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A Firefly Learning Module for Environmental Sustainable Development in Samutsongkhram Province, Thailand

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Abstract
A firefly learning module for the sustainable development was developed for Thai secondary school students in the study province. A deeper connection between environment, social and economic dimensions, which lies at the core of sustainability, became the key issue for this learning module. Also an important dimension of the module was the empowerment of the students themselves. Through brainstorming and ensuring activities, students were expected to act at the local level and to develop a deeper sense of responsibility. This study aimed at to develop learning module based on both the principle of inquiry approaches and the collaboration of a community of learners. Mixed methods paradigm was employed for data collection and analysis. Four data collection techniques: classroom observations, interviews, written documents, and questionnaire were employed. The Statistical Package for the Social Sciences was applied for quantitative data analysis. The qualitative data were analyzed using open and axial coding techniques. The analyzed data were categorized to describe context of developed learning module, the students' conceptual understanding, and awareness toward ecosystems and firefly conservation. The study involved one-9th grade class of twenty students from one school in Samutsongkhram Province, Thailand. The results indicated that the developed learning module improved students' conceptual understanding, perceptions, and self-reported behavior toward ecosystems and firefly conservation. The results of the effectiveness of this learning module clearly showed that the students gained significantly higher score in conceptual understanding and perceptions after participating in this learning module. The results from interviews showed that the students changed from a poor to a very good level of understanding after involvement in this learning module. The results also indicated that none of the students remained at the poor level after participating in this learning module. Students' perspective toward the developed learning module revealed that most students were happy with the several educational activities and multi-tasks of the module. The results from teachers' interviews showed that all of them had positive attitudes about the learning module.

Keywords: Learning module, firefly, sustainable development, K-12 environmental education, mixed-method, sense of responsibility

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Introduction

Education deals with what students know and can do and how they interact with others and what they will face in the world (Drake, 1998). The educational system has to develop not only academic and life skills, but also moral, social and personal development. The methods of instruction as well as the curriculum content have been changing with the times, reflecting cultural, social, and economic values and needs of communities. For example, environmental educators should pay attention on the wandering the fields and river when dealing with sense of place or sensitivity ideas (Hungerford, 2006). Moreover, educators need to work to accommodate the changing role of environment in lives.

Environmental education (EE) is gaining popularity across the globe including Thailand. It can open the students' minds to the natural existence and develop their senses of responsibility and of self dependence. It also trains them to respect the resources of the earth, as well as teaches them the obligations of citizenship. In addition, the philosophy behind environmental education is actually a combination of the philosophies behind experiential education, ecological literacy, and environmental awareness (Subramaniam, 2002). It involves teaching children through personal discovery in a natural setting, where they learn ecological principles that govern all life, as well as develop a sense of connection with the land.

Environmental education (EE) has been implemented in schools' curriculum since the past three decades, with many different forms and varieties of teaching strategies. Most environmental education for K-12 students occurs in the classroom; while teachers, curriculum designers, and researchers often neglect the outdoor learning setting (Orion & Hofstein, 1994). Development of knowledge and attitudes among the children is an important issue for environmental educators. They need to develop the environmental literacy to think about the system and promote the awareness from knowledge to actions. Nevertheless, EE is still inadequate, relatively inconsistent, and scattered in curriculum (Hungerford & Volk, 2003). EE has taken place in many venues apart from the formal school curriculum i.e., non-formal education for children, youth and adults. Orr (1992) has proposed that EE will be ineffective in advancing its own goal of creating an environmentally or ecologically literate citizenry if it continues to restrict itself within the norms of general education. The socio-economic, politics, and deeper cultural aspects of the ecological problem cannot be neglected if EE were to be effective.

During the last two decades, several research works on the connections between schooling and the global ecological crisis have been 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. For example, the study of the educational framework for vocational education which aimed to assist educators in restructuring their current practices to promote environmental stewardship revealed the challenges on teacher training in environmental concepts and teaching strategies (Arenas, 2004). A ramification of

this literature is the connection between environmental perceptions and behaviors with environmental education programs in school systems.

In many Asian countries, including Thailand, EE is 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 (Bhandari & Abe, 2000). Therefore, EE is undergoing a reorientation away from learning in the classroom toward learning by doing outside classroom. The most efficient and effective way of solving environmental problems is to raise awareness, especially among the young. This is an important role of environmental educator to promote not only environmental awareness but also change attitudes or behaviors (Hungerford & Volk, 1990). 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 EE in Thailand has been conducted using the traditional top-down approach of teacher-centered instruction. Thus there is a need for more appropriate teaching-learning method.

In light of the above, learning modules on ecosystems were developed to encourage students to learn through the scientific inquiry process: asking questions, analyzing data, reasoning, and formulating evidenced-based explanations. This learning module was designed to accommodate the practical limitations of time and cost. The firefly has contributed to the rapid development in tourism in the Samutsongkhram province because tourists of many home-stays have supplemented the community income with tourism-related activities, especially, by visiting the firefly habitat by motorboats. Increasingly this activity now annoys the villagers. The latter have begun to destroy some of the firefly habitat the "lumpu" trees (*Sonneratia caseolaris*) nearby. Therefore, fireflies and their habitats were chosen as a model in this study because it is not easily to understand without participation in real-life situations. This learning module 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).

The developed learning module in this study was based on the collaboration of community of learners that included supervisors, local teachers, community members, environmental educators, scientists, and science educators from university according to Wenger's theory (1998). The theory of communities of practice is based on imparting "learning as social participation which is not just local events engagements but to a more encompassing process of being active participants in the "practice" of social communities and constructing "identities" in relation to these communities". This learning module should be an educational material for a sustainable development. Moreover, this learning module would make teaching and learning the most powerful instruments for bringing about the changes required to succeed at sustainable development.

In response to the challenges as mentioned above, this study aimed at developing the learning module to enhance knowledge and promote awareness toward firefly conservation, and promote students' behaviors for firefly's habitats and their ecosystems. This learning module was designed based on the inquiry approach, scientific investigation, and community-based principle. This study also concerned the impacts of the newly developed learning module on pedagogic practices and students' performance.

An inquiry approach was applied in the learning module's development and implementation. These are the learning module to learn about, in, and for environment, as suggested by Lucas (1979). This learning module is integrated the knowledge learned from school together with the knowledge gained from outside school. Through these learning modules, students will hopefully develop the suitable actions for their ecosystems.

This study attempted to develop learning module based on both the principle of inquiry approaches and the collaboration of a community of learners. In the learning module the students are made to 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.

Objectives

The objectives of this study were as follow.

1. To develop the firefly learning module for environmentally responsible and sustainable choices for lower secondary school students to improve their conceptual understanding on ecosystems, and awareness of ecosystems and firefly conservation.
2. To investigate the effectiveness of the learning module on students' achievement and perceptions.

Research Questions

Based on the objectives, the study addressed the following research questions:

1. Can the newly developed learning module promote lower secondary school students' conceptual understanding on firefly conservation and their local ecosystems?
2. How do lower secondary school students perceive the learning module based on their experiences of the educational activities?
3. Do students become more aware of ecosystems and firefly after exposure to the learning module?
4. Is there any change in students' behavior firefly conservation and their local ecosystems?

Methodology

The firefly learning module with different approaches was developed as a semester-long community-based learning module which involved the collaborative efforts of supervisors, local teachers, community members, local sages, and science educators from Mahidol University. The learning module which was developed for lower secondary school students was implemented through a variety of hands-on activities, the self-learning computer assisted instruction about firefly, extra-time exercises, and field trips.

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

Based on the theoretical concepts of mixed-methods and triangulation, the researchers employed four data collection techniques: qualitative- (1) classroom observations, (2) interviews, (3) written documents and (4) quantitative - questionnaire to gather data for the study (Patton, 1990).

During the semester-long implementation of the firefly learning module, the researchers designed the schedule for pre-test and post-test questionnaires and classroom observations. The written documents including course syllabus, teaching materials, fieldtrip reports, and student's works were collected. The interviews were also conducted as data collection. 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 module, the students' conceptual understanding and awareness toward ecosystems and firefly conservation.

Development of Firefly Learning Module

Development of firefly learning module was implemented in following sections.

Development of Content

A firefly learning module 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 learning module aimed to provide opportunities for students to learn, understand, and become aware of firefly conservation and their local ecosystems, and then take actions on firefly conservation and their habitats. The local ecosystems in Muang District Samutsongkharm province, Thailand were used as learning sites. The development of learning module comprised two main phases: brainstorming for contents of the program, and construction of the program.

Brainstorming for the contents of the instruction

The scope of the learning module 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. 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 learning module derived from brainstorming were designed to be consistent to the National Science Curriculum Standards (IPST, 2001: NRC, 2000).

Construction of the firefly learning module

After agreement on the content, the lesson plans for the instruction and self-learning computer-assisted instruction were designed and developed. These were done through four focus group meetings composed of a supervisor from ESAO, a local school teacher, 2 local sages, two science educators, and an environmental educator. The local teacher who was involved in the study used the knowledge and skills acquired from teacher training workshops as well as opinions from focus group meetings to generate the lesson plans under researchers supervision. 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.

The developed lesson plans of firefly learning module was assessed for content validity by three experts and three teachers, and revised according to their comments. Before firefly learning module implementation, a pilot trial was conducted in lower secondary school with 10 students in 8th-grade.

Development of the self-learning computer-assisted instruction about firefly

While construction of the firefly learning module, the self-learning computer-assisted instruction about firefly was also developed to be used in this learning module. The 5Es model, derived from constructivist consideration (Bybee, 2003), was applied for the self-learning computer-assisted instruction. The first step was engagement, by stimulating questions in each topic to encourage students to explore the knowledge on firefly. In the second step on exploration, the students explored and verified their own knowledge through the content of the self-learning computer-assisted instruction about firefly. The following step on explanation provided them with opportunities to integrate knowledge to answer formative questions and exercises. The elaboration step is the closure for retention of information and concept as well as to move the student toward application of what they have learned. In the final step is on evaluation that occurs in all four parts of the learning cycle, the students were encouraged to assess their understandings by doing exercises at the end of each topic. The reflection of learning is the abilities of the learners to construct their own knowledge and to develop the suitable actions for their ecosystems.

The developed self-learning computer-assisted instruction about firefly has been assessed for content validity and graphic appropriation by three experts including a science and technology educator, graphical expertise, and a science teacher. The self-learning computer-assisted instruction about firefly was revised according to their comments and suggestions. Before firefly learning module implementation, a pilot trial was conducted in lower secondary school students with 10 8th-garde students.

a) Learning module Components

A firefly learning module 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, learning through the self-learning computer-assisted instruction about firefly, and the evaluation of students' conceptual understanding of ecosystems and awareness toward ecosystems and firefly conservation.

Investigation of the Effects of the Firefly Learning Module

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, firefly and firefly conservation, questionnaire on perceptions and self-reported behaviors toward firefly conservation. The data were collected both before and after participation in the learning module. In addition, the written documents on concept maps, reports, and classroom observations were also used.

Data collection

Questionnaire, adapted from Musser and Malkus's (1994), were used to obtain information on knowledge, perceptions, and self-reported behaviors toward ecosystems, firefly, and firefly conservation 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 0.83 and 0.85 and the reliabilities were 0.85 and 0.87, respectively.

Ten randomly selected students were interviewed on conceptual understanding of the ecosystems and perceptions on local ecosystems and firefly conservation 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 (1990; 1998).

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

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 questionnaires were collected, coded, and analyzed. The significance at $p < 0.05$ was used for mean separation and comparing the students' awareness toward ecosystems and firefly conservation before and after participating in the learning module.

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

Analysis of written documents: 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.

Results

Learning Module Overview

The activities of firefly learning module were designed as a 15 two-period unit and self learning using the self-learning computer-assisted instruction about firefly. The 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 learning module composes of unit overview, learning objectives, instructional materials, activities, and assessment of students' conceptual understanding and awareness toward ecosystems and firefly conservation. The activities were 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 learning module.

Instructional materials

The instructional materials in this curriculum were textbooks, students worksheets, the self-learning computer-assisted instruction about firefly, test kits for measuring chemical properties of water (pH, dissolved-oxygen, nitrate, ammonia), and equipments for measuring firefly population, habitats, and distribution. The self-learning computer-assisted instruction about firefly composes of the introduction (get to know firefly), firefly and lighting, how firefly lives, interesting firefly, firefly profits and conservation. Each topic provides students with opportunity to learn about firefly. Figure 1-3 show some screens of the self-learning computer-assisted instruction about firefly.

Figure 1: Topics of the self-learning computer-assisted instruction about firefly

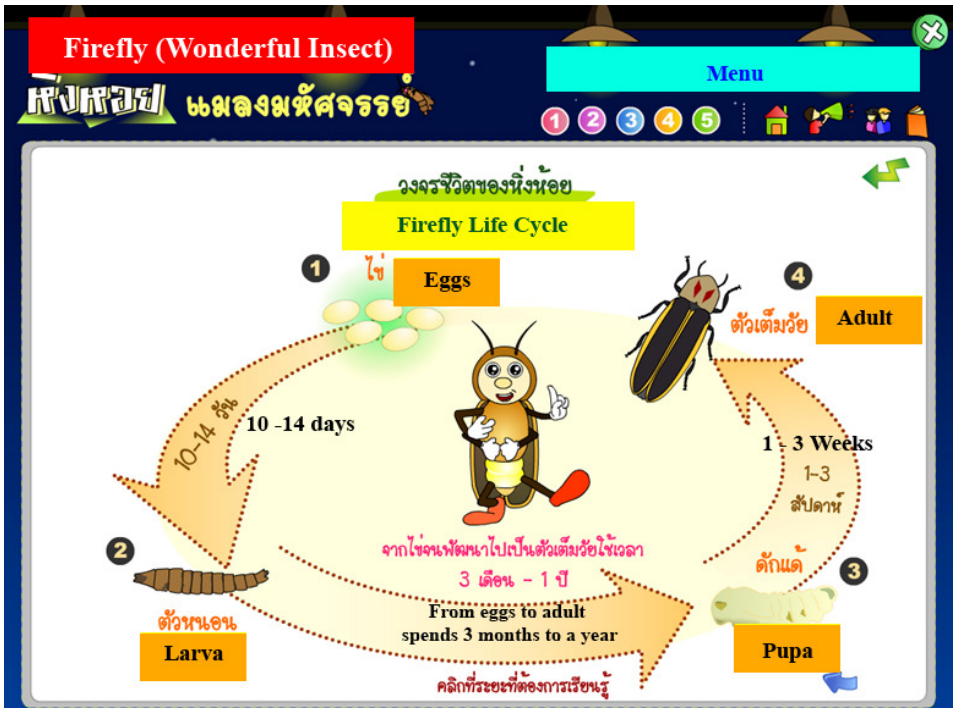

Figure 2: Firefly Life Cycle

Figure 3: Ways to Conserve Firefly

Implementation of Firefly Learning Module

The teaching-learning activities were conducted following the developed lesson plans (Table 1). The study involved one-9th grade class of twenty students from one school in Samutsongkhram Province, about 500 meters from the canal. The students' achievements are at the low level (GPA 2.35 ± 0.23 (on a standard 4.0 grading system). All participants are completely volunteers and anonymous, and they are free to withdraw from the program at anytime. For ethics and respect for human rights, the participants' names were given pseudonym. The details of actual educational activities of a Firefly Learning Module 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 ecosystems and firefly and its importance. The students were encouraged to discuss and draw conclusion by themselves. Then, a lecture on local ecosystems and firefly 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 the environment of local ecosystems and firefly tourism under teacher's guidance. The topics of the student's reports were species and number of plants in local

ecosystems, species and number of fireflies in local ecosystems, species and number of mollusks in local ecosystems, physical and chemical properties of water resources, and 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.

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 firefly, the relations of firefly and ecosystems, firefly conservation methods, tourism on firefly and 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). Four field trips within three months were conducted. During field trip, each group of students observed and recorded the data 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. The surveying of tourists and local community people were conducted to study about firefly tourism and management.

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 consulted local sages, experts, and used other resources including additional books, textbooks, journals, the self-learning computer-assisted instruction about firefly, and websites. During this activity, teacher encouraged and facilitated students to discuss and share their ideas among group members. The students also discussed the possible actions that should be done for taking care of the local ecosystems and firefly.

Evaluation. At the end of the learning module, students displayed their work as posters, reports etc in front of the class which were subsequently presented at exhibition organized by the research team. The students and teachers from other schools, local sages, district educators, and local people were invited to attend this exhibition.

Table 1: Teaching-learning Activities

Scope of contents	Teaching-learning Activities	Week	Time (hours)
1. Our Ecosystems	- Brainstorm about the 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. Firefly status	- Work in group of five or six on the worksheet "Firefly Status in Samutsongkhram"	2nd	2

Scope of contents	Teaching-learning Activities	Week	Time (hours)
	- Discuss and compare the situation in the past and present in group then share in class		
3. Environmental problems and actions	- Watch video about "Firefly" - Work as pair and discuss on questions "What is (are) environmental problems on firefly?" - Present to class - Discuss and summarize the lesson learned	3rd – 4th	4
4. Environmental problems and actions	- Lecture by Local Sages on local ecosystems and firefly conservation - Discuss and summarize the lesson and present to the class	5th	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 firefly habitat and status under teacher's supervision - Present their own plans to the class - Generate the schedule for field trips and report the progress	6th	2
6. Explorer 2	- Learn how to use basic equipments for explore firefly habitat and status in class and schoolyard	7th	2
7. Learning with local sages 1	- Lecture by local sages on firefly and conservation - 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 Firefly Exploration in community	Three field trips for investigating the firefly habitat, ecosystems, and status	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 firefly conservation	15th	2
16. Exhibition	- Students presented their results to local community	16th	2

Note: During the semester, students learn the concepts of firefly using self-learning computer-assisted instruction about firefly

The Effects of the Firefly Learning Module

The effects of the firefly learning module were evaluated by various data sources: questionnaires (pre-test and post-test), four true-false questions, interviews on conceptual understanding of ecosystems and firefly conservation. 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.

Students' conceptual understanding

The conceptual understanding of local ecosystems and firefly conservation was analyzed using true-false questions, concept maps, reports, and interviews both before and after learning module participation.

Table 2: Pre-test and Post-test Analysis of Students' Conceptual Understanding of Ecosystems and Firefly Conservation by Using the Four True-false Questions (n=20)

Item	Pre – test* Correct answer (%)	Post – test * Correct Answer (%)
Q1: Components of river ecosystems are only animals and plants.	2.2	70.0
Q2: Firefly eats the leaves and mollusks.	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, fireflies will have more food for living.	67.8	92.0

Pre-test and Post-test

An analysis of the pre-test and post-test four true-false questions is shown in Table 2 as percentage of correct answers. For the pre-test, 2.2% of twenty students gave correct answer about components of the ecosystems: animals and plants were mentioned (Q1). Twenty percent (20.6%) of students gave the correct answer about firefly's roles in ecosystems (Q2). The 22.5% of students who provided correct answer Q3 shows that students overlooked the relationship among components of ecosystems. However, 67.8% of students gave the correct answer to Q4 about firefly tourism and conservation. 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 correct answers between pre-test (M=1.09, SE=.064) and post-test (M=2.65, SE=.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 the firefly learning module.

Table 3: Pre- and Post-test Scores of Students' Conceptual Understanding of Local Ecosystems and Firefly by using the 15-true-false Questions

Item	% Correct answers*		Difference	*p*
	Pre-test	Post-test		
Q1: Water pollution problems in our area are caused by industries more than communities.	15	80	+65	**
Q2: Water quality can be improved if people have enough knowledge.	60	75	+15	-
Q3: Produce the souvenir from firefly is a good idea for firefly tourism.	30	40	+10	-
Q4: Drain the wastewater directly into the river will help aquatic animals' growth due to increase of nutrient.	30	50	+20	-
Q5: Throwing garbage into the river is not a cause of water pollution.	40	55	+15	-
Q6: Firefly tourism does not affect the ecosystems and water quality.	55	60	+5	-
Q7: If we put more chlorine into tab water, water quality will increase.	65	65	0	-
Q8: The increasing of tourists is a cause of environmental degradation.	40	50	+10	-
Q9: Using long-tail boats for firefly tourism is not good for the environment.	55	65	+10	-
Q10: Avoiding resorts or home stay construction and expansion near river is one of the methods for wastewater control.	55	75	+20	**
Q11: There are fifty percents of water in the world for human living.	35	75	+40	**
Q12: We can throw any foods into the river as much as we can because aquatic animals can eat them all.	5	95	+90	**
Q13: Wastewater means the water that does not have enough oxygen for fish to breath.	0	85	+85	**
Q14: Firefly is an indicator of water quality.	60	95	+35	**
Q15: If people living upstream throw the garbage into the river, our environment will be affected.	35	100	+65	**

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

** $p<.01$

Table 3 shows percentage of correct answers, difference, and statistically significant results of paired t tests comparing pre- and post- assessment of 15-true-false 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. Sixty-five percent increases was observed in pre and post test of both questions 1 and 15 thus suggesting that students had clearer understanding of the relationship between community, industrial activities and water pollution.

Table 4: Number of Students at Different Category from Interview I and Interview II of the Ten Randomly Selected Students

Topics	Category*	Number of students (%)	
		Interview I	Interview II
1. Structure of ecosystems	1	6 (60%)	0
	2	4 (40%)	7 (70%)
	3	0	3 (30%)
2. Recognition of firefly's roles in the ecosystems	1	7 (70%)	0
	2	2 (20%)	7 (70%)
	3	1 (10%)	3 (30%)
3.Activities of firefly conservation	1	6 (60%)	0
	2	3 (30%)	6 (60%)
	3	1 (10%)	4 (40%)
4. Tourist's roles to conserve the ecosystems	1	8 (80%)	0
	2	2 (20%)	7 (70%)
	3	0	3 (30%)
5. Student's roles for firefly conservation	1	8 (80%)	0
	2	2 (20%)	7 (70%)
	3	0	3 (30%)

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

Interviews

The interview results as shown in Table 4 concerning ecosystems and firefly conservation indicate that 60% of students changed from poor level to very good level of understanding after participating in the learning module. Similar changes were observed on the other two topics on relationships among the firefly tourism, firefly conservation, and roles in firefly conservation, 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 module.

Concept Maps

The results on concept map of students on ecosystems and firefly conservation were significantly different after participating in this learning module. The holistic scoring rubrics increased from 24.8 to 56.5 from 60 points. The overall results indicated that students gained much better conceptual understanding on ecosystems and firefly conservation in several aspects indicating that most students achieved the objectives of the learning module.

Results from group of students' concept maps on the ecosystems and firefly conservation were used for probing further the students' conceptual understanding of ecosystems and firefly conservation. Almost half of the group (47%)were categorized at the good level indicating that students understood the overall concepts of ecosystems and firefly conservation but still had a few errors in

relationship between the concepts. About 25% of students were in the excellent level indicating ability to understand the whole concepts and have a clear picture of realtionship between the relevant concepts. 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 incorrect links. However, 8% of students were scored at the fair level of understanding after participating in the learning module.

The analysis of group reports using scoring rubrics of the six components shows thatthe highest average score were in the scope of study (3.75) and results (3.75) while the lowest score were in the title and introduction (2.51). Other components of 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 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 resources provided. 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.

Students' Awareness toward Ecosystems and Firefly Conservation

The students' awareness toward ecosystems and firefly conservation before and after participating in this learning module indicated that there were significant increases in students' awareness in all 15 items tested. The means increased from 36.85 to 54.30. The overall results indicated that students behaved much better toward ecosystems and firefly conservation in all aspects.

Table 5: Students' Awareness toward Ecosystems and Firefly Conservation before and after Participation in the Program

Items	Before	After	Different	*p*
1. Tourism is a cause of wastewater problem.	1.85	4.20	2.35	**
2. Water pollution affects the firefly tourism.	1.80	3.65	1.85	**
3. My family and I have ever saved the firefly.	2.90	3.85	0.95	**
4. Take care the water resources can help firefly to live longer and reproduce more fireflies.	2.45	3.55	1.10	**
5. To improve water quality is a waste of time.	2.85	3.95	1.10	**
6. Everyone should be responsible for water quality and firefly conservation.	2.70	3.60	0.90	*
7. Firefly will not be extinct because there have a lot of firefly in the community.	2.70	3.85	1.15	**
8. Government should have strict regulations for punishment of the environmental destroying people.	2.75	3.95	1.20	**
9. Local people should do something for environmental and firefly conservation.	2.30	3.55	1.25	**
10. Monitoring of changes in environmental and firefly	2.65	4.05	1.40	**

Items	Before	After	Different	*p*
population is the responsibility of the government officials not the citizen.				
11. Law abandon is related to environmental problems.	2.20	3.55	1.35	**
12. We have to take care of the firefly as soon as possible.	2.75	4.15	1.40	**
13. We should educate children and people about environmental problems and firefly conservation.	2.90	3.70	0.80	*
14. Local community should be continuously involved in environmental problem solving and firefly conservation.	2.85	4.25	1.40	**
15. Disseminating knowledge on environmental awareness is a good strategy for protecting environment.	3.40	4.00	0.60	*
Total	36.85	54.30	17.45	**

Note: 5-point Likert scale ranging from strongly agree (score 5) to strongly disagree (score 1), * p <.05 ** p < .01

Table 5 presents statistically significant results of paired t tests comparing pre- and post-assessment of 15-Likert Scale questions. The 20 participants had an average difference from pre-test to post-test awareness scores of 17.45 (SD = 4.27), indicating the participating in the program resulted in a highly significant increase in awareness levels, $t(19) = -18.262$, $p = .001$ (one-tailed).

After participating in this program, the responses indicate that the twenty students more aware on the ecosystems and firefly conservation. The excerpts showed that students realize the important of ecosystems and firefly, they also indicated that they aware about their activities which will not disturb the firefly. The interviewing results from ten students also revealed that students' awareness changed toward a good level after participation in this learning module. The excerpts taken from interviews showed students' awareness toward ecosystems and firefly conservation as following.

> Student#2: "… *I have ever killed the firefly larva because I didn't know what it looks like. After learning about firefly's life cycle, I am very happy because I kept two of them. I promise I will not kill them anymore …*"
> Student#5: "… *I told my parents what I have learned from school. We have to care and cure our environment and firefly …*"

Students' Self-Reported Behaviors toward Ecosystems and Firefly Conservation

The results on self-reported behaviors toward ecosystems and firefly conservation were significantly higher after enrolling in the learning module. The means increased from 33.7 to 58.2. However, there were no significant changes in score of two items (items 9 and 14) between before and after participation in the learning module. The overall results as shown in Table 6 indicated that students behaved much better toward ecosystems and firefly management in several aspects.

Table 6: Students Self-reported Behaviors toward Ecosystems and Firefly Conservation 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	**
2. Clean the road by sweeping the garbage into the canal.	2.75	4.20	1.45	**
3. Keep the larva of firefly	2.80	4.05	1.25	**
4. Participate in the conservation programs.	2.60	3.65	1.05	**
5. While brushing the teeth, turn off tap water.	2.70	4.70	2.00	**
6. Tell the parents about firefly life cycle.	2.20	4.05	1.85	**
7. Write the board for the tourist about eco-tourism.	1.75	3.25	1.50	**
8. Consider water level in the utensil during dishes washing.	2.35	3.65	1.30	**
9. Don't throw garbage into the canal.	2.55	2.90	0.35	-
10. Don't pour wastewater after clothes washing into the river.	2.05	3.10	1.05	**
11. Inform government officials, when you see someone destroy water quality and firefly.	2.90	4.55	1.65	**
12. You help people in firefly conservation.	3.00	3.75	0.75	*
13. You are willing to join the environmental conservation projects.	2.45	3.70	1.25	**
14. Help communities in cleaning the water resources and communities.	2.65	3.15	0.50	-
15. You have joined the project on cleaning water resources.	2.70	3.40	0.70	*
Total	33.70	58.20	17.50	**

Note: 5-point Likert scale ranging from always (score 5) to never (score 1)
* p <.05 ** p < .01

Table 6 presents statistically significant results of paired t tests comparing pre- and post- assessment of 15-Likert Scale questions. The 20 participants had an average difference from pre-test to post-test self-reported behaviors scores of 17.50 (SD = 9.13), indicating the participating in the program resulted in a highly significant increase in self-reported behaviors levels, $t(19) = -8.563$, $p = .001$ (one-tailed).

After participating in this learning module, the responses indicate that the twenty students more behave on the ecosystems and firefly conservation. The excerpts also showed that students have done something for ecosystems and firefly conservation. The interviewing results from ten students also revealed that students' behaviors changed toward a good level after participation in this learning module. The excerpts taken from interviews showed students' awareness toward ecosystems and firefly conservation as following.

> Student#7: "*... Before I participated in this program, I don't want to participate in any conservation campaign. But after learning about firefly and ecosystems, I would like to do something for our ecosystems …*"

> Student#9: "… *I posted the signboard at the backyard for telling the tourists to conserve the river and fireflies …"*

Students' Perspectives on the Learning Module

The students' perspectives on the learning module revealed that most students were happy with the several educational activities and multi-tasks of the learning module. 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.

Surprisingly, all randomized ten students had positive feedbacks toward the learning module. The following are excerpts from the interviews and self-reflection journal toward the learning module and teacher.

> Student#3: "…*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#4: "…*I love to learn from the firefly CAI, I like the pictures…"*
> 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 …"*
> Student#9: "…*I don't like to learn from the textbooks, I love these activities…"*

However, there were some drawbacks about the learning module. The main obstacles were time consuming and budget constraints. Another problem was in students themselves, most of them lack the 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 field 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 learning module in their schools. The two local sages and other community people were satisfied with the program and expressed their willingness for further supports.

Teachers' Perspectives toward the Learning Module

Interviews with the three teachers after implementation of the unit showed that all of them had positive views about the learning module. They mentioned that this learning module is very different from the traditional lesson plan and is very encouraging. They were impressed by the activities and instructional materials that stimulated students to explore and manipulate data and to construct the concept of

interrelationships within the ecosystems and firefly conservation by working in group. They stated that the learning module was suitable for the lower secondary classes especially for schools which have similar circumstances. They expressed their willingness to continue using this learning module in their classes and it should not pose any problem to their colleagues in implementing it.

Conclusions

The Firefly Learning Module improved students' conceptual understanding, perceptions and self-reported toward ecosystems and firefly conservation. The results of the effectiveness of this learning module clearly showed that the students gained significantly higher score in conceptual understanding and perceptions after participating in this learning module. The results from interviews showed that the students changed from a poor to a very good level of understanding after involvement in this learning module. The results also indicated that none of the students remained at the poor level after participating in this learning module. Students' perspective toward the Firefly Learning Module revealed that most students were happy with the several educational activities and multi-tasks of the module. The results from teachers' interviews showed that all of them had positive attitudes about the learning module.

Discussion

The Firefly Learning Module was developed through collaboration among community members both in and outside the school context. This learning module can be seen as a mean for situated learning based on participation and interaction among communities. 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.

This learning module involved asking guiding questions to direct students' investigations and field trip exploration, students learned about firefly through self-learning computer-assisted instruction, students gathered the data and analyzed the data according to their plans, students interpreted the data and construction their poster to present to the public at the end of semester. In this learning module, 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 and behaviors on ecosystems and firefly conservation (Ausubel, 2000). This present study is also accordance with several previous findings that guided-inquiry approach which indicated as an valuable tool for teaching (Woods, 1989; Kolb, 1984; Beyer, 1979; NRC, 2000).

This learning module is similar to several other studies (Gatt *et al*., 2007; Beyer, 1979) 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 (Kolb, 1984; Beyer, 1979).

The students fulfilled the five-step activities of learning module which is "guided-inquiry approach" (Beyer, 1979: NRC, 2000). The students have gone through the process of inquiry since students should be able to do science, produce the meaningful explanation, and connect to the natural world. This study is in accordance with several studies that guided-inquiry approach is valuable for teaching complex topics (Woods, 1989; Kolb, 1984; Beyer, 1979; NRC, 2000). In this study, the students accomplished the specific learning objectives of the learning module as reflection the abilities in manipulating data, generating questions, and communicating, discussing, and generating explanations to the public according to Beyer (1979) and NRC (2000) concepts. This present study also confirmes that the inquiry approach helps students to learn the concept using the guided questions and data (Duit & Glynn, 1996) and provides the opportunity for sharing the experiences to others, and passing the ideas to the other in group discussion process (Gilbert & Priest, 1997).

Results from students' perception both from the questionnaire and interviews suggested that this learning module revealed that is one of the effective means for learning about ecosystems and firefly conservation. 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 and firefly conservation concepts. However, the students had less positive attitude toward teacher support when compared to the group activities (Lucas, 1979). This is not surprising since it is well established that students claim to learn from peers more than from teacher. About 15% of the students seemed not to like this kind of learning environment, not even guided-inquiry; they were more comfortable with the old way of spoon-feeding without having to think or express them. The students did not realize that they could not gain knowledge on environmental changes just from lecture and textbooks according to the study by Bureekul and Brown (2003) and Balster *et al*. (2001). The teachers had positive attitude toward this learning module (interviewing results). They were willing to try this learning module in their schools, with large numbers of students and limitation of time, especially, with the underprivileged students of rather low scholastic achievement.

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 according to Hungerford and Volk (1990). We hope this present study will inspire more teachers to adapt and adopt the similar activities in the schools.

The community members in this study have experienced the community of learning. This study has also shown the important of learning cycle through inquiry process learn through the scientific inquiry process: asking questions, analyzing data, reasoning, and formulating evidenced-based explanations. This learning module gave students a chance 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 in this study 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 according to Hungerford and Volk (1990).

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 according to Musser and Malkus (1994), Wenger (1998), and Tompkins (2005).

In this learning module, 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; Tompkins, 2005).

The statistical analyses of the pre- and post-test on students' perceptions and self-reported behaviors toward ecosystems and firefly conservation 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 module on ecosystems and firefly conservation (Wenger, 1998; Arenas, 2004; Bowers, 1992; Hungerford & Volk, 1990; Gruenewald, 2003). 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. The results of this study are also corroborated by the concepts in the studies of Orion and Hofstein (1994) and Sobel (1996).

In this study, some of the factors that may facilitate the learning on local ecosystems and firefly have been highlighted. Several activities influenced the students to initiate discussion both inside and outside the classroom. The hands-on activities such as 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 issues. 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 firefly conservation issues related to tourism in the local ecosystems as illustrated in this study helps the students to learn and make the connections with the real world according to the studies of Tompkins (2005). In addition, this learning module also enhanced the students' sense of ownership (Sobel, 1996). Our findings reinforce the importance of including an action component in the learning module. 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 (1994) but is also likely to lead to meaningful and relevant discussions with community people regarding environmental issues and the need for community action (Orion & Hofstein, 1994; Sobel, 1996).

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 learning module is time-consuming and uses up resources in the form of time, money, and man-power. However, 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 module on ecosystems and firefly conservation 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).

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).

Throughout this learning module, students explored the local ecosystems composed the river hydrology and biology, tested water quality, firefly study using assisted instruction about firefly, and calculated a standard water quality, identified plants and fireflies found in their local ecosystems. The learning module 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.

Educational Implications

Like most countries, environmental education is not taught as a distinct subject (Bhandari & Abe, 2000). The developed learning module 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 will inspire the teachers in others countries to change their learning style using local environment as lerning resources. 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 (Orion and Hofstein, 1994). 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 firefly tourism and management to conserve fireflies 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 module.

Results from this study on the advantages of the learning module should enable teachers to adopt them as part of the local curriculum as encouraged by the government. This study, however, still have some limitations such as the experiment was tried on one group of twenty 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.

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. This learning module can be a good supplement to teaching in the classroom to enhance students' understanding of the ecosystems and ecology concepts. This study could be an example or alternative for teachers and educators who will design the hands-on activities, learning units, learning module, and curricula in schools. This study shows the involvement of different extent collaborative efforts from local sages, teachers, science educators, science educational researchers, and other community members.

The development of learning module in this present study is an example for promoting environmental literacy and environmental education communities. However, this learning module was implemented in 9th grade class; the results indicated that this learning module can be continuing implement in the secondary school and the college educational level in Thailand and the other countries.

The results of this study also present the involvement of teaching children through personal discovery in a natural setting, where they learn ecological

principles that govern all life, as well as develop a sense of connection with the land for the young people.

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