	7.83	8.53	6.20	12.00	21.67	24.11
7	7.70	8.69	6.40	11.00	22.22	24.11
8	7.89	8.68	4.40	10.00	21.67	24.94
9	7.83	8.75	4.50	10.30	22.22	24.89
10	7.87	8.80	4.50	10.50	22.00	23.56
11	7.70	8.82	5.40	10.70	21.78	23.56
12	7.80	8.98	5.00	11.80	21.89	24.83
13	7.87	8.92	3.50	10.40	22.06	24.78
14	7.70	8.50	5.40	10.24	21.78	23.33
15	7.98	8.96	7.00	15.60	19.89	24.83
16	8.16	9.40	4.30	11.50	21.44	23.89
17	8.50	9.40	5.00	11.50	21.22	23.89
18	8.21	9.27	4.50	12.10	21.67	22.78
19	8.34	9.27	5.40	12.10	19.56	22.78
20	8.63	8.92	6.90	10.40	21.11	24.78

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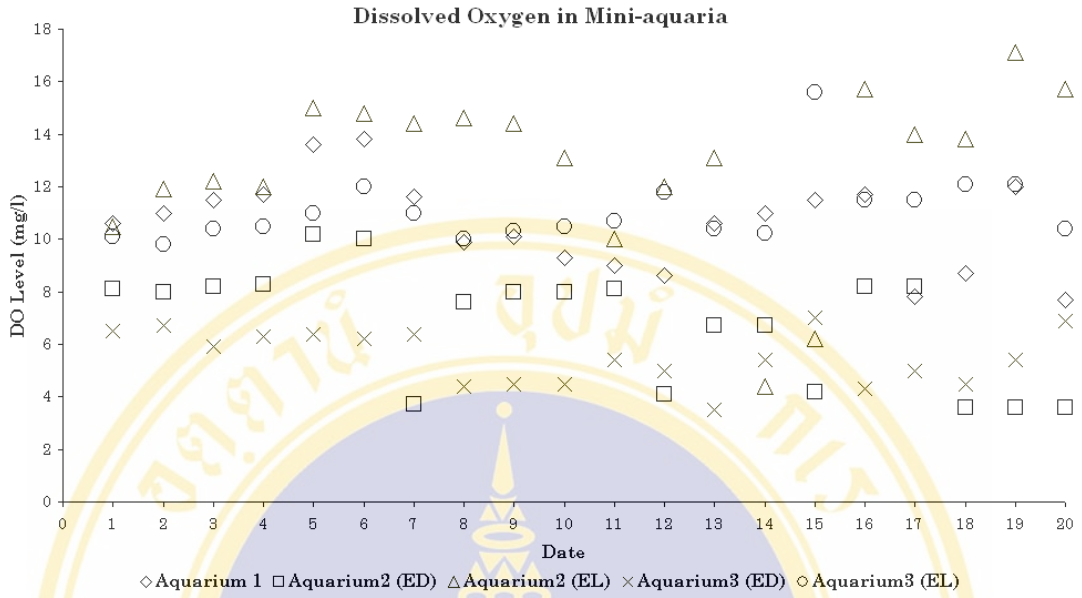
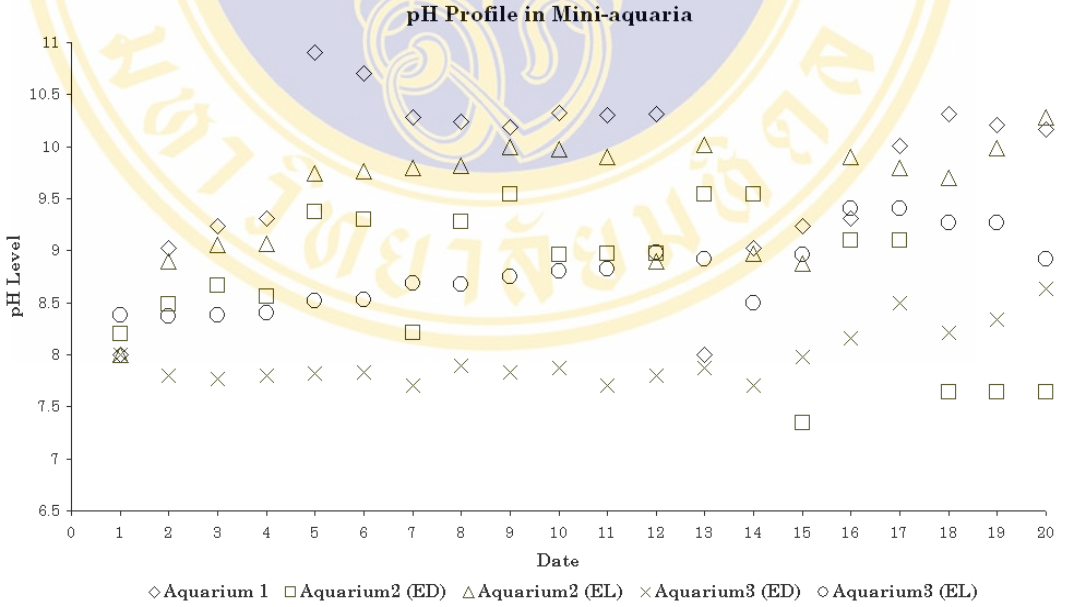


Note: ED = End of Dark period, EL = End of Light period

Figure 4-1 Dissolved Oxygen (DO) in the three mini-aquaria



Note: ED = End of Dark period, EL = End of Light period

Figure 4-2 pH in the three mini-aquaria

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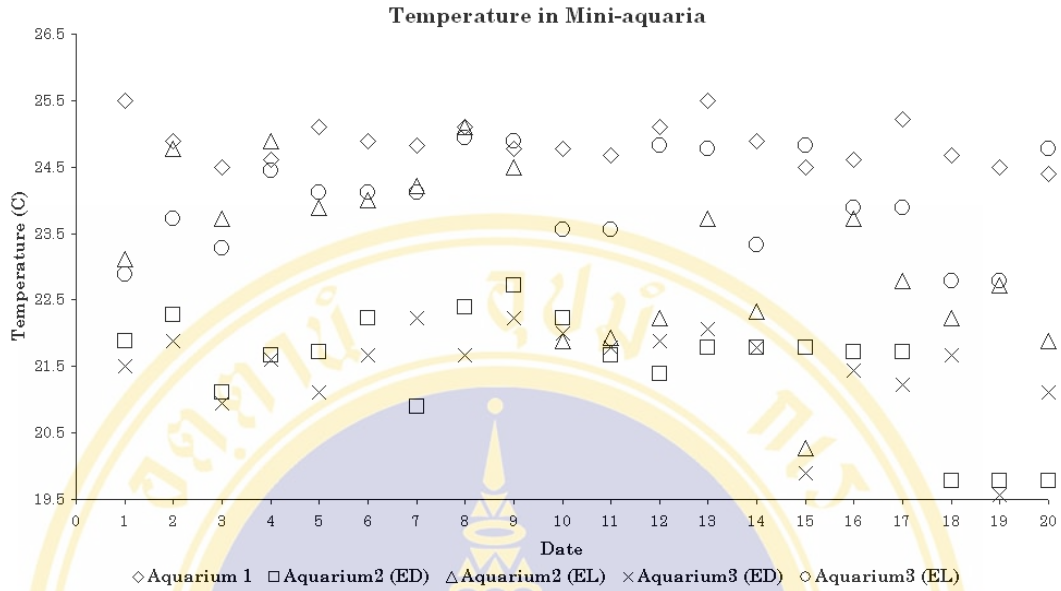

Note: ED = End of Dark period, EL = End of Light period

Figure 4-3 Temperature in the three mini-aquaria

Table 4.4 shows the concentrations of nitrate, phosphorus, and iron in three mini-aquaria with different experimental setting at different periods of time (1-4 weeks). The nutrients were measured weekly (every Wednesday at midday). The graphs comparing amount each nutrient at different periods of time are presented in Figure 4-4, 4-5, and 4-6.

Table 4.4 Concentrations of nitrate, phosphorus, and iron in the three aquaria at different periods of time.†

Time (week)	Nitrate (mg/L)			Phosphate (mg/L)			Iron (mg/L)		
	Aquarium			Aquarium			Aquarium		
	I	II	III	I	II	III	I	II	III
1	22.44	22.44	22.44	0.71	0.71	0.71	0.32	0.32	0.32
2	8.8	35.64	40.48	0.24	0.26	1.61	0.11	0.09	0.21
3	12.76	27.72	15.4	0.2	1.06	0.22	0.04	0.04	0.08
4	14.52	18.92	6.16	0.96	0.15	0.05	0.02	0.09	0.03

†Measured weekly (Wednesday at midday).

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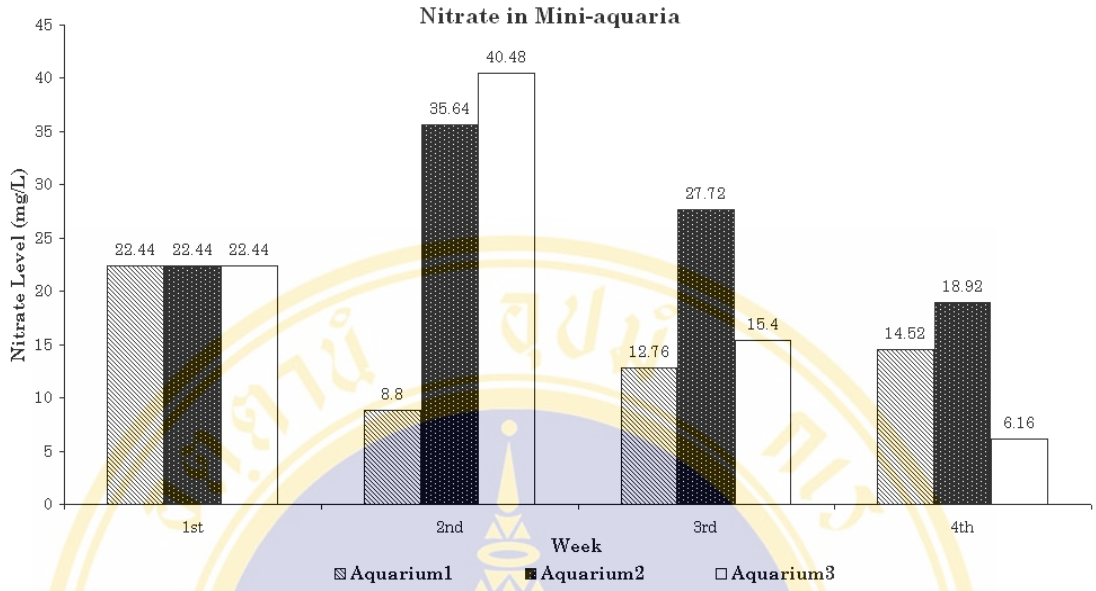

Figure 4-4 Nitrate profile at different period of time (week 1-4)

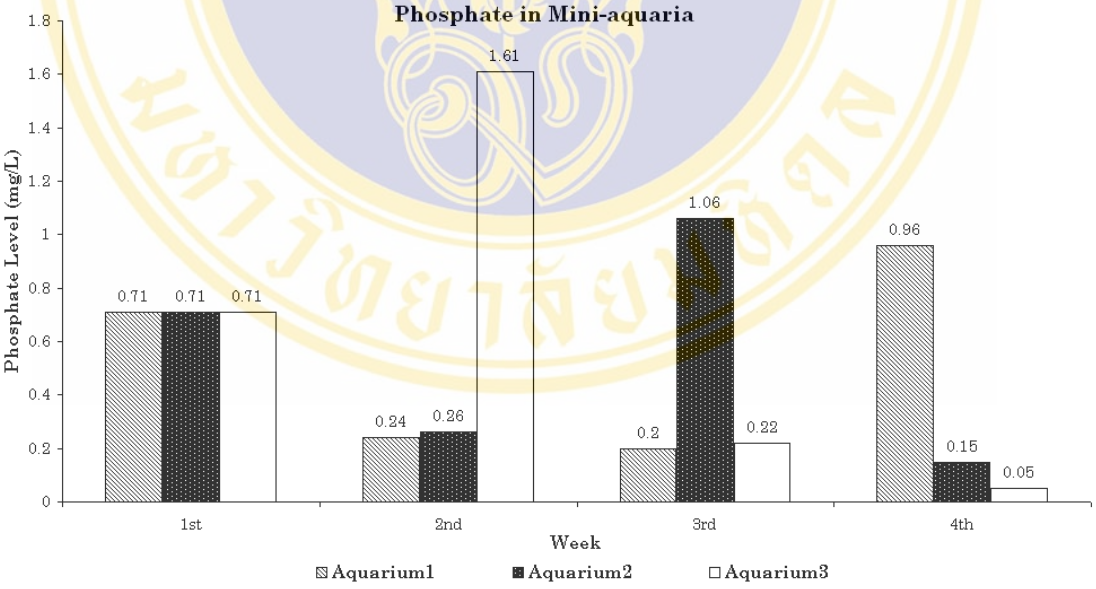

Figure 4-5 Phosphorus profile at different period of time (week 1-4)

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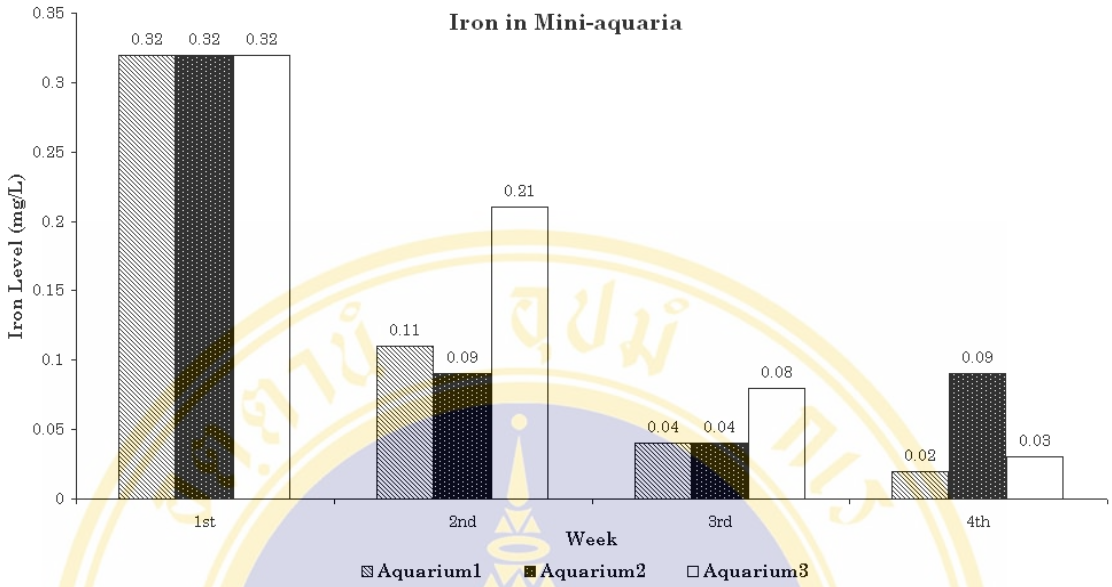

Figure 4-6 Iron profile at different period of time (week 1-4)

Aquarium I	Aquarium II	Aquarium III
24-h light period with no dark period [24L:0D]	16-h light period with an 8-h dark period [16L:8D]	8-h light period with an 16-h dark period [8L:16D]

Figure 4-7 Photos of mini-aquaria at the first week of experiment

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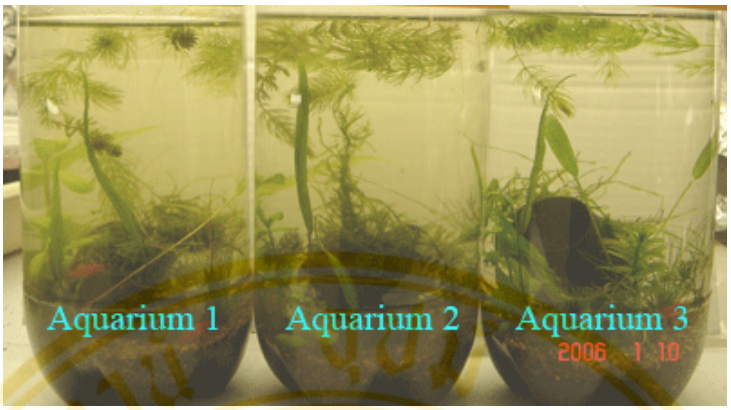
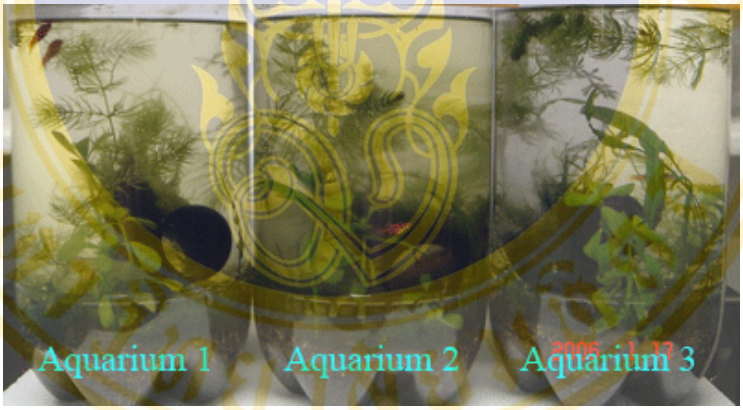


Aquarium I [24L:0D] | Aquarium II [16L:8D] | Aquarium III [8L:16D]

Figure 4-8 Photos of mini-aquaria at the second week of experiment



Aquarium I [24L:0D] | Aquarium II [16L:8D] | Aquarium III [8L:16D]

Figure 4-9 Photos of mini-aquaria at the third week of experiment

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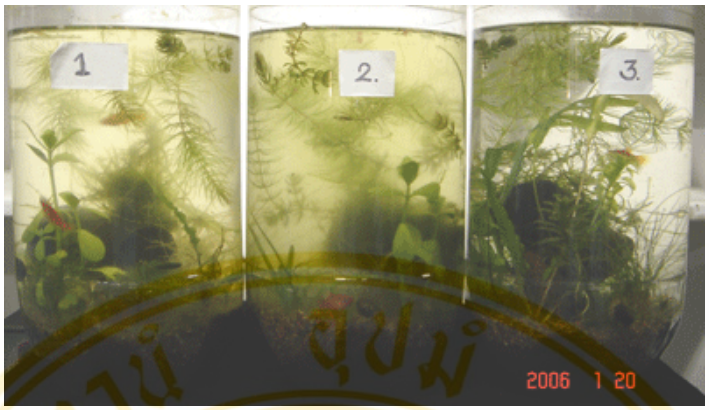

Aquarium I [24L:0D] Aquarium II [16L:8D] Aquarium III [8L:16D]

Figure 4-10 Photos of mini-aquaria at the fourth week of experiment

4.2.2 Results from Implementation of the Three Learning Packages

The three learning packages were implemented in the lower secondary school. These learning packages gave the students the opportunities to learn ecology concepts. The effective of these learning packages on student's knowledge and perceptions on local ecosystems were investigated. The results of this study were reported in three parts according to the type of the learning packages. The effectiveness of each learning package on students' achievement reveals that these three learning packages gave the students the opportunities to learn ecology concepts on ecosystems, interrelationship within ecosystems, components of ecosystems, and local ecosystems management.

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4.2.2.1 A Guided Inquiry Learning Package on Aquatic Ecosystems

1) Activities

The activities of a guided inquiry learning package on aquatic ecosystems are described as follow:

Step 1: Define a problem (20 min)

Prior to defining a problem, the teacher first engaged students with pictures of the aquatic ecosystems in different seasons and an open-ended question: “What changes occur in the aquatic ecosystems in different seasons?” Each group of five students then brainstormed on factors responsible for causes of changes in ecosystems at different seasons.

Step 2: Generate research questions and design experiment (30 min)

Each group of students discussed the effects of light period on components in ecosystems and generated plausible research questions. The following questions were given to guide their efforts: What will occur in the aquaria with different light periods? How does it occur? Students brainstormed on designing experiments to investigate the effects of light period. The teacher acted as facilitator to encourage students to discuss and share ideas until they developed an experimental design.

This step helped students practice asking the right questions and designing appropriate experiments.

Step 3: Data exploration and analysis (50 min)

The teacher told students that due to shortage of time and equipment, they would instead be given data from a previously performed mini-aquaria experiment. The data were presented in tables with details of experimental setting and data collection (as described in section 4.2.1). The teacher encouraged students to compare their experimental design from step 2 to the experiment performed previously. However, in schools equipped with facilities for this mini-aquaria experiment, the students should be encouraged to do the experiment by themselves and generate their own data.

In this step, the students worked in groups of five to consider and discuss first whether the given data fit their experimental design.

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Step 4: Construct explanations from the evidence (50 min)

Each group of students used the results from their graphs and charts as evidence to draw conclusions and develop their own explanations of the effects of light periods on chemical, physical, and biological components in mini-aquaria. They were also asked to extend their ideas on relationships between light periods and components in ecosystems in general and consider why such a change occurred. During group discussions, teachers encouraged students to generate, as clearly as possible, their own explanations based on the evidence they studied rather than from what was written in a text. At this step, teacher did not yet give comments on the scientific correctness of the explanation, but supported students in developing their own explanations through appropriate questions and comments. Each group of students then presented their results and explanations to the class; some groups offered differing explanations. The teacher then stimulated discussion in the class so that the students could learn from one another.

Step 5: Test adequacy of the explanation (50 min)

The students were asked to review, compare and contrast, and connect their own explanations with the provided scientific knowledge provided by textbooks, handouts, and graphs from the experimental data. During this phase, the teachers posed questions about the relationships among physical, chemical, and biological components in the aquatic ecosystems. The teacher emphasized and supported students' attempts to formulate correct scientific explanations and to develop conceptual understanding of interrelationships in aquatic ecosystems.

Each group of students detailed explanations on the effects of light period on components of the ecosystems. The written documents from each group varied considerably in terms of length of phrases and sentences.

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2) The Effects of a Guided Inquiry Learning package on Aquatic Ecosystems

The effects of a guided inquiry learning package were evaluated by using a combination of qualitative and quantitative approaches: a questionnaire and written documents such as graphs, charts, their explanations. In addition, interviews and classroom observation were conducted for triangulation with the first two measures. The details of data collection and data analysis are described in Materials and Method. The results of each measure are described by the step of learning activities.

Step 1: Define a problem (20 min)

Students' responses included temperature, light period, food for aquatic animals, and number of species in the ecosystems. During this step, the teacher encouraged students to define a problem based on their prior experience. From classroom observation, 90% of students participated and shared their ideas in the groups, while another 10% only listened quietly.

Step 2: Generate research questions and design experiment (30 min)

Results from classroom observations showed that the teacher succeeded in encouraging students to ask questions and to share and discuss their ideas based on their prior experiences, without commenting on scientific correctness.

Step 3: Data exploration and analysis (50 min)

In this step, the students worked in groups of five to consider and discuss first whether the given data fit their experimental design. Students were happy with the data provided, although some felt that those data were more than what they expected. They then discussed, manipulated, and transformed the data into appropriate forms for interpretation. A typical graph from one group of students is shown in Figure 4-11. Analysis of graphs and charts from all groups (Table 4.5) showed that most of them were able to generate good (37.5%) and excellent (25%) pieces of work. These rankings reflect the students' ability to generate graphs and charts that contained all components with correct data, legends, and description. Some groups (31.25%) had some incorrect description in some components and were scored at a moderate level. Only 6.25% were scored at the fair level (contain all components but description of each component is missing), and none were categorized in an inadequate level (most components are missing). The results suggest that most students were able to

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manipulate and transform data from tables to graphs and charts and to correctly present it in appropriate forms for further interpretation, although there were some mistakes in the description.

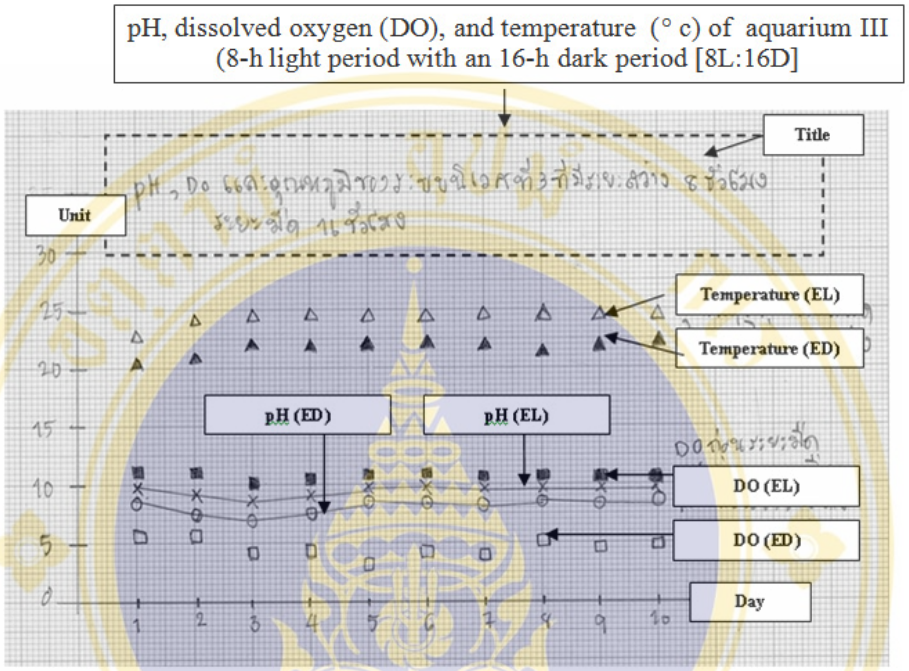

Figure 4-11 Students' graph at the end of light period (EL) and at the end of dark period (ED)

Table 4.5 Analysis of graphs/charts from all groups (N=16)

Level of abilities to generate graphs/charts (score range)	**Description**	**Number of groups (%)**
Inadequate (0-4)	Most components are missing	0 (0%)
Fair (5-8)	Contain all components but description of each component is missing	1 (6.25%)
Moderate (9-12)	Contain all components. Some components are incorrect.	5 (31.25%)
Good (13-16)	Contain all components. Correct descriptions are included in most components of graphs/charts.	6 (37.5%)
Excellent (17-20)	Contain all components. Correct descriptions are included in all components graphs/charts.	4 (25%)

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Step 4: Construct explanations from the evidence (50 min)

From classroom observation, 95% of students participated and shared their ideas in the groups, while another 10% only listened quietly.

Step 5: Test adequacy of the explanation (50 min)

To analyze the written work of the students, a contingency table (Table 4.6) classified their explanations into four main topics including relationships between light period and chemical components, light period and biological components, changes in physical properties of water, and relationships among light and the three component parameters. These topics were further divided into three to five subtopics and the frequency of sentences or phrases was calculated as percentage of the total sentences in all topics. The changes in physical properties of water among different mini-aquaria were mentioned by 38% of students, while those between light period and chemical and biological components were mentioned by 25% and 18%, respectively. However, the overall interrelationships among all components, that is, light period, chemical, biological, and physical parameters were stated by only 19%. The lowest percentage obtained for the biological components might be due to the nature of the given data on mini-aquaria that covered mainly chemical and physical properties of water. The biological data on length of fish and number and length of aquatic plants might not be clear enough to draw a good conclusion. The biological data deficiency might be overcome by encouraging students to develop and observe their own min-aquaria over the period of time.

Nine out of sixteen groups were categorized in the good level indicating a nearly complete written explanation of the interrelationships in ecosystems, and explained what occurred and began to address why it occurred. Three groups were scored at the excellent level, indicating complete explanation including what occurred and why it occurred. Two groups were scored in the moderate level, indicating that an attempt was made but does not meet the expectation. Another, two groups were categorized at the fair level, indicating that students could construct the explanations of which some were vague or difficult to understand (Table 4.7).

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Table 4-6 Contingency table of groups' explanations categorized by topics

Topics	**No. of explanations (% of total)**
1. Relationships between light periods and chemical components	**47 (25%)**
- effects on pH	16
- effects on DO	16
- effects on nutrients	15
2. Relationships between light periods and biological components	**34 (18%)**
- effects on plants	12
- effects on fish	12
- effects on snails	10
3. Changes in physical properties of water among different mini-aquaria	**72 (38%)**
- color	16
- turbidity	16
- sediment	14
- volume	10
- temperature	16
4. Relationships between light periods, chemical, biological, and physical parameters	**37 (19%)**
Total	**190 (100%)**

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Table 4.7 Analysis of explanations from all groups (N=16)

Level of abilities to generate explanations (score range)	Description	Number of groups (%)
Fair (1-4)	Incomplete written explanation of the interrelationships in ecosystems, and without the explanation of what and why it occurred	2 (12.5%)
Moderate (5-8)	Nearly complete written explanation of the interrelationships in ecosystems, and without the explanation of what and why it occurred	2 (12.5%)
Good (9-12)	Nearly complete written explanation of the interrelationships in ecosystems, and explained what occurred and began to address why it occurred	9 (56.25%)
Excellent (13-16)	Complete explanation including what occurred and why it occurred	3 (18.75%)

The following examples reflect student's conceptual understanding of the interrelationships in ecosystems.

1. "Light affects water temperature. The temperature changed at different light periods. The aquarium with no dark period had the highest temperature. The aquarium with long light period had higher temperature than that with short light period."

2. "Different light periods caused differences in pH, DO, temperature, and nutrients. They increased and decreased in the aquaria with light and dark period. However, these values seemed to be stable in the aquarium with no dark period."

3. "The given results that algal bloom occurs in the 16-h light period aquarium is similar to that occurs in the summer season which has a longer light period than in winter."

4.2.2.2 A Learning Package on Scientific Investigation of Bottle Ecosystems

1) Activities

This learning package provides students the opportunities to create their own bottle ecosystems for questioning, hypothesizing, experimenting, observing, data collecting, interpreting, and discussion. The researchers carried out activities over a period of one month, i.e. scientific investigation of bottle ecosystems with the students as follows:

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Activity 1: Evaluation of prior knowledge

All 114 students were given a pre-test of the four true-false questions, which had been validated by three experts from three different disciplines at the beginning of activities to evaluate prior conceptual understanding. In addition, interview I of the eight randomly selected students was conducted on structure and recognition of the ecosystems, relationships among ecosystem components, and roles of plants and animals in the ecosystems. Each 15 minute semi-structured interview was audio-taped and noted.

Activity 2: Construction of the bottle ecosystems

Each group of students was asked to build their own bottle ecosystems that would survive for four weeks. Materials provided were soda bottles, soil, gravels, small fish, water, plants, aquatic plants, snails, and rocks. Each group chose materials that would meet their own design.

Activity 3: Observation and diary writing

Each group of students was required to keep a diary of their own bottle ecosystems over four-week periods concerning ‘what can be seen’, ‘what is going on’, ‘changes in both living and non-living things’, ‘what might be happening in the bottle’, etc. During this activity, students in each group observed, recorded, discussed, and analyzed their own data for the diary, and carried out report preparation and presentation at the end of the fourth week. Students met once a week with their teacher to report their findings, discuss, and solve problems that had arisen. Moreover, students met with their classmates for discussing and sharing of their findings once a week in the classroom.

Activity 4: Presentation

At the end of the fourth week, each group of students presented their own findings and what they had learned. The reports and concept maps were also collected for further analysis.

Activity 5: Evaluation of conceptual understanding

Post-test of the four true-false questions as previously used for pre-test was given to all 114 students. Thirty focused students were interviewed for fifteen minutes through a semi-structured interview with the same topics as interview I. These interviews were audio-taped and noted.

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2) The Effects of a Learning Package on Scientific Investigation of Bottle Ecosystems

The effects of a learning package on scientific investigation of bottle ecosystems were assessed by mix-methods approach. The quantitative data consisted of pre-test and post-test of the four true-false questions. The qualitative data included an interview of 30 focused students at the beginning of activities and at the end of activities. In addition, group diaries, group reports, and group concept maps were collected and analyzed after the activities had been carried out.

a) Pre-test and Post-test

An analysis of the pre-test and the post-test of four true-false questions is shown in Table 4.8 as percentage of correct answers. For the pre-test, only 1.4% of 114 students answered correctly about components of the ecosystems: only animals and plants were mentioned (Q1). Only 13.2% of students gave the correct answer about plants' roles in ecosystems (Q2). The students overlooked the relationship among components of ecosystems as reflected by only 26.7% correctly answered Q3. However, 72.2% of students gave the correct answer to Q4 about aquatic plants as food for fish. When compared to the post-test, the percentage of correct answer increased extensively in Q1, i.e. from 1.4% to 66%. However, these percentages increased to a lesser extent in questions Q2, Q3, and Q4, i.e. 3.1, 2.1 and 1.3 folds respectively. Paired t-test analysis showed a significant difference in percentage of correct answers between pre-test and post-test in all questions ($p<0.05$). The results clearly show that the students gained significantly higher score after participating in the activities.

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Table 4.8 Pre-test and post-test analysis of students' conceptual understanding of ecosystems by using the four true-false questions (n=114)

Item	Pre – test* Correct Answer (%)	Post – test * Correct Answer (%)
Q1: Components of pond ecosystems are only animals and plants.	1.4	66.0
Q2: Plants use oxygen for respiration in the night only.	13.2	45.1
Q3: Ecosystems compose of living and non-living things and there are relationships among them.	26.7	54.9
Q4: If the aquatic plants are doubled, fishes will have more food for living.	72.2	91.0

b) Interview I and Interview II

The interview results from the 30 focused students before and after the one-month activities are summarized in Table 4.9. Categories 1, 2, 3, and 4 represented level of understanding in various topics. Prior to the activities, 60% and 73% of the students were at level 1 on the topics of structure of ecosystems and recognition of organisms, and relationship among components. However, 50% and 80% of students were at level 2 on the topics of plants' roles and animals' roles in ecosystems respectively. For interview II after completion of the activities, a higher percentage of students was at higher levels of understanding. On the structure of ecosystems, the majority of students' understanding shifted from category 1 to 2. Similar results were observed on other topics. The excerpts taken from interviews I and II showed changes in student's conceptual understanding of ecosystems from simple to more complex explanations. Typical responses from students in the interview II included the following.

Student #3: *"An ecosystem is an environment around us. There are relationships among living and non-living things. They occupy the same space be it plants, animals, soil and air."*

Student #8: *"An ecosystem is a group of non-living things and living things such as plants, flowers, aquatic animals, wild animals, and humans that live together and interact with each other"*

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These responses show that students improved their understanding in the meaning and components of ecosystems. In addition, students' understanding of relationships among ecosystem components also changed, as shown in the following.

Student #6: *"Light affects plants and animals. Plants need light to generate food. Animals need light for living."*

Student #14: *"Water quality affects plants and animals. My aquarium has algae blooming. I saw fish gasping for oxygen at the water surface."*

Student #25: *"I learned from observing my own aquarium that plants and animals are related to each other. Plants generate oxygen, animals get oxygen from plants and release waste to fertilize plants."*

Student #27: *"When aquatic plants decrease, aquatic animals will also decrease. Everything is related to each other and depends on each other."*

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Table 4.9 Number of students at different category from Interview I and Interview II of 30 focused students

Topics	Category*	Number of students (%)	
		Interview I	Interview II
1. Structure of ecosystems	1	18 (60%)	8 (27%)
	2	10 (33%)	12 (40%)
	3	2 (7%)	7 (23%)
	4	0 (0%)	3 (10%)
2. Recognition of organisms in the ecosystems	1	18 (60%)	8 (27%)
	2	11 (37%)	20 (67%)
	3	1 (3%)	2 (6%)
3. Relationships among components	1	22 (73%)	10 (33%)
	2	8 (27%)	18 (60%)
	3	0 (0%)	2 (7%)
4. Plant's roles in ecosystems	1	1 (3%)	0 (0%)
	2	15 (50%)	8 (26%)
	3	14 (47%)	17 (57%)
	4	1 (3%)	0 (0%)
5. Animal's roles in ecosystems	1	2 (7%)	0 (0%)
	2	24 (80%)	15 (50%)
	3	4 (13%)	15 (50%)

* the levels of understanding increase from category 1 to 3 and 4.

These responses indicate more understanding of the meaning, components and relationships. The results on the levels of understanding show that most of the students moved from fair to moderate level. However, only 1 student showed understanding at a good level (Table 4.10).

Table 4.10 Level of understanding for interview I and II of the 30 focused students

Level of understanding	Score Range*	Interview I Number of students (%)	Interview II Number of students (%)
Fair	5-8	26 (87%)	0 (0%)
Moderate	9-12	4 (13%)	29 (97%)
Good	13-17	0 (0%)	1 (3%)

* A minimum of 5 and a maximum of 17 are derived from summation of the scores from the five topics (Table 4.9)

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c) The Diaries

Diaries collected from each group varied considerably in the extent and quality of writing. The contingency table (Table 4.11) shows the classification of the diary contents and frequency of phrases or sentences mentioned in the diaries over a four-week period. The data are displayed as percentage of observations in each of the four weeks. The frequency of observations increased in all topics from the first to the fourth week especially in the topics of animals from 2.22% to 13.11% and science process from 4.00% to 13.11%. However, the students' perceptions did not seem to change overtime. Upon more detailed reading of the students' diaries, the results were more impressive. Several groups of students described short incidents of reproduction, growth, swimming and amount of animals in the bottle ecosystems. These phenomena can only be noticed from extensive observation. Other observations, however, were related to personal experience e.g. fishes are happy, sleeping, resting and mating. Moreover, there was a shift from simple to complex observations and interpretations.

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Table 4.11 Students' observations from diaries during the four-week periods

Topics	1st week	2nd week	3rd week	4th week	Total
Plants					
- Color	2	3	3	4	
- Growth	1	3	5	5	
- Amount	2	4	5	7	
Total of Plants	**5 (1.11%)**	**10 2.22%)**	**13(2.89%)**	**16(3.56%)**	**44(9.78%)**
Animals					
- Color	4	6	9	10	
- Swimming/moving	4	5	7	9	
- Position	1	4	7	8	
- Eating	1	3	3	5	
- Respiration	0	2	4	4	
- Growth	0	8	10	14	
- Reproduction	0	2	3	6	
- Death	0	0	0	3	
Total of Animals	**10(2.22%)**	**30 6.67%)**	**43(9.56%)**	**59(13.11%)**	**142(31.56%)**
Water					
- Color	0	2	3	4	
- Turbidity	2	4	4	5	
- Sediment	0	0	1	1	
- Volume	0	2	4	4	
- Smell	0	0	1	2	
Total of Water	**2 (0.44%)**	**8 (1.78%)**	**13(2.89%)**	**16 (3.56%)**	**39 (8.67%)**
Relationships					
- Living-living things	2	6	10	18	
- Living –nonliving things	0	2	4	8	
Total of Relationships	**2 (0.44%)**	**8 (1.78%)**	**14 3.11%)**	**26 (5.78%)**	**50 (11.11%)**
Science Process					
- Quantifiable Observation	10	10	20	25	
- Interpretation	4	6	10	14	
- Hypothesis	1	5	8	12	
- Take actions	3	3	5	7	
Total of Science Process	**18(4.00%)**	**24(5.33%)**	**43(9.56%)**	**59(13.11%)**	**144(32.00%)**
Perceptions					
- Appreciation	1	1	2	2	
- Enjoyment	6	6	6	7	
Total of Perception	**7 (1.56%)**	**7 (1.56%)**	**8 (1.78%)**	**9 (2.00%)**	**31 (6.89%)**
Total of All Topics	**42**	**79**	**120**	**159**	**400 (100%)**

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d) Concept map

A high percentage of students (46.7%) was categorized in the good level indicating that the students understood the overall concepts of ecosystems but still had a few errors in links between concepts (Table 4.12). About 20% of the students were in the moderate level indicating that they were able to understand concepts, albeit lacking in sufficient clarity which resulted in concept maps that had incorrect links. Nevertheless, no students scored at the highest level of understanding. Concept maps of one group described ecosystems as population in a habitat with the relationships among trophic levels, i.e. producers, consumers and decomposers. They expressed the idea that ecosystems had two types: terrestrial and aquatic ecosystems. In another group, terrestrial and aquatic ecosystems were mentioned and the relationships between living things themselves with non-living things were shown. The maps described components of ecosystems as producers, consumers and decomposers. In addition, examples of each trophic level were correctly given. The overall concept maps contained all concepts of the ecosystems but some groups showed errors in links and/or spelling.

Table 4.12 Level of understanding for concept maps of ecosystems (N=15)

Level of conceptual understanding	Score Range*	Number of groups (%)
Inadequate	1-8	3 (20%)
Fair	9-16	2 (13.3%)
Moderate	17-25	3 (20%)
Good	21-33	7 (46.7%)
Excellent	34-45	0 (0%)

* The holistic score rubrics are sum of scores derived from concept, proposition, hierarchy, and example of concept map (Novak and Gowin, 1984). The minimum and maximum scores are 1 and 45.

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e) Reports

Each report was analyzed for components as described in section 3.4.5.2 in the previous chapter. 40% and 33.33% of students were categorized in excellent and good levels indicating that most groups generated good reports which contained all components with correct descriptions. However, 26.67% scored at a moderate level, indicating some incomplete descriptions of the components reported. It is possible that they had a fairly coherent understanding that guided their report writing. Analysis of the reports showed that students were able to summarize and discuss results from their observations and correctly transfer their comments from their diary into proper sections of the report.

4.2.2.3 A Community-Based Learning Package on Local Ecosystems

1) Activities

The developed community-based learning package on local ecosystems was implemented in *Maeklong School* as an elective course for 8th grade students. The teaching-learning activities were conducted following the developed lesson plans. The details of educational activities of this learning package are described in chronological order.

Engagement

The class started with engagement of the students into the class by brainstorming on the meaning of environment, natural resources, and ecosystems. Each student constructed concept map on ecosystems. Then, they discussed on their interested field trip topics. The next activity was hands-on activity which was an introductory exploration on water and its importance. The students were encouraged to discuss and draw conclusion by themselves. Then, a lecture on local aquatic ecosystems and problems by local sages was arranged for the students.

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Exploration

The exploration stage continued with planning and designing field trip activities in classroom by brainstorming. For field trip, each group of 5-6 students planned and designed for the activities and sampling areas to investigate physical, chemical, and biological components of local ecosystems under teacher's guidance. The topics were the study of species and number of plants in local ecosystems, the study of species and number of mollusks in local ecosystems, the study of species and number of birds in local ecosystems, the study of physical and chemical properties of local ecosystems, the study of water quality of local ecosystems. Students were encouraged to design their own plan for data collection and analysis. Nevertheless, they presented the plans to the class and discussed for the most appropriate schedule, with the supports from teacher as consultant.

Before field trips, students were required to practice the water quality measurement by using the test kits for pH, dissolved oxygen, nitrate, ammonia, as well as, Secchi disc, meters for measuring water depth. Students were given opportunity to go to local sage's house to attend the lecture on the importance of water resources, utilization, water problems, and water management. Students also made minor field trip on the river bank around the community member with great local sage's house. Then, students discussed, summarized, and presented the lesson learned to the class.

Exploration (Field trips)

Three field trips within three months were conducted. During the field trip, each group of students observed and recorded the physical, chemical, and biological components according to their interests and plans. Students measured water quality including pH, dissolved oxygen, nitrate, and ammonia by using test kits. The physical properties of water were also measured, i.e., tide, general appearance, turbidity, temperature as well as width, depth of the river.

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Explanation and Evaluation

After the field trips, each group of students analyzed the data and prepared group report with guidance about the techniques from teacher. Students also consulted local sages, experts and used other resources including additional books, textbooks, journals, and websites. During this activity, teacher encouraged and facilitated students to discussion and sharing of ideas among group members. The students also discussed the possible actions that should be done for taking care of the local ecosystems. At the end of the class, students displayed their work as posters, reports etc. at the exhibition hall of Educational Service Area Office (ESAO). Students and teachers from other schools, local sages, district educators, and local people were invited to attend the exhibition.

2) The Effects of a Community-Based Learning Package on Local Ecosystems

The effects of a community-based learning package on local ecosystems were evaluated by various data sources: questionnaires (pre-test and post-test), four true-false questions, interviews on conceptual understanding of ecosystems. The data were collected both before and after participation in the class. In addition, the written documents on concept maps, reports, and classroom observations were also collected and analyzed for triangulation. The results of student's achievements of each measure are shown as follow.

a) Pre-test and Post-test

An analysis of the pre-test and the post-test of four true-false questions is shown in Table 4.13 as percentage of correct answers. For the pre-test, only 2.2% of twenty students answered correctly about components of the ecosystems: only animals and plants were mentioned (Q1). Only 20.6% of students gave the correct answer about plants' roles in ecosystems (Q2). The students overlooked the relationship among components of ecosystems as reflected by only 22.5% correctly answered Q3. However, 67.8% of students gave the correct answer to Q4 about aquatic plants as food for fish. When compared to the post-test, the percentage of correct answer increased extensively in Q1, i.e. from 2.2% to 70%. However, these percentages increased to a lesser extent in questions Q2, Q3, and Q4, i.e. 2.72, 3.03 and 1.36 folds respectively. Paired t-test analysis showed a significant difference in percentage of

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correct answers between pre-test (mean=1.09, SE=0.064) and post-test (mean =2.65, SE=0.081) in all questions ($p<0.05$) as analyzed by the paired t-test. The results clearly show that the students gained significantly higher score after participating in the activities of community-based learning package on local ecosystems.

Table 4.13 Pre-test and post-test analysis of students' conceptual understanding of ecosystems by using the four true-false questions (n=20)

Item	Pre – test* Correct answer (%)	Post – test * Correct Answer (%)
Q1: Components of pond ecosystems are only animals and plants.	2.2	70.0
Q2: Plants use oxygen for respiration in the night only.	20.6	56.0
Q3: Ecosystems compose of living and non-living things and there are relationships among them.	22.5	68.2
Q4: If the aquatic plants are doubled, fishes will have more food for living.	67.8	92.0

The conceptual understanding of local ecosystems was also analyzed using 15-true-false questions, concept maps, reports, and interviews both before and after program participation.

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Table 4.14 Pre- and post-test scores of students' conceptual understanding of local ecosystems by using the 15-true-flase questions

Item	% Correct answers*		Difference	*p value*
	Pre-test	Post-test		
Q1: Water pollution problems in our area are caused by industries more than communities.	15	80	+65	0.00
Q2: Water quality can be improved if people have enough knowledge.	60	75	+15	0.49
Q3: Using detergent in powder form is better than in the liquid form.	30	40	+10	0.21
Q4: Drain the wastewater directly into the river will help aquatic animals' growth due to increase of nutrient.	30	50	+20	0.33
Q5: Throwing garbage into the river is not a cause of water pollution.	40	55	+15	0.77
Q6: Residential housing on the river, does not affect water quality.	55	60	+5	1.00
Q7: If we put more chlorine into tab water, water quality will increase.	65	65	0	0.58
Q8: Using fertilizer and pesticide in plantation are causes of water pollution.	40	50	+10	0.54
Q9: If we don't drink water for four days, we will die.	55	65	+10	0.21
Q10: Avoiding residential construction and expansion near river is one of the methods for wastewater control.	55	75	+20	0.00
Q11: There are fifty percents of water in the world for human living.	35	75	+40	0.00
Q12: We can throw any foods into the river as much as we can because aquatic animals can eat them all.	5	95	+90	0.00
Q13: Wastewater means the water that does not have enough oxygen for fish to breath.	0	85	+85	0.00
Q14: Firefly is an indicator of water quality.	60	95	+35	0.00
Q15: If people living upstream throw the garbage into the river, our environment will be affected.	35	100	+65	0.00

* Results from 20 students are presented as percentage of correct answer.

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Table 4.14 shows percentage of correct answers, difference, and statistically significant results of paired t tests comparing pre- and post- assessment of 15-true-flase questions. The paired t-test of the fifteen questions showed a significant increase in percentage of correct answer in all items tested. The percentage of difference between the pre- and post-test ranged from 5% to 95%. A striking difference was observed in questions 12 (90%) and 13 (85%) which represented the cause and meaning of water pollution. A 65% increase in questions 1 and 15 suggested that students had clearer understanding on the relationship between community, industrial activities and water pollution.

b) Interviews

The interviewing results are shown as concerning structure and recognition of the ecosystems, 60% of students changed from poor to a very good level of understanding after enrolling in this learning package (Table 4.15). Similar changes were observed on the other two topics on relationships among the ecosystems components and roles of plants and animals in the ecosystems, although the percentage of increase was somewhat smaller in the latter topic. It should be noted that none of the students remained at the poor level after participating in the learning package. In all these topics, 12.5-25%, 25-37.5%, and 50-65% of students were raised up to fair, good, and very good levels, respectively.

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Table 4.15 Number of students at different category from Interview I and Interview II of the eight randomly selected students.

Topics	Category*	Number of students (%)	
		Interview I	Interview II
1. Structure of ecosystems	1	18 (60%)	8 (27%)
	2	10 (33%)	12 (40%)
	3	2 (7%)	7 (23%)
	4	0 (0%)	3 (10%)
2. Recognition of organisms in the ecosystems	1	18 (60%)	8 (27%)
	2	11 (37%)	20 (67%)
	3	1 (3%)	2 (6%)
3. Relationships among components	1	22 (73%)	10 (33%)
	2	8 (27%)	18 (60%)
	3	0 (0%)	2 (7%)
4. Plant's roles in ecosystems	1	1 (3%)	0 (0%)
	2	15 (50%)	8 (26%)
	3	14 (47%)	17 (57%)
	4	1 (3%)	0 (0%)
5. Animal's roles in ecosystems	1	2 (7%)	0 (0%)
	2	24 (80%)	15 (50%)
	3	4 (13%)	15 (50%)

Note: the levels of understanding increase from category 1 to 3 and 4.

Results from group of students' concept maps on the ecosystems were used for probing conceptual understanding of ecosystems. High percentage of groups (45.45%) were categorized at the good level indicating that students understood the overall concepts of ecosystems but still had a few errors in linking between the concepts. About 27% of students were in the excellent level indicating ability to understand the whole concepts and have a clear picture of linking between the relevant concepts. About 18% of the students were in the moderate level indicating that they were able to understand concepts, albeit lacking in sufficient clarity which resulted in incorrect links. However, 9% of students were scored at the fair level of understanding after participating in the program.

Analysis results of group reports by using scoring rubrics of the six components. The highest average score were in the scope of study (3.83) and results (3.83) while the lowest score were in the title and introduction (2.83). Other components on objective(s), materials and methods, and discussion were also at the excellent quality (Score was 21 to 23). The results revealed that most groups generated very good reports which contained all components with correct descriptions, although the quality of the title and introduction were not as good. Analysis of the reports

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showed that students were able to summarize and discuss results from their observations, field trips, laboratory experiences, and correctly transfer their experiences into proper sections of the report. During the report development, students used the various provided resources. This was a good practice that students could generate good reports from using not only the textbooks but also local sages, science educators, and science educational researchers.

c) Students' Perceptions toward Local Ecosystems

Table 4.16 shows means, different, and statistically significant results of paired *t* tests comparing students' perceptions towards local ecosystems. There were significant increases in students' perceptions in all 15 items tested. The holistic scoring rubrics increased from 36.9 to 54.3. The difference in score between before and after joining the program ranged from 0.6 to 2.4. The results revealed that the misconception on the reason for location of industries near the river was corrected. In addition, students had increase perception about water conservation, including how to maintain good water quality.

The interviewing results from eight students also revealed that students' perceptions towards local ecosystems changed toward a good level after participation in the program. Only 12.5% of students were at a good level in Interview I, while the percentage increased to 75% in Interview II after joining the whole program. Although 25% of students were at the fair level but none of them remained at the poor level.

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Table 4.16 Students perceptions towards local ecosystems and management before and after participation in the program

Items	Before	After	Different	*p*
1. Industrial plants have to locate near river for convenience in releasing wastewater.	1.85	4.20	2.35	0.00
2. Water pollution affects the economical status of community.	1.80	3.65	1.85	0.00
3. After washing clothes, wastewater should be thrown into river to increase water's odor.	2.90	3.85	0.95	0.00
4. Watergate can improve water quality by collecting and making more sedimentation.	2.45	3.55	1.10	0.00
5. To improve water quality is a waste of time.	2.85	3.95	1.10	0.00
6. Everyone should be responsible for water quality.	2.70	3.60	0.90	0.02
7. Mae – Klong river will not be rotten because it has a huge volume of water for diluting wastewaters and solid wastes.	2.70	3.85	1.15	0.00
8. Government should have strict regulations for punishment of the environmental destroying people.	2.75	3.95	1.20	0.00
9. People should pay for the water fee depending on the amount used.	2.30	3.55	1.25	0.00
10. Monitoring of changes in water quality is the responsibility of the government officials not the citizen.	2.65	4.05	1.40	0.00
11. Law abandon is related to environmental problems.	2.20	3.55	1.35	0.00
12. We have to take care of the water resources as soon as possible.	2.75	4.15	1.40	0.00
13. We should educate children about environmental problems and conservation.	2.90	3.70	0.80	0.03
14. Local community should be continuously involved in environmental conservation.	2.85	4.25	1.40	0.00
15. Disseminating knowledge on environmental awareness is a good strategy for protecting environment.	3.40	4.00	0.60	0.04
Total	36.85	54.30	17.45	0.00

Note: 5-point Likert scale ranging from strongly agree (score 5) to strongly disagree (score 1)

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d) Students' Self-Reported Behaviors

The results in Table 4.17 on self-reported behaviors toward local ecosystems management were significantly higher after enrolling in the learning package. The holistic scoring rubrics increased from 37.8 to 55.3, with differences in the score range from 0.5 to 2.0. However, there were no significant changes in score of two items (items 9 and 14) between before and after participation in the learning unit. The overall results as shown in Table 4.17 indicated that students behaved much better toward management of water resources in several aspects.

Table 4.17 Students self-reported behaviors toward local ecosystems management before and after participation in the program

Items	Before	After	Different	*p*
1. Tell other people not to throw garbage into the river.	2.35	3.20	0.85	0.01
2. Clean the road by sweeping the garbage into the canal.	2.75	4.20	1.45	0.00
3. Before washing dishes, the dirt should be poured into the garbage can.	2.80	4.05	1.25	0.00
4. In taking a bath, turn off shower during soaping.	2.60	3.65	1.05	0.00
5. In brushing your teeth, turn on tap water to drain the toothpaste bubble.	2.70	4.70	2.00	0.00
6. Use high concentrate detergent to clean the bathroom.	2.20	4.05	1.85	0.00
7. Use detergent that has environmental concerning label.	1.75	3.25	1.50	0.00
8. Consider water level in the utensil during dishes washing.	2.35	3.65	1.30	0.00
9. Throw garbage into the canal.	2.55	2.90	0.35	0.45
10. Pour wastewater after clothes washing into the river.	2.05	3.10	1.05	0.00
11. Inform government officials, when you see someone destroy water quality.	2.90	4.55	1.65	0.00
12. You help people in water conservation.	3.00	3.75	0.75	0.05
13. You are willing to join the environmental conservation projects.	2.45	3.70	1.25	0.00
14. Help communities in cleaning the water resources and communities.	2.65	3.15	0.50	0.17
15. You have joined the project on cleaning water resources.	2.70	3.40	0.70	0.04
Total	37.80	55.30	17.50	0.00

Note: 5-point Likert scale ranging from always (score 5) to never (score 1)

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4.2.3 Students Perspectives toward the Learning Packages

4.2.3.1 Perspectives toward a Guided Inquiry Learning Package on Aquatic Ecosystems and a Learning Package on Scientific Investigation of Bottle Ecosystems

The students' perceptions toward the learning packages were collected at the end of the unit by using open-ended questions and a questionnaire composed of 15 Likert scale items. 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 questions covered mini-aquaria experiment, unit activities, role of the teacher, and role of the group members (Table 4.18). The minimum and maximum values of students' perceptions on the learning package were found to be 4.14 and 4.65. The mean and standard deviation of the 15 items were 4.41 and 0.41, indicating moderate level of approval.

The results in Table 4.18 show student had positive perspective. Students perceived the experiment (mean±SD = 4.50±0.12) as helping them to understand the interrelationship in the ecosystems (4.64 on a 5-point scale), providing clear data for deriving the effects of light periods (4.55) and generating the explanation (4.33). They rated their perception toward activities (mean±SD = 4.44±0.22) as appropriate (4.50), providing opportunities for collaboration (4.53) and discussion (4.35), the activities are fun (4.30) and encourage communication (4.53). Students rated their perception towards teacher (mean±SD = 4.27±0.19) as providing enough time to think (4.26), encouraging data analysis (4.40) and group discussion (4.14). Their perception toward group members (mean±SD = 4.39±0.24) was rated as sharing an equal responsibility (4.51), capable of planning together (4.50) and finishing on time (4.31), and having the ability to conclude and present their work (4.31).

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Table 4.18 The students' perceptions of the learning package (N=80)

Items	Perception toward a learning package				
	Strongly disagree (%)	**Disagree (%)**	**Undecided (%)**	**Agree (%)**	**Strongly agree (%)**
Part 1 Perception towards experiment (Mean = 4.50±0.12)					
1. The experiment used in the learning package helps to understand the interrelationship in the ecosystems.	0	0	0	29 (36.25)	51 (63.75)
2. The experiment provides clear data for generating the explanation.	0	2 (2.5)	5 (6.25)	38 (47.5)	35 (43.75)
3. The data are enough for deriving the effects of light periods.	0	0	1 (1.25)	34 (42.5)	45 (56.25)
Part 2 Perception towards the activities (Mean = 4.44±0.22)					
4. The activities in a learning package are appropriate.	0	0	3 (3.75)	34 (42.5)	43 53.75)
5. The activities provide opportunity for collaboration with other students.	0	0	1 (1.25)	36 (45)	43 (53.75)
6. The activities provide opportunity for discussion.	0	0	3 (3.75)	46 (57.5)	31 (38.75)
7. The activities are fun.	0	0	1 (1.25)	54 (67.5)	25 (31.25)
8. The activities provide good communication among group members.	0	0	2 (2.5)	34 (42.5)	44 (55)
Part 3 Perception towards teacher (Mean = 4.27±0.19)					
9. Teacher provides enough time to think.	0	0	5 (6.25)	49 (61.25)	26 (32.5)
10. Teacher encourages data analysis in the group.	0	0	2 (2.5)	44 (55)	34 (42.5)
11. Teacher facilitates group discussion.	0	0	1 (1.25)	67 (83.75)	12 (15)
Part 4 Perception towards group members (Mean = 4.39±0.24)					
12. Each group member has an equal responsibility.	0	0	0	39 (48.75)	41 (51.25)
13. All group members plan together before doing the activities.	0	0	1 (1.25)	43 (53.75)	37 (46.25)
14. All members can finish the work on time.	0	0	5 (6.25)	45 (56.25)	30 (37.5)
15. The group can conclude and present the results that conform to other groups.	0	0	4 (5)	47 (58.75)	29 (36.25)

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The excerpts taken from open-ended questions showed positive attitudes about the unit; for examples:

1. *"These activities help me to understand the ecosystems more than reading from textbook."*

2. *"I like to design the experiment, since I believe that good experimental design will lead to a good result."*

3. *"I learn and understand by doing and discussing within group."*

During implementation of the learning package, about 10% of the students asked whether they could carry out their own experiment. The teacher explained the limitations of such venture due to constraints of class-time, budget, and apparatuses, however, the students were encouraged to work in their spare time. 5% of the students did perform part of the mini-aquaria experiment under teacher supervision. In addition, after completing these learning packages, the students in one of the three schools did similar mini-aquaria experiment at home to explore interrelationships in ecosystems, mainly between light and biological components and physical properties of water, and reported the results to the class.

4.2.3.2 Perspectives toward a Community-Based Learning Package on Local Ecosystems

The students' attitudes toward the program revealed that most students were happy with the several educational activities and multi-tasks of the program. These teaching-learning activities including the out-of-classroom activities have met their interests. Most importantly, there was much improvement in relationships not only among teacher-students but also students-students. They noted that the teaching-learning activities provided opportunities for students to participate, discuss, share ideas, and learn with classmates, teacher, and local sages. They reported less discomfort in speaking in front of the class and in the exhibition. They reported increased ability to think creatively, engage in group discussion, lead a group, work with classmate and community people and experts, and communicate with others.

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Surprisingly, all eight students had positive feedbacks toward the program and teacher. The following are excerpts from the interviews and self-reflection toward the learning package and teacher.

Student#5: *"… Teacher encouraged us to think and understand by giving the examples of things around us. We had good opportunities to learn from field trips and from local sages …"*

Student#7: *"... Teacher made me more enthusiastic on working and expressing my ideas. Now, I dare to think, speak out, and do many things that I've never dare to do it before… I realized the importance of collaborative learning …"*

Student#8: *"… I gained more experiences in learning both inside and outside classroom. I had opportunities to train myself in several things during the program. It is a worthwhile learning experience. I realized that we all have to take care of our environment, starting from ourselves …"*

However, there were some drawbacks about the learning packages. The main obstacles were time consuming and budget constraints. Another problem was in students themselves, most of them lack of skills used in the field trip such as, sampling of specimen, keep data record, including ware quality measurement. They need to spend extra time for studying and practicing before the filed trips. At the end of the exhibition, the students also expressed their sincere thanks to the local sages, community people, teachers, parents, in supporting and encouraging. Three schools have adapted the idea of this community based learning package. The two local sages and other community people were satisfied with this program and expressed their willingness for further supports.

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4.2.4 Teachers Perspectives toward the Learning Packages

Interviews with the three teachers after implementation of the unit showed that all of them had positive views about the unit. They mentioned that this learning package is very different from the traditional lesson plan and is very encouraging. They were impressed by the activities that stimulated students to explore and manipulate data and to construct the concept of interrelationships within the ecosystems by working in group. They stated that these learning packages were suitable for the lower secondary classes especially for schools with limited budgets, lab equipment, and time. They expressed their willingness to continue using this learning package in their classes and it should not pose any problem to their colleagues in implementing it. Some teachers thought that the students would gain more knowledge upon doing the experiment themselves. However, with such a constraint they agreed that the learning package still could encourage students to analyze the data which would benefit them than the traditional teaching.

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CHAPTER V
DISCUSSION

5.1 Overview

This chapter comprises discussion from the overall findings. It begins with the discussion on guided inquiry learning package on aquatic ecosystems, followed by scientific investigation of the bottle ecosystems, and community-based learning package on local ecosystems for lower secondary school students. The effects of these three learning packages on students' performance are discussed. Finally, educational implications are described.

5.2 A Guided Inquiry Learning Package on Aquatic Ecosystems

This study demonstrates the successful implementation of a guided-inquiry learning package on aquatic ecosystems for students who participated in the environmental education program. After participating, the students can construct their own explanations about the interrelationship in ecosystems and can link the laboratory results with seasonal changes. Both teachers and students have positive attitudes toward this learning package.

In this learning package, only one set of real data from three replicated experiments with similar results was used for each student group to analyze and interpret. It is suggested that the teachers should emphasize the importance of replication in obtaining more reliable data. Moreover, the teacher should also encourage students to perform at least part of the experiment at school or at home. In reality, a few students did part of the experiment at school and tried to compare their results with the ones given. Three groups of students carried out their own experiments at home after completing this learning package. It is worth mentioning here that in a separate study students designed and performed the whole experiment under teacher's facilitation. Even though the students appeared to have no problem in conducting the latter experiment, the teachers seemed not to like it due to alleged time and budget

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constraints (researchers' unpublished data), requiring extra effort and resourcefulness on the part of the teachers: hence the present research works.

The main experimental data used in the learning package cover the relationships in ecosystems at different conditions. The data are similar to those from previous studies on the aquatic environmental chemistry illustrating the relationship between oxygen contents of water, temperature, and photosynthetic activity of algae and plants (Tang and Vincent, 2000; Rytwo and Gonen, 2005). DO in water decreased as temperature increased and it varied during the day apparently due to temperature and biological activity. The results of scientific experiment (Table 4.1-4.4, Chapter 4) showed a slight fluctuation in DO despite the relatively constant temperature. This might be due to the consumption of oxygen by algae and animals, and their waste products. The results also showed a small increase in pH (about 1-2 pH unit) after 1 week, which might be due to alkalinity of the waste products in the aquatic system. The teachers also discussed these aspects with the students and encouraged them to express their opinions.

There are only a few journal reports on the use of mini-ecosystem learning packages as an effective tool to teach ecology. Our study design is similar in principle to those of Balster et al. (2001) on Mini Poplar Ecosystems (MPE) as collaborative tool to teach forest ecosystems process for the undergraduate students. In this model the students designed and performed a semester-long experiment, collected data, and did the interpreting. Both studies shared the common feature that students actively participated in the learning process to witness changes in the ecosystems. The differences were that students in MPE conducted the actual experiment while the students who participated in present study received only secondary data. However, both models are effective learning tools in natural resources and ecology education.

In another similar study, high school students were asked to create and observe mini-ecosystems in bottled botanical gardens (Brown et al., 2008). However, this model focused on students' creativity in designing the mini-ecosystems. In this guided inquiry learning package on aquatic ecosystems, students were encouraged to ask questions throughout the learning sequence. From observation the students asked more intelligent questions, generated fruitful ideas, and finally developed their own understanding. Such an outcome was observed in the study of Magtorn and Hellden

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(2007) that a bottom-up teaching sequence was designed to help students read nature from river ecosystems. The students were able to relate several abstract processes and correlated back to the key organisms studied earlier in the teaching sequence. The guided inquiry learning package in this study is similar to several other studies (Gatt et al., 2007; Ausubel, 2000) in that students were given examples to derive the relationship between concepts and to integrate their understanding with other concepts and propositions. In all these studies, including ours, the students had the chance to learn the subject matter in such a way that knowledge was not received as in the traditional top-down approach, but was constructed by them.

The students in this study have gone through the process of inquiry which is important for learning science since students should be able to "do science" and "produce meaningful explanations" not merely report results. This study is in accordance with several previous findings that guided-inquiry approach is an important and valuable tool for teaching complex topics (Antunes et al., 1998; Woods, 1989; Kolb, 1984; Beyer, 1979; NRC, 2000). The students accomplished the specific learning objectives of the unit as reflected by their abilities in manipulating data, generating questions, and communicating, discussing, and generating explanations. They fulfilled the five-step activities of the learning package according to Beyer's guided-inquiry method (1979) and the NRC's recommendations (2000). This study also confirms that "guided-inquiry approach" helps students to generate explanations using the given data (Duit and Glynn 1996) and provides a valuable opportunity for sharing and passing the ideas to others with the help of group discussion (Gilbert and Priest 1997).

Results from students' perception both from the questionnaire and interviews suggested that this learning package is one of the effective means for learning about ecosystems. Questionnaire results revealed that students did like both the content and activities of the learning package. They also enjoyed working in groups. They realized that collaborative learning and guided-inquiry help them understand ecosystems concepts more. However, the students had less positive attitude toward teacher support when compared to the group activities. This is not surprising since it is well established that students claim to learn from peers more than from teacher. About 10% of the students seemed not to like the inquiry learning environment, not even guided-

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inquiry; they were more comfortable with the old way of spoon-feeding without having to think or express themselves. The students did not realize that they could not gain knowledge on environmental changes just from lecture and textbooks as reported by Balster et al. (2001). The teachers had positive attitude toward this learning package (interviewing results). They were willing to try the guided-inquiry method for the first time, with large numbers of students and limitation of time, especially, with the underprivileged students of rather low scholastic achievement (average GPA of 2.35 in science).

5.3 A Learning Package on Scientific Investigation of Bottle Ecosystems

This learning package was based on mini-aquaria experimental data used to enhance students' abilities to transform data and to explore ecological concepts about the interrelationships between organisms and their environment. It emphasized particular aspects of scientific investigations, i.e., generating testable questions, analyzing data, interpreting data, posing explanations, and communicating the results and implications. The scientific content arose from the interrelationships among components in ecosystems under different light periods.

Results from this study indicate that the conceptual understanding of ecosystems of the students improved through scientific investigation of bottle ecosystems. The results of paired t-test were supported by results from interviewing. The main achievement is that most students were able to not only describe but to ascribe meaning to the ecosystems, i.e. recognize not only plants and animals but also the non-living things as components of the ecosystems, and relationships among components after the activities. It was noticeable during interviews that students' ideas were clearly expressed. It appeared that students had already developed their understanding through observation, recording data, and discussion. Most students mentioned only superficial structures in the ecosystems, such as animals and plants in interview I while they expressed more reasonable and more functional explanations of the ecosystems in interview II, such as plants generate oxygen for fish and also for plants' respiration. In addition, the results of the diaries, reports, and concept maps corresponded and were corroborated by interviews. The diaries showed a progression

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of students' writing and understanding overtime from simple to more complex descriptions. The scientific process skills also developed overtime as indicated by the increased percentage of components of the scientific process with each passing week. Not only did they increase but also the diaries expressed long and more complex explanations from the first to the fourth week. Moreover, during a four-week period students developed their ideas through questioning, observations, discussions, and communications with the researcher, teacher, and classmates, thus allowing them to generate better understanding through diaries, concept maps, and reports. The largest number of comments in students' diaries came from their observations, then questions were turned into hypotheses leading to understanding. Moreover, students were actively applying their understanding to create positive actions for their ecosystems e.g. they changed water in bottle ecosystems every three days. Many students wrote comments that indicated a high emotional attachment. A possible reason why the students' scores on concept maps did not reach the highest score is that students had not yet practiced constructing concept maps.

The overall results support the research questions that the activities can encourage students to construct conceptual understanding of ecosystems and promote scientific skills. With these activities students could interpret what happened to things in bottle ecosystems overtime in their diaries. The results from diaries, reports, and concept maps demonstrated a progression of understanding, although to a limited extent within the time frame. The results of interview I and pre-test supported each other about many limited and incomplete understandings held by students before learning about ecosystems according to Leach et al (1992) e.g. they mentioned only living things in ecosystems, did not mention the relationships among living and non-living things. Moreover, the results of this study agree with the findings of other studies on secondary level children's ideas of ecosystems in that students harbored misconceptions on the interconnection of living and non-living things in the ecosystems (Leach et al, 1996).

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It was suggested by Gatt et al (2007) on a strategy for improving students' understanding of ecosystems that it would be worthwhile to provide students with activities which allow them to learn and generate ideas. The present study followed the suggestion and lends support to the findings of Driver et al (1985) that Thai students can learn the subject matter in such a way that knowledge is not passively received but is constructed by the learners themselves. Moreover, the students developed conceptual understanding and ownership of their ecosystems through scientific investigation of bottle ecosystems with results that relate to those of Rezba et al (1995) and Ogborn and Martins (1996). These results also concur with one of the constructivist views that students have prior concepts and these concepts could be changed through a simple investigation (Driver, 1994).

Although, this study was conducted with a limited number of participants and no attempts to infer for all students in different contexts, the results show that the understanding can be developed through simple investigation within the current shortcomings in schools in many countries including Thailand. In addition, these activities can also be implemented in other levels because it is simple but can nevertheless be planned in a scientifically investigative way. In this particular study there was no traditional teaching done but students still developed their own understanding. Moreover, these activities incurred low costs for implementation. Effective learning activities through bottle ecosystems are an example of easy and inexpensive activities for learning ecology topics leading to independence and invention. We hope this article will inspire more teachers to adapt and adopt the similar activities in the schools.

The interview I and pre-test of the learning through scientific investigation of the bottle ecosystems in this present study suggest that it is important for teachers to identify and use strategies to enhance the prior understanding of students. We found that the activities, which used scientific investigation through bottle ecosystems, help students to practice, learn, share, discuss, and interpret the concepts of ecosystems. During the activities, the various data sources, i.e. interviews, diaries, reports and concept maps were used to assess students' understanding. These can provide important formative assessment tools for teachers to improve classroom learning.

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The findings of this learning package have shown that it is possible for lower secondary school students to make their own ecosystems, observe them, and develop the concepts of ecosystems with the help of facilitator and their classmates. This offers an alternative to traditional teaching: the teachers' roles need to be changed to support and facilitate the broadening and organization of the students' ideas of the ecosystems. The activities of scientific investigation of the bottle can be a good supplement to teaching in the classroom to enhance students' understanding of concepts of the ecosystems.

5.4 A Community-Based Learning Package on Local Ecosystems

A community-based learning package on local ecosystems was developed through collaboration among community members both in and outside the school context. This learning package on local ecosystems can be seen as a mean for situated learning based on participation and interaction among community. This study established a culture in community, one in which local people, local teachers, science educators, science educational researchers, students, and local sages hold expectations for engaging together in the learning process.

The community members in this study have experienced the community of learning. This study has also shown the important of community-based learning package that students have potential to influence the extent and manner through participating in community as suggested by Tompkins (2005). Results from these findings suggest that the participants in this learning community have been experiencing within the combination of local schools, local communities, university, workplace, and local sages. The results reveal that the developed learning community has provided opportunities and places in which students have been able to develop their understanding, perceptions, and in a supportive and challenging environment.

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This particular study presents the possibility that school curriculum conducted through community participation can play a vital role in promoting community involvement from the beginning. These findings are encouraging because the students can develop their conceptual understanding, share their learning and have perceptions toward ecosystems and management with their classmates, teachers, and local sages.

In this learning package, the local environment was used as educational resources to provide students to develop environmental literacy and promote awareness from knowledge to actions which is in accordance with those of Orion and Hofstein (1994). It is also corroborated by the place-based education as described by Sobel (1996). The place-based learning connects to the experiential learning, constructivist, outdoor education, indigenous education, and environmental education (Gruenewald, 2003).

The statistical analyses of the pre- and post-test on students' perceptions and self-reported behaviors toward local ecosystems management showed significant increase in perceptions as well as in self-reported behaviors. The students also made some interesting shifts in their stances as illustrated in the comparisons of interviews before and after program participation. Upon analyzing the qualitative data, the results supported the importance of incorporating communities of practice with the learning package on local ecosystems. A significant increase in students' perceptions indicates the importance of the teaching strategies that provided the students with the firsthand experiences necessary to develop a conceptual understanding of ecology concepts and the perceptions toward their local environment.

In this study, some of the factors that may facilitate the learning on local ecosystems have been highlighted. Several activities influenced the students to initiate discussion both inside and outside the classroom. The hands-on activities such as guided inquiry laboratory, scientific investigation of the bottle ecosystems, monitoring water quality, or working with local sages, are not only interesting and joyful but they also have a powerful influence on students' interest and awareness of local environmental problems. These students are more likely to discuss and share their interests and concerns with their classmates, teacher, and local sages in the community. Focusing on local ecosystems and local environmental problems as illustrated in this study helps the students to learn and make the connections with the

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real world. In addition, this learning package also enhanced the students' sense of ownership. Our findings reinforce the importance of including an action component in the learning package. Providing positive experiences that students can have an influence on their own local environment not only helps to overcome the action paralysis identified by Uzzell and Rutland (1994) but is also likely to lead to meaningful and relevant discussions with community people regarding environmental issues and the need for community action.

The results of this study provide strong support for the views expressed by Lave and Wenger (1991), Drake (1998), Wenger (1998), and others that learning and interacting with the nature can provide insight into students' perceptions on the natural world. The local environment is used as educational resources to provide students to develop environmental literacy and promote awareness from knowledge to actions as described by Orion and Hofstein (1994). However, this community-based learning package is time-consuming and uses up resources in the form of time, money, and man-power. This study attempted to unfold the challenges in developing and implementing the environmental education program by community involvement. This can be seen as the stakeholders' interest in school teaching that provides students more ways of learning based on principles for situated learning (Lave & Wenger, 1991).

The learning package on local ecosystems in this study can be seen as a mean for situated learning based on participation and interaction among community members both in-school and outside the school context. This study also corroborated by Resnick's studies on the interaction with stakeholders outside school to provide teachers to work more situation-specifically and construct relations with the community, and as embodying competencies relevant for activities (Resnick, 1987).

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This study has shown that learning can both contribute to, and be brought through the observing, measuring, identifying, and solving of environmental problems. In Wenger's theories of communities of practice the educational practitioners, novices, stakeholders, and experts have to involve in the encompassing process as active participants of social communities to share knowledge and skills (Wenger, 1998).

The teachers mentioned that these learning packages are very different from the traditional lesson plans and very encouraging. They were impressed by the activities that stimulated students to explore and manipulate data and to construct the concept of interrelationships within the ecosystems by working in group. They stated that this learning package was suitable for the lower secondary classes.

Throughout these learning packages, students explored the local ecosystems composed the river hydrology and biology, tested water quality, and calculated a standard water quality, identified plants and animals found in their local ecosystems. These three learning packages provided the opportunities for students to gain experiences in interacting with community people, researchers, and teachers that could lead to trust, mutual understanding and shared the practices as Wenger (1998) states as social aggregation for learning.

5.5 Educational Implications

Results from this study on the advantages of the learning packages should enable teachers to adopt them as part of the local curriculum as encouraged by the policy of the Ministry of Education. This is because it has easily available local components as well as guided-inquiry activities and this unit has proved to be successful as mentioned in the Results part. These learning packages, however, still have some limitations such as the experiment was tried on one group of approximate 100 rural students with low socio-economic status. Similar experiments should be tried on other more privileged ones. Perhaps a higher number of students with different backgrounds should be involved especially those that live in the urban areas.

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One advantage of the guided inquiry learning package, that the students were given secondary data, is in its low implementation cost while producing effective learning activities especially in schools with fiscal and time constraints. In schools with proper facilities, students should conduct their own experiments and thus would make the learning cycle more complete. This learning package provided data for the students to interpret in the hope that they would derive proper scientific skills without actually doing things hands-on. To improve the outcome, students should be more involved in carrying out the experiments, at least partially. We expect the psychomotor experience gained from “dirtying their hands” would give the students feelings of reality. The educators should keep in mind that this study has described a piece of work done in a tropical country with long daylight time and relatively high temperature. Shorter light periods and lower temperature of temperate countries should provide data that complement those from this work. In other words, the more varied circumstances under which this type of work is subjected to the better we can draw conclusions about interrelationship, mechanisms, and important factors involved in such a chosen ecosystems.

Results from learning package on scientific investigation of bottle ecosystems suggested that it is important for teachers to identify and use strategies to enhance the prior understanding of pupils. The results reveal that the activities in this learning package, which use scientific investigation through bottle ecosystems, help students to practice, learn, share, discuss, and interpret the concepts of ecosystems. During the activities, the various data sources, i.e. interviews, diaries, reports and concept maps were used to assess students’ understanding. These can provide important formative assessment tools for teachers to improve classroom learning. In this study we have shown that it is possible for lower secondary school students to make their own ecosystems, observe them, and develop the concepts of ecosystems with the help of facilitator and their classmates.

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In the community-based learning package which was designed through community involvement, although it was only a small part of the participants' everyday work, it indicates that using local environment as a learning resources are challenged for teachers, community people, and students. This study, however, was conducted on too small a scale to permit conclusions on a more general level, but there are indications that when students learn more about their own environment, learn about how community people think, and practice with community people, they can understand their own environment and ecology concepts more easily. Approximately half of the students participated in this learning activity conveyed messages to their parents and relatives about their learning and what they found including environmental problems in their local areas. This finding suggests that teachers may be able to widen the perceptions of both students and parents by consciously considering this issue in planning of the learning units.

The overall findings in this study offer an alternative to traditional teaching: the teachers' roles need to be changed to support and facilitate the broadening and organization of the students' ideas of the ecosystems. These learning package can be a good supplement to teaching in the classroom to enhance students' understanding of the ecosystems concepts. These developed learning packages could be an alternative for teachers and educators who will design the hands-on activities, learning units, learning packages, and curricula in schools. These three learning packages in this study involved to different extent collaborative efforts from local sages, teachers, science educators, science educational researchers, and other community members. The collaboration was done, for example through conducting interviews to identify people's perceptions toward the program, as well as presenting reports of the finding through a public forum.

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CHAPTER VI
CONCLUSION

The newly developed learning packages in this study have shown to be effective upon implementing in lower secondary schools, even with the schools with time and budget constraints. The effectiveness of these learning packages was evaluated using mix-methods approach. The results showed that these learning packages enhanced students' knowledge and perceptions on local ecosystems. The results of this study were concluded as follows:

1. Results from a Guided Inquiry Learning Package on Aquatic Ecosystems:

1.1 This learning package aimed at enhancing students' understanding on basic ecological principles involved in relationships among physical, chemical, and biological components in aquatic ecosystems.

1.2 The mini-aquaria experiment on the effects of light period on aquatic ecosystems was developed and used in the learning package. This learning unit is based on the five-step process of inquiry teaching by Beyer (1979).

1.3 This learning package involved asking guiding questions to direct students' investigations and experimental designs, providing experimental data for analysis and interpretation, and facilitating students' construction of explanations.

1.4 In this learning package, students were encouraged to ask questions throughout the learning sequence, in which they did ask more intelligent questions, generate fruitful ideas, and finally develop their own understanding.

1.5 Statistical results showed that the students enrolling in a guided inquiry learning package on aquatic ecosystems achieved significantly higher scores on the post-test compared to the pre-test ($p < 0.05$).

1.6 The minimum and maximum values of the students' perceptions on the learning unit were found to be 4.14 and 4.65(on a 5-point scale). The mean and

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standard deviation of the 15 items on perception were 4.41 and 0.41, indicating a moderate level of approval.

1.7 The results from this learning package suggested that most students were able to manipulate and transform data from tables to graphs and charts and to correctly present it in appropriate forms for further interpretation, although there were some mistakes in the description.

1.8 Students gradually accumulated conceptual understanding through the designed learning activities, and both students and teachers had a positive attitude toward the learning unit.

2. Results from a Learning Package on Scientific Investigation of Bottle Ecosystems:

2.1 This learning package aimed at enhancing students' conceptual understanding of ecosystems and promoting scientific skills in questioning, hypothesizing, experimenting, observing, data collecting, interpreting, and discussion.

2.2 This learning package provided the opportunities for students to learn ecology through scientific experiment. Students could construct knowledge, skill, and value from direct experiences.

2.3 Statistical results showed that the students achieved significantly higher scores on the post-test compared to the pre-test ($p < 0.05$).

2.4 The results from interviews, diaries, and concept maps demonstrated a shift in students' conceptual understanding of ecosystems from simple to complex explanations. The students' detailed observations on bottle ecosystems also became more quantifiable over time.

2.5 The results from reports analysis showed that students were able to summarize and discuss results from their observations and correctly transfer their comments from their diary into proper sections of the report.

2.6 The overall results indicated that these simple and inexpensive activities help enhance students' conceptual understanding of ecosystems. The students improved their understanding in the meaning and components of ecosystems. In addition, students' understanding of relationships among ecosystem components also improved.

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2.7 The students had positive perceptive toward this learning package. Most students agreed or strongly agreed with the learning packages with mean score ranked from 4.14 and 4.65.

3. Results from a Community-Based Learning Package on Local Ecosystems

3.1 The learning package improved students' conceptual understanding on local ecosystems, perceptions toward local ecosystems, and self-reported toward local ecosystems and management.

3.2 The results on the effectiveness of this learning package clearly showed that the students gained significantly higher score on conceptual understanding and perceptions after participating in this program.

3.3 The results from interviews showed that the students changed from a poor to a very good level of understanding after enrolling in this learning package. The results indicated that none of the students remained at the poor level after participating in this learning package.

3.4 Students' perspective toward the developed community-based learning package revealed that most students were happy with the several educational activities and multi-tasks of the program.

3.5 The results from teachers' interviews showed that all of them had positive attitudes about the learning packages.

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APPENDIX

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APPENDIX A
QUESTIONNAIRE

Section 1: Perceptions toward ecosystems and management

Instruction: Please check ✓ in the box, which is the most related you opinion

Items	Opinion				
	Strongly agree	**Agree**	**Undecided**	**Disagree**	**Strongly disagree**
1. Industries have to locate near river because they can leave wastewater into water directly and more convenience.					
2. Water pollution can affect economic.					
3. After washing clothes, we have to release wastewater into river for increasing water's odor.					
4. Watergate can improve water quality by collecting and making more sedimentation.					
5. Water quality improving is boring and waste time.					
6. Everyone has responsibility for water quality concern					
7. Mae – Klong will not decay because it has a huge volume that enough for draining wastewater and solid waste.					
8. Government has to make and strict using regulations for punishment people who destroy the environment.					
9. People who use water have to pay water fee, which depend on amount of water that they use.					
10. Water changing monitoring responsibility is the government officials tasks not citizen tasks.					
11. Law abandon is related to environmental problems.					
12. We have to begin water conservation as soon as possible.					
13. Environmental awareness is necessary for kids. We have to teach kids about environmental problems and environmental conservation.					
14. People in communities have to continuously involve in environmental conservation and promotion.					
15. Environment study is good for environmental conservation.					

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Section 2: Self-reported behaviors toward ecosystems and management

Instruction: Please check ✓ in the box, which is the most related you action

Items	Action				
	Always	**Frequently**	**Occasionally**	**Seldom**	**Never**
1. Tell another one "Don't throw garbage into the river."					
2. Kick the garbage on the road into the canal for cleaning the road.					
3. Before washing dishes, you pour food in trash.					
4. Use shower and turn off it during soaping.					
5. During you brushing your teeth, you turn on tap water for draining toothpaste bubble.					
6. Using high concentrate detergent for cleaning bathroom.					
7. Using detergent, which has environmental concerning label.					
8. Using container for dishes washing. Consider about water level during washing.					
9. Throw garbage into canal.					
10. Throw water, which is used for clothes washing into river.					
11. When you see someone destroyed water quality, you told government officials.					
12. You have ever assisted another people for making announcement about water conservation.					
13. If you have chance for joining environmental conservation projects, you will be willing to attend.					
14. You have ever helped communities for cleaning water resources and communities.					
15. Have you ever joined cleaning water resources projects.					

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APPENDIX B
INTERVIEW QUESTIONS
FOR STUDENTS

Objective: To obtain information regarding the students' conceptual understanding and perception of the learning packages

Background

1) What is your name?
2) What grade are you at?
3) Where is your house?
4) What subjects or areas are you interested in?

Students' Level of Understanding of Ecosystems Concepts

Please answer these questions, either true or false

1. Water pollution problems in our area are caused by industries more than communities.
2. Knowledge about how to use water is the one way to improve water quality.
3. Using powder detergent is better than liquid detergent for water quality concern.
4. Throw wastewater directly into river or canal helps aquatic animal growth because wastewater has a lot of nutrients.
5. If we throw a few of garbage into the river, it will not damage the environment.
6. Residential housing located on the river does not affect water quality.
7. If we put a lot of Chlorine in tab water, water quality will increase.
8. Using fertilization and pesticide are caused of water pollution.
9. Water is very important. If you don't drink for four or five days, you will die.

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10. Wastewater control includes controlling of residential construction and expansion near river.
11. Water is the main component of the world. We can use fifty percent of water for our lives.
12. We can throw any foods into the river as much as we can. Fish and aquatic animals will eat up all the foods, which we throw away.
13. Wastewater is water that has not enough oxygen for fish to breath.
14. Presence of fireflies is an indicator of air and water quality.
15. If people upstream throw garbage and solid waste into the water, Samuthsongkram will be affected from water pollution problems.

Student's Perception of the Learning Packages

1) How did you learn this subject/topic?
2) Does the learning in this subject/topic differ from the others? How?
3) Could you tell me how do you feel when you study this subject/topic?
4) Are these activities interesting? Why?
5) What activities did you like? Why?
6) Can you tell me what you love in this subject/topic?
7) Can you tell me what you not like in this subject/topic?
8) Did this subject/topic stimulate you to think?
9) Did the teacher help you to learn?
10) Did the teacher encourage you to learn? Why?
11) What would you like to learn from this subject/topic?
12) What have you learnt from this subject/topic? Please explain.

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APPENDIX C
INTERVIEW QUESTIONS
FOR TEACHERS

Objective: To obtain information regarding the teachers' perception of the learning packages

Background

1) What is your name?
2) At what grade do you teach?
3) How long have you been teaching at your school?
4) Have you taught at other schools?
5) How long have you taught at other schools (for each of the other schools)?
6) What subjects have you taught?
7) How long have you taught XXX (for each of the subjects)?
8) What is your main role in your present school?
9) Have you had other roles in your school?
10) Have you had other roles in other schools or organizations?
11) How are you involved in environmental education programs?
12) What subjects or areas are you interested in?

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Teacher's Perception toward Developed Learning Packages

1) Does the learning in this subject/topic differ from the others? How?
2) Could you tell me how do you feel when you teach this subject/topic?
3) Are these activities interesting? Why?
4) What activities did you like? Why?
5) Can you tell me what the things that you love in this subject/topic?
6) Can you tell me what the things that you not like in this subject/topic? How it will be improved?
7) What are some difficulties have you identified in this subject/topic?
8) What you have learnt from this subject/topic? Please explain.

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APPENDIX D
OBSERVATION PROTOCOL

Observation Aims:

1) To investigate local context and environment both in classroom and out of classroom
2) To define the actual activities employed in the learning packages

Observation Guidelines

School …… **Observer** …….

Teacher …….. **Grade** ….…….

Date…. …….. **Class period** ……

Time begin …… **Time finish** …….

Contexts:

1) What are teacher's activities?
2) What are students' activities?
3) What are community people activities?
4) What technology and materials are used by teacher, students or community people?
5) Attach written documents (lesson plan, handouts, notebook, reports, and related documents)
6) Video tapes and digital images

Notes for observer:

- Describe the range and nature of activities that occurred.
- Report dialogue/behaviors that illustrate in class/out of class.
- Describe teacher/community people moves that appear to have affected teaching and learning process.
- Provide relevant information you have encountered about the lessons surrounding the one observed.
- Identify possible impacts of observer being present on teacher or students.

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