THE DEVELOPMENT OF AN E-LEARNING MODULE ON SANDY SHORES ECOSYSTEM FOR MATHAYOMSUKSA 2 STUDENTS

A DISSERTATION

BY

ARCHAREE PUMMAWAN

Presented in Partial Fulfillment of the Requirements for the

Doctor of Education Degree in Science Education

at Srinakharinwirot University

May 2007

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การพัฒนาบทเรียนโมดูลอิเล็กทรอนิกส์ เรื่อง ระบบนิเวศหาดทราย
สำหรับนักเรียนชั้นมัธยมศึกษาปีที่ 2

บทคัดย่อ

ของ

อัจฉรีย์ ภุมวรรณ

เสนอต่อบัณฑิตวิทยาลัย มหาวิทยาลัยศรีนครินทรวิโรฒ เพื่อเป็นส่วนหนึ่งของการศึกษา

ตามหลักสูตรปริญญาการศึกษาดุษฎีบัณฑิต สาขาวิทยาศาสตรศึกษา

พฤษภาคม 2550

อัจฉรีย์ ภุมวรรณ. (2550). ***การพัฒนาบทเรียนโมดูลอิเล็กทรอนิกส์เรื่องระบบนิเวศหาดทรายสำหรับนักเรียนชั้นมัธยมศึกษาปีที่ 2***. ปริญญานิพนธ์. กศ.ด. (วิทยาศาสตรศึกษา). กรุงเทพฯ: บัณฑิตศึกษา มหาวิทยาลัยศรีนครินทรวิโรฒ คณะกรรมการควบคุม: ว่าที่ร้อยตรี ดร.มนัส บุญประกอบ, รองศาสตราจารย์สมจิต สวธนไพบูลย์, ผู้ช่วยศาสตราจารย์พิชาญ สว่างวงศ์.

การวิจัยครั้งนี้มีจุดมุ่งหมายเพื่อพัฒนาบทเรียนโมดูลอิเล็กทรอนิกส์เรื่อง ระบบนิเวศหาดทรายสำหรับนักเรียนชั้นมัธยมศึกษาปีที่ 2 การพัฒนาบทเรียนโมดูลอิเล็กทรอนิกส์ แบ่งออกเป็น 4 ขั้นตอน คือ ตอนที่ 1 ศึกษาและวิเคราะห์ข้อมูลพื้นฐาน ขั้นตอนที่ 2 พัฒนาบทเรียนโมดูลอิเล็กทรอนิกส์และหาค่าประสิทธิภาพ ขั้นตอนที่ 3 นำบทเรียนโมดูลอิเล็กทรอนิกส์ไปใช้ในการทดลองภาคสนาม และขั้นตอนที่ 4 การปรับปรุงบทเรียนโมดูลอิเล็กทรอนิกส์ การทดสอบนำร่องและการทดลองภาคสนามเริ่มตั้งแต่เดือนพฤศจิกายน-ธันวาคม 2549 กลุ่มตัวอย่างที่ได้จากการสุ่มแบบเจาะจงประกอบด้วย นักเรียนมัธยมศึกษาชั้นปีที่ 2 จำนวน 3 ห้อง ที่เรียนในภาคเรียนที่ 2 ปีการศึกษา 2549 โรงเรียนสุนทรภู่พิทยา อำเภอแกลง จังหวัดระยอง การวัดผลและประเมินผลนักเรียนที่ใช้บทเรียนโมดูลอิเล็กทรอนิกส์นี้แบ่งเป็น 3 ด้าน คือ ด้านผลสัมฤทธิ์ของนักเรียน ด้านทักษะทางเทคโนโลยีสารสนเทศและการสื่อสารและด้านเจตคติต่อสิ่งแวดล้อมหาดทราย

บทเรียนโมดูลอิเล็กทรอนิกส์ที่พัฒนาขึ้นบรรจุในซีดีรอม (CD-ROM) โดยใช้รูปแบบการสอน 5E (5E Instructional Model) บทเรียนโมดูลอิเล็กทรอนิกส์แบ่งเป็น 5 บท โดยมีเนื้อหาสอดคล้องกับมาตรฐานการเรียนรู้ในช่วงชั้นที่3 และสาระการเรียนรู้ที่ 2: ชีวิตและสิ่งแวดล้อม มาตรฐาน ว. 2.1 และมาตรฐาน ว. 2.2 เวลาที่ใช้ในการเรียนการสอนในแต่ละหน่วยการเรียนคือ 2 คาบเรียนหรือประมาณ 100 นาที หน่วยการเรียนมีทั้งสิ้น 10 หน่วยและแผนการศึกษา 8 แผน ซึ่งใช้เวลารวม 20 คาบเรียน

ผลการวิจัยพบว่าบทเรียนโมดูลอิเล็กทรอนิกส์เรื่องระบบนิเวศหาดทรายมีค่าประสิทธิภาพ (E_1/E_2) สูงกว่าเกณฑ์มาตรฐาน 80/80 ผลสัมฤทธิ์ทางการเรียนของนักเรียนและทักษะทางเทคโนโลยีสารสนเทศและการสื่อสารของกลุ่มตัวอย่างแต่ละกลุ่ม หลังจากใช้บทเรียนโมดูลอิเล็กทรอนิกส์เพิ่มขึ้นสูงกว่าระดับก่อนใช้บทเรียนโมดูลอิเล็กทรอนิกส์ อย่างมีนัยสำคัญทางสถิติที่ระดับ .05 ด้านเจตคติของนักเรียนที่มีต่อสิ่งแวดล้อมหาดทราย ในแต่ละกลุ่มตัวอย่างหลังใช้บทเรียนโมดูลอิเล็กทรอนิกส์ไม่สูงกว่าก่อนใช้บทเรียนโมดูลอิเล็กทรอนิกส์ นอกจากนี้ยังพบว่าผลสัมฤทธิ์ทางการเรียนและทักษะทางเทคโนโลยีสารสนเทศและการสื่อสารของนักเรียนหลังใช้บทเรียนโมดูลอิเล็กทรอนิกส์ไม่สัมพันธ์กับผลการเรียนวิชาวิทยาศาสตร์ รวมทั้งผลสัมฤทธิ์ทางการเรียนและทักษะทางเทคโนโลยีสารสนเทศและ การสื่อสารของนักเรียนในกลุ่มตัวอย่าง ทั้ง 3 กลุ่ม หลังใช้บทเรียนโมดูลอิเล็กทรอนิกส์ไม่แตกต่างกัน จากผลการวิจัยสรุปได้ว่าบทเรียนโมดูลอิเล็กทรอนิกส์ เรื่อง ระบบนิเวศหาดทรายที่ผู้วิจัยพัฒนาขึ้นมีประสิทธิภาพและสามารถนำไปใช้ได้กับนักเรียนมัธยมศึกษาชั้นปีที่ 2 เพื่อเสริมสร้างความสามารถด้านการรู้คิดและเพิ่มพูนทักษะทางเทคโนโลยีสารสนเทศและ การสื่อสารต่อไป

THE DEVELOPMENT OF AN E-LEARNING MODULE ON SANDY SHORES ECOSYSTEM FOR MATHAYOMSUKSA 2 STUDENTS

AN ABSTRACT

BY

ARCHAREE PUMMAWAN

Presented in Partial Fulfillment of the Requirements for the
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at Srinakharinwirot University
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Archaree Pummawan. (2007). ***The Development of an E-Learning Module on the Sandy Shores Ecosystem for Mathayomsuksa 2 Students***. Dissertation, Ed.D. (Science Education). Bangkok: Graduate School, Srinakharinwirot University. Advisor Committee: Acting Sub Lt. Dr. Manat Boonprakob, Assoc. Prof. Somchit Savathanaphaibul, Asst. Prof. Dr. Pichan Sawangwong.

The research objective was to develop an e-learning module on the Sandy Shores Ecosystem for Mathayomsuksa 2 Students. The module development was divided into four stages: Stage 1 Studying and analyzing basic information, Stage 2 Developing the e-learning module and investigating its efficiency, Stage 3 Test piloting the e-learning module, and Stage 4 Improving the e-learning module. The pilot testing ran from November to December, 2006. The sample groups, derived by means of purposive sampling, included three classes of Mathayomsuksa 2 students at Sunthonphu Pittaya Secondary School in Klang District, Rayong Province, studying in the second semester of the academic year 2006. The measurement and evaluation for the students had three parts: student achievement assessment, ICT skills assessment, assessment of attitudes towards the sandy shores environment.

The e-learning module was written on a CD-ROM. The 5E instructional model was the central model of learning in the module. The module's framework comprised of six lessons. The subject contents were defined in accordance with Learning Standards of Key Stage 3, and with the content specified in Substance 2: Life and Environment, Standard Sc 2.1 and Standard Sc. 2.2. The time spent for teaching and learning in each unit was two periods, or approximately 100 minutes. The total number of units was ten which covered eight study plans in twenty periods.

The results of the study indicated that the e-learning module revealed higher efficiency than the standard criterion set, which the E_1/E_2 was at 80/80. The students' academic achievement and ICT skills in each sample group after using the module were significantly higher than previously at the .05 level. On the other hand, the students' attitudes towards the sandy shores environment in each sample group after using the module were found to not be higher than previously. Their academic achievement and ICT skills after using the module were not related to their science learning outcomes. Their academic achievement and ICT skills, of the three sample groups after using the module were found to be no different. The research findings revealed that the e-learning module on the sandy shore ecosystem was effective and could be used for Mathayomsuksa 2 students, as one of the vehicles fostering the development of the cognitive abilities and ICT skills.

The dissertation titled

"The Development of an E-Learning Module on

Sandy Shores Ecosystem for Mathayomsuksa 2 Students"

by

Archaree Pummawan

has been approved by the Graduate School as partial fulfillment of the requirements for the Doctor of Education Degree in Science Education of Srinakharinwirot University.

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May 18, 2007

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CHAPTER 1

INTRODUCTION

Needs for the Study

Technological grown in our present era of globalization has spurred social and economic changes world wide. To prepare the younger people to keep pace with these changes, it is necessary to improve the national education curriculum.

The main problems facing the Thai education system have been identified as curricula, teacher quality, problems of students' learning, non-standardized educational criteria, and learning-teaching methods. (Curriculum and Instruction Development, Department. 2002: 3)

The results of the teaching and learning processes in Thailand are monitored by the Department of Curriculum and Instruction Development of the Ministry of Education, which researches curriculum development continuously. The present curriculum, now over 10 years old, is outdated is holding back the development of the knowledge–based society in Thailand. Most importantly, the old scientific curriculum cannot push Thailand to be a scientific leader, so it is necessary to improve teaching and learning processes for Thai people to better develop scientific skills and attitudes. (Curriculum and Instruction Development, Department. 2001: 1) This view is supported by Soitulum (2001: 34) who states that Thailand does not value science education and relies mainly on the memorization of material from text-books rather than getting students to develop their own ideas. As a result, students have found the study of science boring. The teaching and learning of science in Thai schools would be improved in terms of content, knowledge and scientific processes.

Science knowledge helps us understand about natural phenomena, which then can be applied to improving our quality of life, as well as in environmental and natural resources care and protection to maintain balance and sustainability. Furthermore, science knowledge is the source of a great deal technological development; and vice versa, technology plays a great role in the continual search for more advanced knowledge. This view is supported by Reynolds and Robertta (1996: 6-7) who state that technology could contribute to the learning process in three ways: 1) Technology motivates students in the affective domain as well as in the cognitive domain. 2) Technology empowers students to produce their own creative work. 3) Technology, provided fun and an area for exploration, experimentation, adventure, socialization, and honing skills. In fostering the strength of science knowledge, one of the main ingredients is to provide education to prepare us to live in advanced science and technology societies by becoming both efficient producers and users. (Institute of Promotion Science Teaching and Technology (IPST). 2003: 1)

Information technology (IT) is a combination of computer technology and communication. IT enables people to send and receive information from every corner of the world instantly, making the world borderless. To develop learners to be able to communicate through IT will enable the students to learn just about anything from any place and at any time. (IPST. 2003: 229)

Information and Communication Technology (ICT) is a diverse range of technologies, continually growing. For example, the growth of multimedia, the Internet, and the talking word processor, etc.. Each technology offers something unique and of interest to education. (Ratcliffe. 1998: 192) Ross; Lakin; & Callaghan (2002: 132) who stated that IT is a subject in its own right on the National Curriculum, whereas ICT is the name given to its application in learning.

Thailand has developed a master plan for ICT's usage in education for 2004-2006. There are four major strategies: 1) The use of ICT to improve teaching and learning. 2) The use of ICT to enhance the effectiveness of educational management and services. 3) Personnel training and developing. 4) ICT equipment provisioning and distribution at all educational levels. Moreover, the Ministry of Education has pushed forward a policy to support 100 Researches and Development in terms of ICT usage in education, including high quality digital learning and teaching materials for developing the level of ICT skills and attitudes necessary to create a knowledge society. (National Education Commission, Office. 2002: 14); (Suktrisul. n.d.: Online)

ICT is appropriately used in science courses, (Poole. 2000: 210), and used for learning as a constructivist tool. (Ross; Lakin; & Callaghan. 2002: 132) This view is supported by Poole (2000: 210) who stated that science as taught in schools should reflect the practice of the scientific community, so students using ICT as a natural part of their learning experience is imperative. The use of ICT for learning and teaching science is divided into three categories: 1) Gaining the stimulus to work. 2) Exploring database files to look for information and patterns. 3) Using science software to develop learning experiences. (Trowbridge and Bybee. 1996: 326-335); (Ratcliffe. 1998: 192-200); (Weld. 2004: 276-278) Similarly, Regional Support Centre for London (RSC) (n.d.: Online) states that ICT enables learners to interpret data collected from virtual communities, artificial environments, webs of knowledge, and sensory input, to draw conclusions from research findings to support or not support hypotheses. Learners can use ICT to develop learning experiences. Reiss. (1999: 218-237) applied ICT to the teaching of ecology and divided it into two aspects: 1) Using ICT as a secondary resource to find more information. 2) Collating and analyzing data. Indeed, ICT allows learners to spend their time developing their understanding of ecological concepts through observation, inference, classification, prediction and analysis of the data.

The study of science should be made more interesting by apply ICT into the teaching and learning processes. Using ICT may boost learner's motivation and commitment to work. It can stimulate learners and positively affect their attitude towards science and science skills. (Ratcliffe. 1998: 192-200) Similarly, Education Review Office (ERO) (n.d.: Online) suggested that in learning to use ICT effectively, students need to develop the knowledge, skills, and attitudes to engage in e-learning meaningfully. Fostering critical thinking and information literacy, learning to use ICT, and learning through ICT are all complementary. This idea fits well with the National Education Act of B.E. 2542 (1999); Section 22 which states that educational management must follow in the principle that all learners are important and capable of further learning and self-development. (National Education Commission, Office. 2002: 14)

E-learning is information sharing that uses digital technology, and used in both formal and informal education. (Suktrisul. n.d.: Online) E-learning as instruction delivered on a computer by way of CD-ROM, Internet, or intranet. (Clark and Meyer. 2003: 13) This idea is supported by RSC (2005: Online) which states that if someone is learning in a way that uses ICT, they are e-learning. Similarly, Nichols (2003: Online) describes e-learning as the use of various technological tools that are either Web-based, Web-distributed, or Web-capable for the purpose of education. Clark and Meyer (2003: 13) divided the features of E-learning into four features: 1) Includes content relevant to the learning objectives. 2) Uses instructional methods, such as examples and practice to help learning. 3) Uses media elements, such as words and pictures to deliver the content and methods. 4) Builds new knowledge and skills linked to individual learning goals or to improve organizational performance. Similarly, Suktrisul (n.d.: Online) suggested that the necessary components to enable e-learning accessible for students, are connectivity, capability, contents, and culture. It is useful to refer to ICT as the learning tools and infrastructure that support e-learning. (ERO. n.d.: Online) Finally, e-learning also improves science teaching and learning, and provides other learning experiences, for example, opportunities for self-directed learning, collaboration with others, and creative use of interactive, multimedia technology.

Teaching processes in scientific investigation naturally focus on the learners. They must provide the students the opportunities to build their knowledge by using a variety of learning processes. (Curriculum and Instruction Development, Department. 2001: 21) One such learning processes is the inquiry cycle.

Inquiry is the process scientists use to learn about the natural world by discovering new knowledge through investigation. This method can be applied in science teaching and learning strategies so that students can manipulate ideas to increase their understanding from experiences. (NRC. 1996: 6) Jenifer Tang (NRC. 1996: 15) suggested that the scientific inquiry process plays upon natural human curiosity and engages the students to stop parroting knowledge in textbooks, to develop scientific knowledge, to understand scientific ideas and explanations for what they observed, as well as to understand of how scientists study the natural world. Inquiry strategies can be an effective way to boost student performance in academics, critical thinking, and problem solving. (Jarrett. 1997: 45) These strategies teach students to do science as well as study the results of science.

One instructional model that uses the inquiry processes is the 5E instructional model. This model has five phases: engagement, exploration, explanation, elaboration, and evaluation. First, students are engaged in the concepts through a short activity or relevant discussion. Next, students explore the concepts with others to develop a common set of experiences. In the explanation the teacher guides the students as they develop an explanation for the concepts they have been exploring. In the elaboration, the students extend their understanding or apply what they have learned in a new setting. In the evaluation, the students and the teacher have an opportunity to evaluate the students' understanding of the concepts. The 5E instructional model is an important learning model in science. This model is to engage students in learning and to encourage inquiry skills. Students can learn scientific concepts and principles faster and have good attitudes towards teaching and learning science. (Trowbridge and Bybee. 1996: 213); (Weld. 2004: 381-382)

The use of the 5E instructional model enables students to build up their knowledge from their past experiences and to teach them the skills of problem solving, which will certainly be useful elsewhere in life. Practice within artificially structured situations can allow more rapid application of these skills in real life. However, the input from the individual school allows more local relevance so every school can provide a more relevant experience for its students. This conforms to the principles of the National Education Act of B.E. 2542 (1999): Section 28 “Curricula at all levels of education shall be diversified and commensurate with each level, with the aim of improving the quality of life suitable for each individual's age and potentiality…" (National Education Commission, Office. 2002: 18)

Thailand has a special economic zone, costal areas covering over 316,000 kilometers. These areas are presently used for tourist attractions, sea transportation development, industrial development, and agriculture etc. The coast is divided into two sides: the Gulf of Thailand side extending 1,700 kilometers and covering 17 provinces; and the Andaman Sea side spanning 937 kilometers and stretching through six provinces. Sandy shores are located in the intertidal zone that shore area lies between the extremes of high and low tides. It represents the transitional area from marine to terrestrial conditions. It is a zone of abundant life and ecosystems. (Nybakken. 2001: 236 – 304); (Rojchanapraiwong. 2003: 13-31) Environmental studies, including the Sandy Shores Ecosystem, should be conducted to generate knowledge about the environment to develop better quality life, to have a good management system of a clean environment for sustainable development.

The studies of environmental science and ecology in Thailand are contained in the science curriculum and relevant to local communities. This idea is supported by Department of Curriculum and Instruction Development (2002: 4) who stipulated that environmental study in Thailand is a requirement in the Basic Education Curriculum of B.E. 2544, by stating that environmental study is required in the study of science, religions and culture, as well as health and physical education. Sandy Shores Ecosystem has a place in the science learning, Substance 2: Life and environment, according to the Standard Sc. 2.1 and Standard Sc. 2.2 (Curriculum and Instruction, Department. 2002: 25)

From the above mentioned details, the researcher hopes to develop an e-learning module on the Sandy Shores Ecosystem for Mathayomsuksa 2 students. The 5E instructional model will be used as the central model of learning. Several interactive learning activities and the instructional materials were delivered via computer either orally or through texts and pictures such as illustrations, photos and animation will be included. The research will focus on student-centered approach, which enables students to recognize what kind of knowledge students bring to the learning process. Secondary school teachers will be able to use the results of this research for teaching and perhaps to develop their teaching and learning processes. The approach will allow more relevant interactions with the local community, its wisdom and its problems. The students should develop their knowledge and scientific skills, and undergo a wider variety of learning experiences, which should improve their motivation to learn further. This e-learning module can also serve as a model in e-learning module development for science studies in many other fields. Finally, the researcher believes that the use of the e-learning module will be one of the vehicles that foster the cognitive development, ICT skills, and improved attitudes towards sandy shores environment.

Research Objectives

In conducting the research, the researcher develops the e-learning module on Sandy Shores Ecosystem for Mathayomsuksa 2 students. The details of the research objectives are as follows:

1. To develop the e-learning module on Sandy Shores Ecosystem for Mathayomsuksa 2 students.
2. To compare the students' academic achievement in each sample group before and after the implementing the e-learning module.
3. To compare the students' ICT skills in each sample group before and after implementing the e-learning module on Sandy Shores Ecosystem.
4. To compare the students' attitude towards Sandy Shores Environment in each sample group before and after the e-learning module.
5. To study the relationships between the students' academic achievement and the students' ICT skills, and their science learning outcomes, divided into three levels, after using the e-learning module.
6. To compare the students' academic achievement and the students' ICT skills on the three sample groups after using the e-learning module.

Significance of the Study

This research will yield an e-learning module on Sandy Shores Ecosystem for Mathayomsuksa 2 students in which will develop students' cognitive ability domain, ICT skills domain, and attitudes towards Sandy Shores Environment. The e-learning module will be an academic work which will be utilized for the development of the teaching and learning process on Sandy Shores Ecosystem, as well as guidelines for the development of other e-learning modules alike.

Scope and Limitation of the Study

Population

The population consisted of five classes of Mathayomsuksa 2 students at Sunthonphu Pittaya Secondary School in Klang District, Rayong Province, studying in the second semester of the academic year 2006.

Sample groups

The sample groups, derived by means of purposive random sampling, included three classes of Mathayomsuksa 2 students at Sunthonphu Pittaya Secondary School in Klang District, Rayong Province, studying in the second semester of the academic year 2006.

Variables

1. Treatment variable

The treatment variable is the e-learning module based on Sandy Shores Ecosystem for the Mathayomsuksa 2 students.

2. Dependent variables

2.1 Academic achievement

2.2 ICT skills

2.3 Attitudes towards Sandy Shores Environment

Contents of the Research

The e-learning module is in a CD-ROM format. The framework of the e-learning module was divided into the following six lessons, as shown:

Module: Sandy Shores Ecosystem

Lesson 1: Living Organisms and Adaptation of Living Organisms in Sandy Shores Ecosystem

Lesson 2: Components of Sandy Shores Ecosystem

Lesson 3: Food Chains and Food Webs in Sandy Shores Ecosystem

Lesson 4: Mineral Cycles and Water Cycle

Lesson 5: Population

Lesson 6: Conservation in Sandy Shores Ecosystem

Conceptual Framework

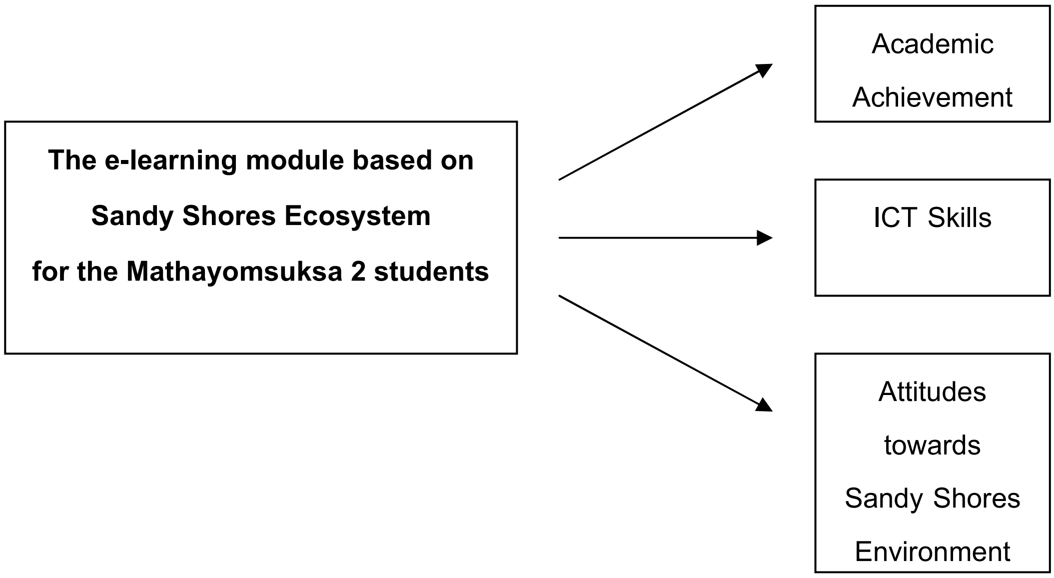

Figure 1 The Conceptual Framework

The conceptual framework for this study is shown in Figure 1. The main aim of the research is to develop the e-learning module on Sandy Shores Ecosystem for Mathayomsuksa 2 students. This study focuses on two types of variables as follows:

1. Treatment variable

Treatment variable is the e-learning module based on Sandy Shores Ecosystem for the Mathayomsuksa 2 students.

2. Dependent variables

2.1 Academic achievement

2.2 ICT skills

2.3 Attitudes towards Sandy Shores Environment

Definitions

Sandy Shores: sandy shores are located in the intertidal zone, lying between the extremes of high and low tides.

Sandy Shores Ecosystem: an ecosystem, which is the interactions among living organisms or between living organisms and their environment in the system, in a tidal zone. Sandy Shores are among the most physically dynamic environments in the sea.

Marine Ecology: the branch of ecology which is relevant to the ecosystem and the relationships between living organisms and the environment in sea water.

The E-Learning Module Based on Sandy Shores Ecosystem for Mathayomsuksa 2 Students: The e-learning module is in a CD-ROM format. The 5E Instructional Model is the core of learning model. The framework of the e-learning module is divided into the following six lessons, as shown:

Module: Sandy Shores Ecosystem

Lesson 1: Living Organisms and Adaptation of Living Organisms in Sandy Shores Ecosystem

Lesson 2: Components of Sandy Shores Ecosystem

Lesson 3: Food Chains and Food Webs in Sandy Shores Ecosystem

Lesson 4: Mineral Cycles and Water Cycle

Lesson 5: Population

Lesson 6: Conservation in Sandy Shores Ecosystem

The components of the e-learning module in each lesson are divided into five categories: learning objectives, concepts and subject contents, pre-assessment, learning activities, and post-assessment.

Academic Achievement: a student's abilities in studying Sandy Shores Ecosystem, which can be measured by an academic achievement test, constructed by the researcher. The academic achievement test is designed to measure students' abilities in the following aspects.

Knowledge refers to ability in recalling what has been learned about facts, assumptions, terminology, and principles of Sandy Shores Ecosystem.

Understandings refers to ability in describing the meaning, elaboration, and interpreting on the basis of facts, assumptions, terminology and, principles of Sandy Shores Ecosystem.

Application refers to ability in applying the scientific approach in new and different situations, especially in daily life situations.

Scientific process skill refers to a person's ability in searching for knowledge through systematic practice and drills until they become skills. Scientific process skills related to the subject contents in this study are observation skills, classification skills, and inferring skills.

ICT Skills: a person's ability in using ICT through systematic practice and drills until it becomes skills. ICT skills connected with the subject contents in this research are information searching from electronic media skills, organizing data and communication skills, and presentation skills.

Attitudes towards Sandy Shores Environment: a student's feelings and opinions towards a certain thing, as well as readiness to behave towards Sandy Shores Environment, for instance, agree or disagree. These attitudes are measured by an attitude test on Sandy Shores Environment, constructed by the researcher. The attitude test is designed to classify the emotional feelings in the following aspects:

Positive attitudes are emotional feelings expressed as satisfaction, agreement, and favor towards Sandy Shores Environment.

Negative attitudes are emotional feelings expressed as dissatisfaction, disagreement, and disfavor towards Sandy Shores Environment.

Research Hypotheses

In this research, the researcher generated the following hypotheses:

1. The e-learning module efficiency is 80/80 or higher.
2. The students' academic achievement in each sample group after learning via the e-learning module is higher than before.
3. The students' ICT skills in each sample group after learning via the e-learning module is higher than that of before.
4. The students' attitude towards Sandy Shores Environment after learning by using the e-learning module is higher than before.
5. The students' academic achievement and the students' ICT skills after learning via the e-learning module are related with the students' science learning outcomes.
6. The students' academic achievement and the students' ICT skills on the three sample groups after learning via the e-learning module will be different.

CHAPTER 2

DOCUMENTS AND RELATED RESEARCH

In conducting the research, the researcher studied the following related research in topics:

1. Concepts of e-learning modules.
2. Inquiry cycle and the 5E instructional model
3. ICT concepts
4. Environmental studies and ecology concepts
5. Sandy shores ecosystem
6. Measurement and evaluation
7. Related Research

Concepts of E–Learning Modules

Definition of a Module

The term ‘module’ is defined as:

Houston; et.al. (1972: 10-15) an experience kit systemically prepared to facilitate the learners to achieve the goals as a set.

Lawrence (1977: 5-9) neither a textbook nor a workbook, but a teaching unit with the subject-content complete in itself and is prepared for self-study rather than being taught by a teacher. Modules consist of instructional media and a process for transferring a certain subject matter. A module’s components include objectives, learning activities, and assessment. It generally comes out in the form of printed materials or a booklet.

Meyer (1979: 23-26) Module is an innovation dating from the1960s. It is known as Learning Activities Package (LAPS), Individualized Learning Kit, Individualized Packages (IPAC), Unified Packages (Uni Pac), Instructional Packet etc.

Richard (1990: Online) “A learning module is a competency-based tool focused on what a learner will know or be able to do as a result of using the tool.”

Moon (2002: 151-153) “Modules are complete in themselves and are assessed, though they may be obviously related to other modules. On the other hand, courses are short or relatively short periods of learning that may or may not be assessed.”

Referring to the aforementioned definitions of module, it is apparent that module is more focused on experience than content. This is congruent with the concept of teaching and learning as stated by educational philosophers concerning module development in 1920s - 1940s. This philosophy marks a change from subject-centered to student-centered.

In conclusion, a learning module is an experience package complete in itself. It is a kind of instructional media aimed to develop the learners to gain knowledge of what is contained in the goals. The instructional process is more student-based than teacher-based.

Components of E-Learning Modules

Educators have the following opinions about the components of an e-learning module:

Richard (1990: Online) classified the components of an e-learning module into six categories:

1. statement of purpose
2. introduction to module use
3. learning outcomes
4. learning activities
5. learning resources
6. evaluation procedures

For a module to be useful, congruence must be evident between the learners' needs and its content. Special attention should be directed to outcomes, activities, and evaluation procedures. Richard (1990: Online)

Houston; et.al (1972: 15-20) divided the essential components of an e-learning module into five categories, as follows:

1. Prospectus: An explanation of the importance of the lesson, the lesson's scope, and what the learners have to know before learning, including the scope of the whole process of the learning module.

2. Objectives: States what the learners will achieve after learning and is the most important part of the module.

3. Pre-assessment: It has two purposes. First, it determines how much background knowledge the learners have about the topic; and second, to assess whether the learners have the knowledge and skills to reach the stated objectives. Basic assessment may take the form of written tests, oral exams, assignments, or discussions, as what is proper.

4. Learning Activities: These are specific activities leading to the set goals, by allowing the learners to participate in those activities.

5. Post-assessment: A measurement test used after learning.

Rensselaer Polytechnic Institute (RPI) (n.d.: Online) suggested a complete e–learning module should include the following:

1. Interactive lessons
2. Instructor support materials
    2.1 Student handouts
    2.2 Instructor's manual
    2.3 Assessment of the students
3. Metadata
    3.1 Abstract
    3.2 Objectives
    3.3 Prerequisites
    3.4 Technical requirements
    3.5 Other supporting details
4. Documented Reviews
    4.1 Student usability testing
    4.2 Independent content review
    4.3 Pilot testing in classrooms
    4.4 User interface and educational technology
    4.5 Other supporting details

Referring to the aforementioned components of an e-learning module, the researcher divided the essential components of an e-learning module into five categories, as follows:

1. Rationale: A description of the background, importance, hypotheses, the outline of the module, basic knowledge necessary for learning, and a brief outline of the learning process so that the learners can understand what they are going to learn.

2. Objectives of the e-learning module: These must be definitely stated and actually measurable.

3. Pre-assessment: This investigates the learners before they start learning. It is to examine whether or not they have enough background knowledge about the topic, and to determine whether they have necessary skills to reach the goals. Pre-assessment can help in selecting appropriate activities for the learners.

4. Learning activities: These must be congruent with the defined objectives.

5. Post-assessment: This should be conducted during and after learning.

In conclusion, it is evident that an e-learning module has continual learning steps. Each step is related with the others and also provides feedback to the other learning steps. An e-learning module's learning steps, as developed by the researcher, are shown in Figure 2, on page 16.

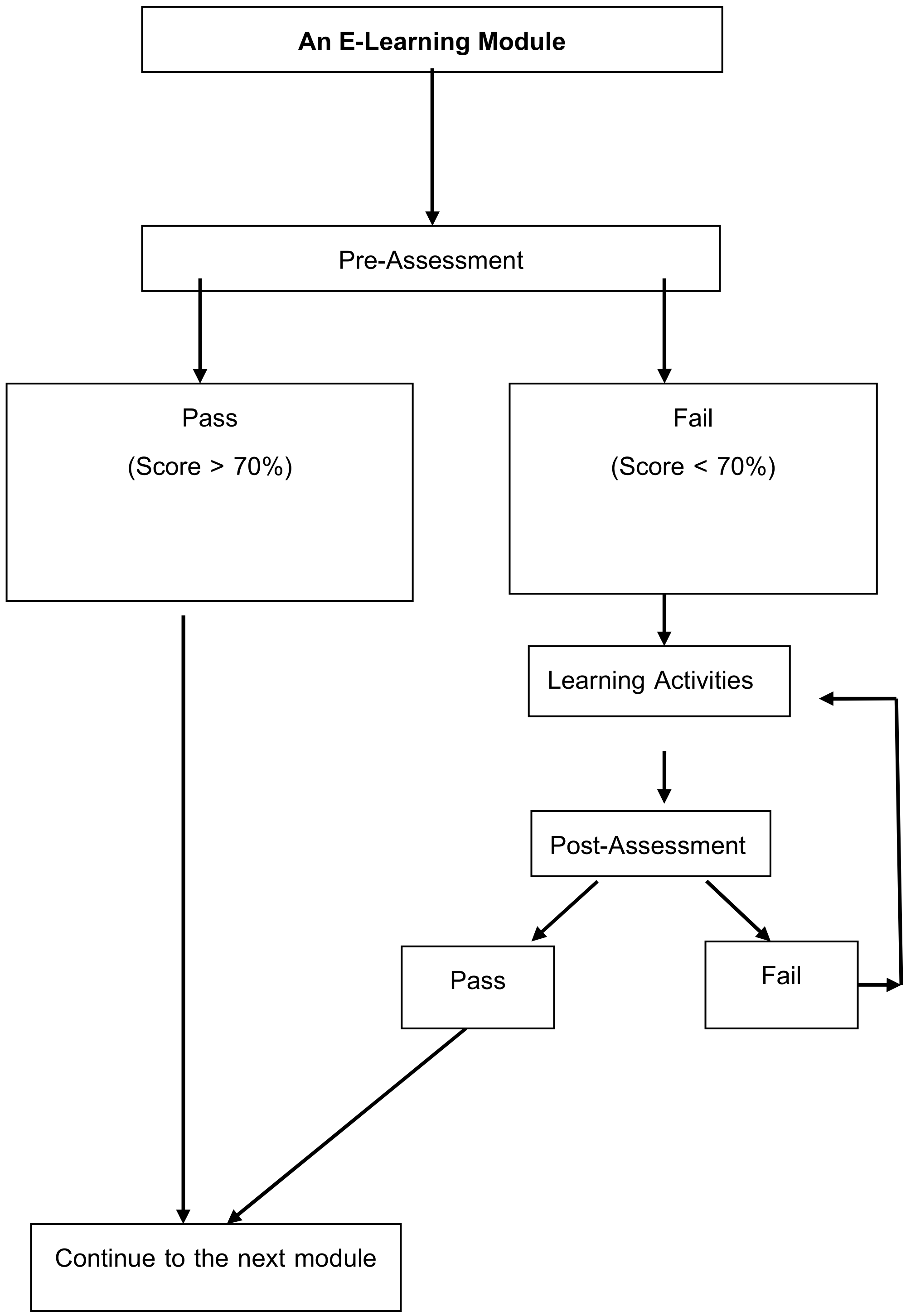

Figure 2 Diagram of the learning steps of an e-learning module

Learning Module Development

The processes of developing a learning module are defined below:

Moon (2002: 15-20) describes the process as follows:

Learning module development (Figure 3) does not necessary the steps which most people use to design a curricula. Learning module developers usually start with an area of curriculum that they want to develop. However, this sequence shows the interrelationships between the elements, and is therefore a checking mechanism for quality review purposes.

In terms of the 'flow' of this sequence, level descriptors and aim statements contribute to the writing of learning outcomes. The former provide an indication of standards, and the latter provide a 'sense of direction' and content. Learning outcomes imply assessment criteria. The assessment method represents the development of the tasks to test assessment of the assessment criteria.

When this model is used to underpin module development, it is important to ensure that there are clear relationships between the elements. In reviewing the process by going 'round the cycle' again, any element can be modified except the agreed level descriptors.

Definitions of elements in the map of learning module development include:

1. Level descriptor: Generic statements describing the characteristics and contexts of learning expected at each level.

2. Aim: This indicates the general direction or orientation of a module in terms of its contents. An aim tends to be written in terms of the teaching intentions or the management of learning.

3. Learning outcomes: What a student will know, understand or be able to do at the end of a period of learning and how that learning will be demonstrated. Learning outcomes are couched in terms of what the learner is expected to learn.

4. Assessment criteria: Statements that indicates, in more detail than learning outcomes, what the learner will need to do in order to indicate that he/she has achieved the learning outcomes that have been specified.

5. Assessment method: The task that is set for learners that will enable a judgment to be made as to whether the learners can achieve the assessment criteria.

6. Teaching strategy: The support that needs to be given to learners to enable them to achieve the learning outcomes. There is recognition that the learning may be achieved without the involvement of teaching.

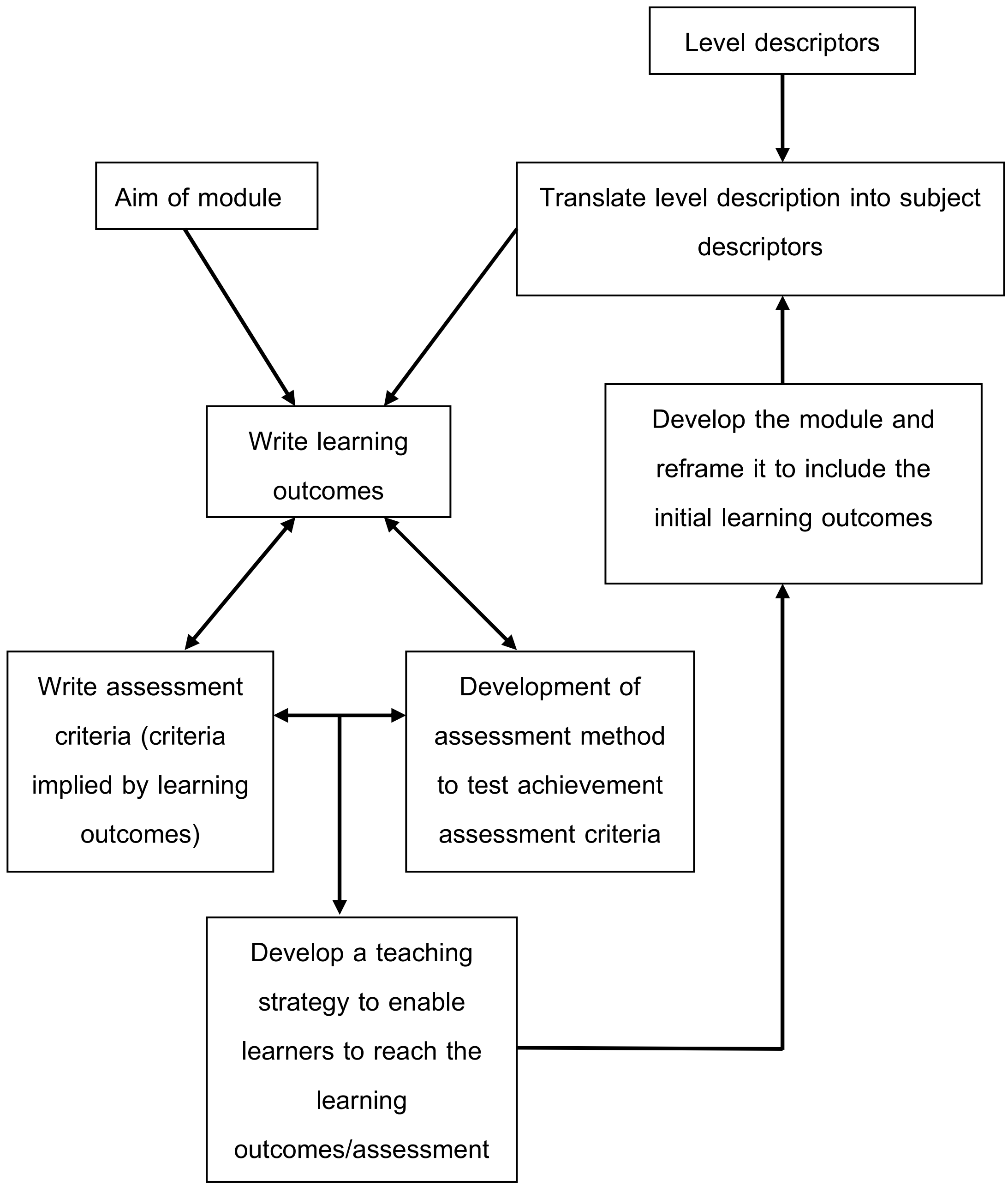

Figure 3 Basic map of learning module development

Source : Moon, Jenifer. (2002*). The module and program development handbook : A practical guide to linking, learning outcomes & assessment.* p. 20.

RPI (n.d.: Online) divided the process of learning module development into thirteen steps, as follows:

1. Complete the Module Design Questionnaire: The questionnaire is designed to help developers organize their ideas and content for a module.

2. Create a storyboard for a lesson: A storyboard is a plan that outlines the ideas and materials needed to build a module. The questionnaire provides information and questions to build a storyboard for a module. Good storyboarding is paramount for building content into a lesson. It is a blueprint for the module. The module is simply one set of materials to be used in the classroom: instructors can and should still use handouts, textbooks, and other materials.

3. Review by the technical manager and authors: Initial review to insure that the new module meets goals and assumptions, and content is presented according to authors' intended design. Checking the module by technical management staff or expert is necessary.

4. Content Review: In general, content reviewers will be asked to work through the module, validating the module content and the accuracy of the materials presented. They will be asked to complete a short review of the module delineating content viability.

5. Edit as necessary based on the content review: Module developers will edit as necessary based on feedback from the content reviewers.

6. Educational Technology and User Interface Review by experts in the field of educational technology: A standard review that looks at the module from a technological/instructional point of view and provides validation of the module's appropriate use of instructional/technological theory.

7. Edit as necessary based on Educational Technology and User Interface Review: Module developer will edit as necessary based on feedback from the ed/tech review.

8. Student Usability Testing: A standard review where a small number of students use the module and provide information pertaining to usability from their point of view.

9. Edit as necessary based on Usability Testing: Module developer will edit as necessary based on feedback from usability testing.

10. Pilot Testing in classrooms (collecting evaluation data): Similar to providing "internal validity" in research. It is proof of the module's "merit," that it does what it is supposed to do. Data in this step can be collected over a long time period if desired by including additional sites, new methods of implementation or new methods of cognitive assessment.

11. Edit as necessary based on Pilot Testing: Module developer will edit as necessary based on feedback from the pilot testing.

12. Utilization in multiple classrooms and at multiple sites: Including observation, interviews, focus groups and paper-pencil methods on instructors and students' perceptions and on cognitive outcomes. This will provide the "external validity" of the module, or in evaluation terms, information pertaining to its "worth."

13. Final editing as necessary.

Referring to the aforementioned learning module development, the researcher divided the process of learning module development into four stages, as shown in Figure 4, on page 22.

In conclusion, the process of learning module development is divided into five main stages: 1) Studying needs assessment 2) Creating a learning module 3) Checking a learning module by experts 4) Pilot testing with small groups of students 5) Implementing with sample groups and multiple groups of students. The learning module is edited as necessary at each stage.

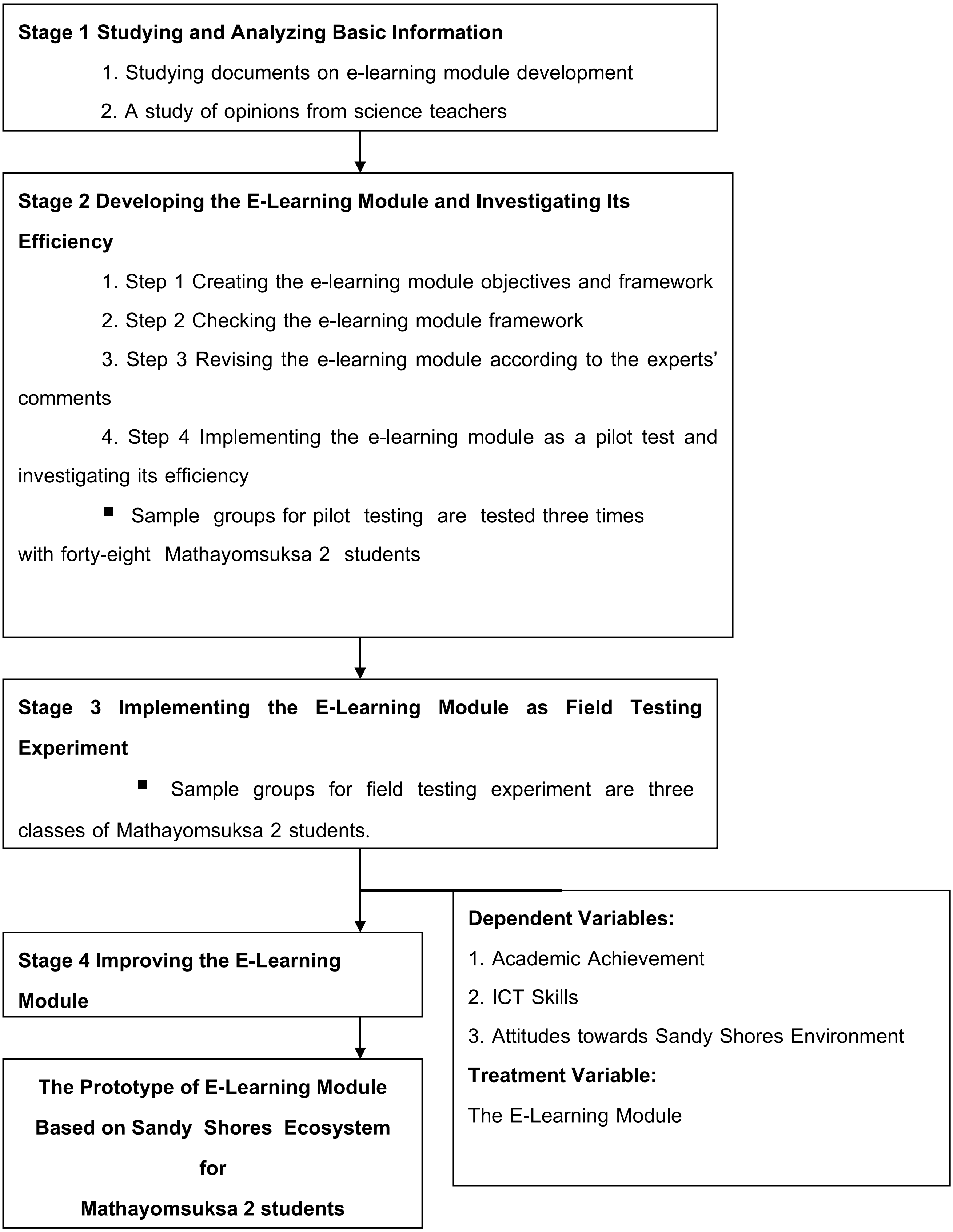

Figure 4 Diagram of the development of e-learning module

Psychological Fundamental Involving in the Development of E-Learning Module

Students need to develop intellectually as well as physically, emotionally and socially. For this reason, an e-learning module developer has to focus on the learners' needs by developing them holistically. Therefore, the developmental and cognitive psychology aspects of learning are needed for e-learning module development.

There are many dimensions in human development, but the focus of this research is limited to cognitive development. The most significant theorist on this field is Jean Piaget.

Piaget's theory of cognitive development, Piaget believed that behavior and biological acts of adaptation to the demands of the physical environment. These acts are the organism's attempt to organize the environment in some significant manner and thus facilitate adaptation to that environment. These principles of adaptation and organization become cornerstones for his view of cognitive development. (Parsons; et.al. 2001: 35)

The basic method a child uses to transfer his or her experience to real life is the working process of intellectual structure, called Assimilation and Accommodation. Assimilation in Piaget's term is the process of making sense of experiences and perceptions by fitting them into previously established cognitive structures, schemata. However, accommodation is the process of creating new scheme, a mental network for organizing concepts and information. Although assimilation and accommodation are both critical cognitive processes, Piaget hypothesized that achieving a proper balance between assimilation and accommodation is called equilibration and it is a self-regulatory process. (Parsons; et.al. 2001: 35-39)

Piaget's stages of cognitive development unfold as the child passes through four distinct and qualitatively different stages: the sensorimotor, preoperational, concrete operation and the formal operation stages, as follows: (Parsons; et.al. 2001: 39-53)

1. The sensorimotor stage (birth to 24 months): It is Piaget's first stage of intellectual development, in which children move from the reflexive activities of reaching, grasping, and sucking to more highly organized ones. The sensory experiences received suggest the existence of some form of objects or events that exist outside of the child. Children's understanding that objects continue to exist apart from the children's perception of them is called object permanence. The development of object permanence forms the basis for using symbols to represent objects in their minds.

Another milestone of the sensorimotor period is the development of the beginnings of problem-solving ability. While at first this is based largely on trail and error, by the end of the period, approaches to problem solving are planned.

2. The preoperational stage (2 to 7 years): This is the second stage in Piaget's theory of cognitive development, in which the lack of logical operations forces children to make decisions based on their perceptions. The major development during this period is the ability to represent objects and events or to use symbolic functions. There are three features: egocentrism, centration and inability to reverse operations.

3. The concrete operational stage (7 to 11 years): The third of Piaget' four major stages is characterized by children's ability to think logically, but only about concrete problems and objects. At this stage of development, a child's "logic" is directed by cognitive activity rather than dominated by immediate experience, as was the case with preoperational thought. Children in the concrete operational stage of development are able to decenter and to reverse operations facilitates the ability to develop conservation skills. Other significant changes in problem solving ability can be seen in children's' ability to engage in classification and serration, which is the ability to mentally arrange objects in sequential order according to a given criteria, such as size, weight or volume.

4. The formal operational stage (over 11 years): It is Piaget's final stage of cognitive development, characterized by children's increasing ability to employ logical thought processes and to solve abstract problems. During this stage of development, thinking has a number of unique structural properties, those of being hypothetical, analogical and deductive. Hypothetical reasoning is the ability to formulate many alternative hypotheses in dealing with a problem and to check data against each of the hypotheses to make an appropriate decision. Analogical reasoning is the heuristic in which one limits the search for solutions to situations that are similar to the one on hand. Deductive reasoning is reasoning from general principles to specific solutions.

The researcher applied the Piaget's theory of cognitive development in developing the e-learning module. To decide the content and activities for teaching and learning, it is important to consider the age, development and interests of the children. The researcher focused on the formal operational stage because the e-learning module has been developed for students in Mathayomsuksa 2, age between 12-14 years.

In order to design and develop the e-learning module, the researcher has to be concerned with not only the children's development but also cognitive psychology to make it really useful for the learners.

In conclusion, the main idea of Piaget's theory in cognitive development is to learn from a child's experiences and to apply it to real life. Learning abilities are relevant to distinct and qualitatively different stages: the sensorimotor, preoperational, concrete operation, and the formal operation stages.

Cognitive Theory Major Psychologists in this group include Jean Piaget, Jerome S. Burner, J Richard Suchman. The basic assumption of this theory is that people behave according to their cognition about the situations of the existing behavior. There are many educational approaches which implement the principles of cognitive theory. Two approaches chosen for curriculum development by the researcher were Jerome S. Bruner's discovery learning approach and J. Richard Suchman's inquiry approach.

Discovery Learning Approach

Four principles in constructing an e-learning module by discovery learning approach are: (Parsons; et.al. 2001: 50-57)

1. Emphasizing the contradiction or differences.

2. Encouraging students to anticipate or guess an answer by generating hypotheses.

3. Encouraging students to participate by observing, collecting data, generating and testing hypotheses.

4. Stimulating learning by having students analyze and find the means to solve problems.

Parsons; et.al. (2001: 438-439) suggested that "Discovery learning encourages students to make guesses based on incomplete information and stimulate them to find their own systematic means to solve problems. Teachers serve only as guides who set up the eventual discoveries by offering basic information and some details without giving students too much information. Students do all the work and determine the best ways to organize new and familiar information for efficient future transfer".

Jerome S. Bruner also expressed his opinion towards discovery learning in that students can develop their own knowledge by learning from things around them. Consequently, teachers should arrange learning experiences for students by providing a variety of activities for their learning. (Parsons; et.al. 2001: 60-63)

In conclusion, discovery learning encourages students to learn by themselves, while teachers act only as facilitators. It is one type of student-centered learning.

Inquiry Approach

The inquiry approach resulted from the concept that curiosity is common in humans. Curiosity, thus, continuously stimulates humans to search for and to invent new things all the time. When this concept is applied in teaching and learning, it will help students find ways of explaining all events reasonably with supported principles from the inquiry approach, according to J. Richard Suchman's cognitive theory-oriented methods, are divided into the following four steps, as follows: (Trowbridge and Bybee. 1996: 175-199)

1. Identifying problems: The most valuable questions are the ones being restricted to the main points of inquiry which will lead to the result.

2. Generating hypotheses: This will be a guideline for collecting the data.

3. Gathering information for hypotheses testing.

4. Adjusting hypotheses and collecting more data and information: students can prove their hypotheses and make the conclusions to explain the situation being observed.

Indeed, the main idea of J. Richard Suchman's inquiry approach is to develop students' thinking by means of seeking knowledge themselves. The inquiry approach encourages students to learn scientific concepts and principles faster and to have good attitudes towards teaching and learning science.

Gagne′'s Learning Theory

Robert M. Gaqne′ translated the information processing model into an instructional one using "phases of learning", as shown at Table 1, on Page 27. (Parson; et.al. 2001: 256-258)

Table 1 Gagne's Internal Processes and Corresponding Instructional Events with Action Examples (Phases of Learning)

Internal Process	**Instructional Event**	**Action Example**
Reception Expectancy	1. Getting their attention 2. Informing learners of the objective	Use abrupt stimulus chance. Tell learners what they will be able to do after learning.
Retrieval to working memory	3. Stimulating recall of prior learning	Ask for recall of previously learned knowledge or skills.
Selective perception	4.Presenting the stimulus	Display the content with distinctive features.
Semantic encoding	5.Providing "learning guidance"	Suggest a meaning organization.
Responding Reinforcement Retrieval & reinforcement	6.Eliciting performance 7.Providing feedback 8.Assessing performance	Require additional learner performance, with feedback.
Retrieval and generalization	9.Enhancing retention and transfer	Provide varied practice and space reviews.

Source: Parsons; et.al. (2001). *Educational Phychology : a practitioner – researcher model of teaching.* p. 27.

From the table, Gagne′ drew parallels between the short term memory store and pre-instructional review, long term memory store and instructional strategies like practice and reinforcement. These pre-instructional and instructional practices enhance the likelihood of transfer of information from the long term memory into the working short term memory where it can be used. (Parsons; et.al. 2001: 256-258)

A more cognitively oriented approach to conceptualizing student learning capabilities is found in the work of Gagne′. The interaction of these external and internal conditions of learning produces the outcomes of learning which include the following: (Parsons; et.al. 2001: 402-403)

1. Verbal information
2. Intellectual skills
3. Cognitive strategies
4. Attitudes
5. Motor skills

By analyzing Gagne′'s learning theory, the researcher has applied this approach to e-learning module development by identifying learning objectives, providing learning experiences to develop knowledge, skills and attitudes, which will result in effective learning according to the educational objectives.

In conclusion, the main idea of Gagne′'s learning theory is to encourage students to have direct experiences in learning the subject matters and to be enthusiastic in furthering their studies.

Constructivism Approach

Philosophers of constructivism believed that knowledge is what human beings have created in their minds by trying to make sense or construct meaning of events or experiences by using their former knowledge, beliefs, and expectations in interpreting meanings and understanding all things. Consequently, knowledge is not reality but only reasonableness and best concurrent knowledge. (Trowbridge and Bybee. 1996: 200-220)

Organizing learning based on the constructivism approach consists of the following major components, as follows: (Trowbridge and Bybee. 1996: 200-220)

1. Associating former knowledge with new knowledge.
2. Constructing the concept of new knowledge.
3. Checking new knowledge.
4. Applying new knowledge to various situations.

It thus can be concluded that the constructivism approach is an approach to learning that emphasizes students' building up new bodies of knowledge which associates existing new knowledge with their available former knowledge. Teachers are simply helpers who provide experiences.

The Department of Curriculum and Instruction Development (2002: 146) recommended that science learning in Thailand be based on constructivism and that students should inquire, seek, investigate and check, and search for knowledge by various means. Students will have a relevant understanding and perception of that knowledge. Students then build up their own body of knowledge which will be processed and kept in their brain for a long time and can be restored when they encounter immediate problems. Hence, it is obvious that students are able to build up their body of knowledge when they have to pass various learning processes, especially the inquiry process.

Booncleab; et.al. (1997: 13) also made the similar recommendations for learning science in Thailand as those suggested by Department of Curriculum and Instruction Development in that instruction should be based on the constructivism approach so learning arises from the students themselves. The most appropriate instruction is the one that students learn by an inquiry method.

Based on the aforementioned approach, the researcher has developed the e-learning module by employing constructivism in organizing learning so that students can construct knowledge by themselves.

Indeed, the main idea of the constructivism approach is to encourage students to apply the ways scientists work and to change their learning orientation from being knowledge receivers to become knowledge seekers and users.

The Inquiry Cycle and the 5E Instructional Model

Teaching science through inquiry has long been promoted by science educators. (Haury, 2001: 8)

DeBoer (1991: 62-63) stated that “If a single word had to be chosen to describe the goals of science educators during the 30 year period that began in the late 1950s, it would have to be *inquiry*”

The Standards of the United States of America also stated that “… inquiry into authentic questions generated from student experiences is the central strategy for teaching science”. (NRC. 1996: 110-114)

In conclusion, inquiry should become a central part of science education. Science teaching and learning processes encourage teachers to focus on inquiry as it relates to student’s real-life experiences and to guide students to fashion their own investigations.

The meaning of inquiry

Many definitions of the inquiry method exist. The meanings of inquiry are shown below:

Dewey (1938: 10) defined the meaning of inquiry as:

As a mode of conduct, inquiry is as accessible to objective study as are other modes of behavior.

According to the Standards the term “inquiry” is used in two different ways. First, it refers to the abilities students should develop to conduct scientific ideas by using investigations and the understanding of what they have obtain about the nature of scientific inquiry. Second, it refers to the teaching and learning strategies that enable scientific concepts to be mastered through investigations. (Dow. 2000: 12-15)

Hinrichsen and Jarrett (1999: 8-10) agreed that the central meaning of scientific inquiry is divided into two large ideas. First, inquiry is the essence of the scientific enterprise. Second, inquiry is a strategy for teaching and learning science.

Jennifer Tang (1996: 45) suggested that scientific inquiry is an approach to learning and refers to the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work. This process, which plays upon natural human curiosity and engages the students to stop parroting what they learned in textbooks, develops scientific knowledge and concepts and provides explanations for what they observed, as well as an understanding of how scientists study the natural world.

Indeed, inquiry is the process scientists use to study the natural world by discovering new knowledge with investigation. This method can be applied in science teaching and learning strategies so that students can manipulate their ideas to increase their understanding from their experiences.

Forms of inquiry

Colburn (2000: 25-30) divided inquiry into four forms as shown below:

1. Structured inquiry: Students engage in hands-on activities and draw conclusions, but follow precise instructions from the teacher. Its purpose is to exemplify scientific ways of thinking and doing and to initiate student responsibility for the process.

2. Guided inquiry: Students may assume responsibility for determining the procedure for the investigation, but the teacher chooses the questions to be investigated. The purpose of guided inquiry is to continue to exemplify scientific ways of thinking and doing while transitioning more responsibility for thinking and doing from the teacher to students.

3. Open inquiry: This is similar to guided inquiry, with the addition that students also formulate their own problem to investigate. Open inquiry allows students to develop their understanding of a concept and use scientific reasoning. An important goal for all students would be to conduct open inquiry independently. For example, students are given batteries, bulbs, wires, and other materials. They are instructed to investigate how bulbs light up in electrical circuits.

4. Learning cycle student-initiated inquiry: Students generate their own questions from a topic selected by the teacher, and design their own investigation. Student-initiated inquiry provides opportunities for them to exemplify thinking and behaving in scientific ways to solve personally and socially important problems.

Indeed, the inquiry method can be applied to teaching and learning in all subjects especially in science subject. This method encourages students to exemplify thinking through investigation by using scientific ways.

The processes of inquiry

Teaching and learning science through inquiry is a multifaceted activity. The processes of inquiry include: (Jarrett. 1997: 15-18)

1. Making observations and posing or generating their own question(s).

2. Through discussion, a problem is identified and narrowed. Students can investigate it similar to making a hypothesis by examining books and other sources of information to see what is already known so they can plan to solve the problem. Often, the discussion of different hypotheses will give students ideas for how to test their own hypothesis. They have to confirm or deny the other hypothesis as well as show that their hypothesis works.

3. Finding the answer involves using tools to gather scientific knowledge, leads to students' discoveries, and proposes a way of looking into the problem including finding the answers to their questions and then collecting data.

4. Interpreting and analyzing the data and summarizing their findings with conclusions for evaluation. Students must interpret the results according to their original question.

5. Forming conclusions which combined explanation and predictions.

6. Communicate their findings and scientific arguments provide students opportunities for giving oral reports or to keep a journal or write a report. Communication is central to the whole inquiry process and classroom environments ought to have a place for it. (Bruce. 2001: Online)

7. New questions arise with new problems which need further investigation which in turn could produce new conclusions. Thus the process is repeated. This is the cycle of scientific discovery. The knowledge one gains through inquiry is the basis for further inquiry. (Bruce. 2001: Online)

Other essential but less readily assessable processes of inquiry include: collaboration, responding to criticism, and practicing habits of mind, such as honesty and integrity in reporting findings. (Hinrichsen and Jarrett. 1999: 20)

In conclusion, teaching and learning science through inquiry is a multifaceted activity. Inquiry is the process scientists use to learn about the natural world. Students can also learn about the world by using the method. First, the inquiry method gives students' opportunities to work out answers by themselves. Second, it can help them improve their skills and scientific knowledge for searching and collecting information.

The inquiry method has been applied to Thai culture. The idea that Buddhism was integrated as well. In addition, the inquiry processes were synthesized with cognition and were divided into five steps as follows: (Moolkham & Moolkham. 2002: 138-141)

1. Concept: This step prepares students' for learning and motivates them by getting them to share their background knowledge and experiences. It also includes needed new information.

2. Observation: It is a step that allows students to observe and analyze problems in detail.

3. Problem explanation: This step gets students to discover the reasons behind causes-effect problems.

4. Prediction

5. Controlling and creating internal and external environment: In this step students apply the result of problem solving to their real lives to control their internal environment (mental). This step encourages creativity.

In conclusion, inquiry is the process of defining and investigating problems, formulating hypotheses, designing experiments, gathering data, and drawing conclusions about problems. The inquiry process is composed of: formulating problem, hypothesizing, designing experiments and demonstrating such as objectivity, curiosity, open-mindedness, and respect for theoretical models, values, and attitude.

The 5E Instructional Model

One of the most important instructional models for teaching science is the 5E instructional model which uses the inquiry processes. This model is an effective way to engage students in learning and to encourage inquiry skills.

Trowbridge and Bybee (1996: 213) reported that Rodger Bybee and other educational researchers created BSCS 5E Model of learning. This is an effective way to engage students in learning. Developed in the 1980s, the BSCS 5E instructional model is a hallmark of these programs. The 5E instructional model has five phases: engagement, exploration, explanation, elaboration, and evaluation.

In this model, the process is explained by employing five “Es”, as follows: (Trowbridge & Bybee. 1996: 213); (Weld. 2004: 381-382)

1. Engagement: Learners are invited to ask questions, define problems, or analyze demonstrations. Successful engagement results in students asking questions and showing motivation to work on their tasks. This phase is an ideal assessment opportunity for teachers to establish students’ prior knowledge.

2. Exploration: Learners have a common base of experiences that are geared towards building understanding and long-term learning. A variety of activities or investigations take place. Learners have time to begin to build a conceptual foundation, prepare them for the next stage.

3. Explanation: Common vocabulary is developed. Clear, comprehensible explanations of the concepts being studied are shared. Learners share their explanations built from prior phases toward a common scientific vocabulary and understanding.

4. Elaboration: It is similar to the concept application phase of the learning cycle. Learners are given novel and extended activities to solidify their new understanding. They apply their new knowledge in comprehending unique situations, and extending subjects competency. During this phase, many misconceptions can be dispelled.

5. Evaluation: At this time and during all other phases, learners receive feedback on their work in a written or oral format. They are also invited to evaluate their own work, directed and facilitated by a teacher who is skilled in the questioning styles of inquiry.

In conclusion, the inquiry processes in terms of 5E Model of learning are: First, students are engaged in the concepts through a short activity or relevant discussion. Next, students explore the concepts with others to develop a common set of experiences. In the explanation phase, the teacher guides the students as they develop an explanation for the concepts they have been exploring. In the elaboration phase, the students extend their understanding or apply what they have learned in a new setting. In the evaluation phase, the students and the teacher have an opportunity to evaluate the students' understanding of the concepts. The 5E instructional model is one of the important models of learning in science. Students can learn scientific concepts and principles faster and develop good attitudes towards teaching and learning science.

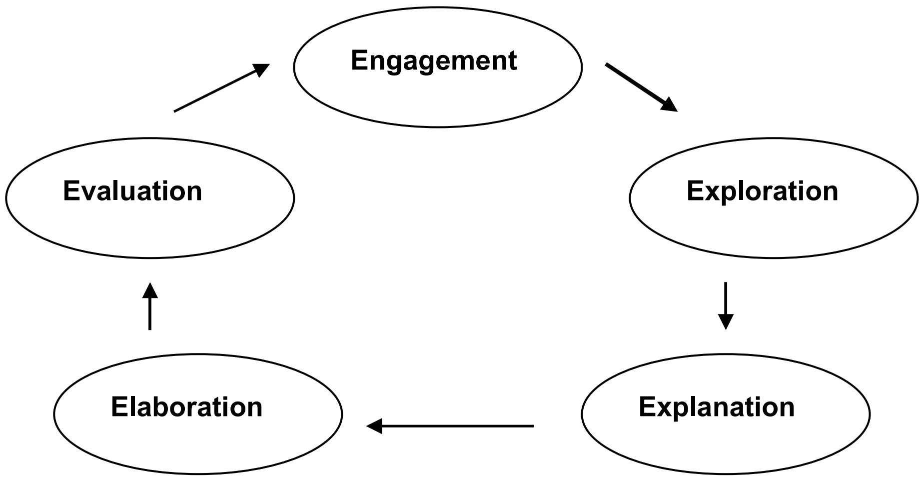

Figure 5 The inquiry cycle in terms of 5E Model of learning

Source: Trowbridge, Leslie W., and Rodger W. Bybee. (1996). *Teaching secondary school scienc : Strategies for developing scientific literacy*. p.215.

Montgomery County Public Schools (MCPS) (2004: Online) suggest designing a science lesson by using the 5E instructional model, as follows:

1. Identify the scientific concept for the lesson.

2. Identify a real-world or practical application related to the concept: This can be a problem students can solve, or a decision student can make, or a question students can answer with information collected from the activities in the lesson. This application will be presented during the engagement and will be completed during the extension.

3. Provide opportunities to collect information from: The media center and/or the internet and / or lab work. This will become the exploration.

4. Develop a series of questions:

4.1 For independent student reflection: Help students analyze the collected information as a guide to developing their thinking skills.

4.2 For class discussion: Compare data and ideas, critique conclusions. This makes up Part 1 of the explanation.

5. Provide explanations that will increase the student's understanding of the concept: Formative assessment is appropriate after the completion of this second part to the explanation.

6. Evaluation occurs throughout the lesson: The evaluation of all important concepts, skills, and processes concludes the lesson.

The 5E instructional model is the central model of learning in the e-learning module. So the researcher has developed an e-learning module on Sandy Shores Ecosystem for Mathayomsuksa 2 students.

The 5E instructional model enables students to construct knowledge and to understand scientific concepts. The use of the e-learning module will be a vehicle to foster the development of the cognitive ability and skills.

Concepts of Information and Communication Technology (ICT)

Definitions of ICT

The term ‘ICT’ can be defined in many ways, as follows:

Ratcliffe (1998: 192) states that “ICT is a diverse range of technologies, with each year bringing in something new. For example, the growth of multimedia, the Internet, and the talking word processor, etc.. Each technology offers something unique and of interest to education.”

ICT is appropriate in science courses as teaching and learning tools.

Definition of e-learning

The term ‘e-learning’ can be defined in many ways, as follows:

Regional Support Centre for London (RSC) (n.d.: Online) states that:

If someone is learning by using ICT, they are e-learning. For example, playing an interactive game, collaborating other people abroad via the Internet, or watching an animated diagram. The key advantage is that increased use of technology brings to education more choice and flexibility coupled with quick responses.

Nichols (Nichols. 2003: Online) describes “e-learning is the use of various technological tools that are Web-based, Web-distributed, or Web-capable for the purpose of education.

In conclusion, e-learning means using new multimedia technologies and the Internet to improve the quality of learning.

The theory of e-learning

RSC (n.d.: Online) described the theory of e-learning “Kolbs Learning Cycle”, as follows:

Kolbs Learning Cycle is at the heart of the theory of e-learning. This is a very useful model for helping teachers focus their attention on the stages that a learner should pass through on their journey. If this cycle is facilitated effectively, this model enables learning to become meaningful and significant.

After analyzing Kolbs Learning Cycle, the researcher applied it to e-learning module development by providing learning experiences to develop knowledge, ICT skills and attitudes towards sandy shores environment.

In conclusion, the theory of e-learning is an important theory for developing e-learning modules for effective learning experiences.

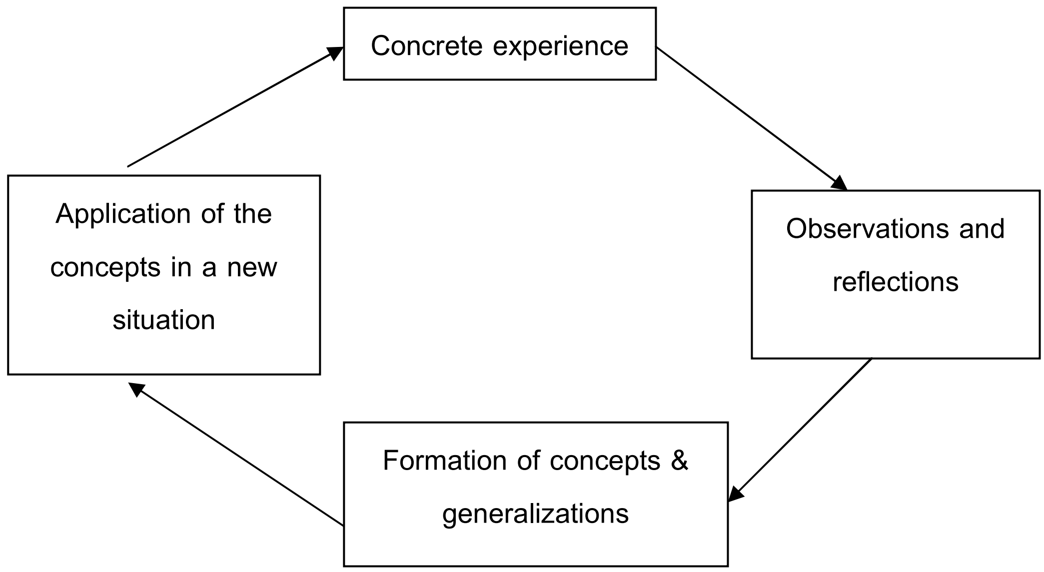

Figure 6 Kolbs Learning Cycle

Source: Regional Support Centre for London. (n.d.). *The theory of e-learning*. Online.

The Use of Information and Communication Technology

The use of ICT for teaching and learning can be concluded, as follows: (Trowbridge and Bybee. 1996: 326-335); (Ratcliffe. 1998: 192-200); (Weld. 2004: 276-278)

1. Gaining a stimulus to work: There is a great deal that learners can do to enhance the quality of their work by using CD-ROM or the Internet. Using ICT can boost learner’s

motivation, enjoyment, and commitment to work. It can stimulate learners and positively affect their attitude to science and science skills.

2. Exploring database files for information and patterns: Learners can research the work of others and pick up facts and pictures from references, such as CD-Rom or online encyclopedia. A CD-ROM may be more limited but it is a useful technology offering multimedia that the Internet is still learning to deliver.

3. Using science software to develop learning experiences: There is a lot of genuinely interactive science software to engage learners in useful tasks. For example:

3.1 Modeling software: Scientists and learners can express their ideas and explain them to others by using models.

3.2 Data logging software: It is extraordinarily helpful to learners in making measurements, and provides useful feedback. The software can calculate changes, gradients and areas.

3.3 Spreadsheet programs: Learners handle data by setting it into a table, sorting it and drawing graphs. They can also do the same on other people's database which today can happen over the Internet.

3.4 Presentation programs: Learners need to plan, write and present their work. They can use a presentation program or word processor to produce professional quality work. They can put the work on the Internet to gain a public audience for this.

3.5 Multimedia software: Software can offer a rich experience through film clips, animation and interaction. Integrated learning systems, like a lot of multimedia software, make claims to being electronic teachers. There may save cost saving because of reduced less teacher and laboratory time.

In conclusion, ICT is appropriately used in science courses. It enables learners to interpret data collected from virtual communities, artificial environments, webs of knowledge, and sensory input, to draw conclusions from research findings to support or not support hypotheses. Learners can use ICT, such as the Internet, science software, etc., to develop learning experiences.

The use of ICT for learning ecology

The use of ICT for learning ecology can be concluded, as follows: (Reiss. 1999: 218-237)

1. Using ICT as secondary resources: Learners use secondary resources (e-journal, the Internet, CD-ROM, etc.) to find more information. There are useful CD-ROMs, available about plants, animals, and habitats.

2. Collating and analyzing data: Using science software, a spreadsheet program, to analyze data enhances learners' satisfaction and provides an excellent opportunity to introduce ICT. Using software designed for field data can be tremendously advantageous. It also has the advantage of providing demonstrations of real ecological models at different times.

In fact, ICT allows learners to spend their time developing their understanding of ecological concepts through observation, inference, classification, prediction and analysis of the data.

Concepts of Environmental Study and Ecology

Definitions of Environment

The term 'environment' can be defined in many ways as follows:

Uppayokin (1987: 30) stated that, "Environment is everything surrounding humans". Environment is classified into the natural environment and man-made environment.

Miller (1990: 76) defined it as "meaning all the things natural or man-made, either useful or harmful, either visible or invisible to the naked eye, either concrete or abstract, and either poisonous or nonpoisonous."

Rattanalertnusorn (2003: 3) defines it as all things natural or are man-made, which surround us. All the things include both living and nonliving things. While 'us' refers to humans, living or nonliving organisms".

In conclusion, environment is all living or nonliving things which surround humans. It can be classified as either natural or man-made.

Scope of Environmental Study

The scope of the environmental study by every environmentalist differs depending on individual interest. Environmentalists study various aspects of the environment, which can be grouped into two levels: (Miller. 1990: 76)

1. Basic environmental studies include the study of environment by focusing on the components, ecosystem, relationship, nutrient transfer and energy. In other words, it is the study about the structure of the whole environmental system for further study.

2. Advanced environmental studies consist of the study of problems and impact of the environment, environmental development, and environmental management. The purposes of the study are to acquire knowledge for utilization and reduce human impact.

The Department of Curriculum and Instruction Development (2002: 4) stipulated that environmental study in Thailand is a requirement in the Basic Education Curriculum of B.E. 2544, by stating that it is required in many subject groups, especially science, religion and culture, health and physical education.

Rattanalertuusorn (2003: 9) suggested that, “Man can integrate his knowledge about environment with his knowledge in pure science or applied science by using scientific procedures for the purpose of developing a better life quality.”

With regards to these concepts, the researcher has developed an e-learning module about the Sandy Shores Ecosystem and classifies this module as part of the science substances, Substance 2: Life and Environment, according to the Standard Sc 2.1 and Standard Sc. 2.2.

The Sandy Shores Ecosystem is classified according to the scope of environmental study as a basic environmental study. Students can gain knowledge and use this knowledge as a basis for further studies at more advanced levels.

Development of Concepts on Environmental Study

Miller’s (1990: 80-85) conclusions on concepts of environmental studies from the 18th to the 21st century are as follows:

Environmental study has been conducted earnestly in the 18th century by Count Buffon. He was the first scientist who presented the idea that humans naturally play a direct role towards the environment. In other words, humans use the environment as a dwelling and consume other living things as food.

During the 19th and 20th century, there were quite a few issues for environmental studies. They mostly centered on the opinion that humans impact the environment; consequently, they must accept all resulting environmental changes.

Presently, the idea of using environmental knowledge to manage the ecosystem in a balanced state is predominant.

The researcher thinks that humans continually have a close relationship with environment. They can not be separated from the environment and key element in making a complete cycle of ecosystem composed of both living and nonliving organisms. Environmental studies should be done earnestly and continually to broaden our knowledge of the environment to develop a better life quality and to create good management system of a clean and healthy environment for sustainable development.

Definitions of Environmental Science

Nebel and Richard (1993: 5) also defined the term environmental science by saying that, “Environmental science is the science of looking at the cause-and-effect relationships underlying environmental issues.”

Environmental science, defined by Khrone (2001: 9) is the study of ecological effects of human activities on the environment. It is an interdisciplinary science that incorporates ecology, chemistry, geology and even aspects of sociology and economics.

The conclusion from the definitions of ecology and environmental science mentioned above is that ecology and environmental science are intimately related; however, they are not identical. Ecology is a basic biological science in the same way that biochemistry and physiology are, whereas environmental science is an applied version of ecology.

Concepts of Ecology

Definitions of Ecology

Miller (1990: 76) briefly explained the origin of the term ‘ecology’ by saying that, “In 1869, German biologist Ernest Haeckel coined the term ecology from two Greek words : oikos, meaning “house” or “place to live,” and logos, meaning “study of”.

Ecology, defined by Miller (1990: 76) is the study of the interactions between organisms and their living (biotic) and nonliving (abiotic) environment.

Nebel and Richard (1993: 12) defined the term ‘ecology’ as the study of relationships among organisms and between organisms and their environment.”

Rojchanapraiwong. (2003: 45) described the difference of ecology and environmental science in that ecology is a science that examines the most complex levels of biological organization; while environmental science is the scientific study which is closely related to ecology.

In conclusion, ecology is the study of interactions among organisms and between organisms and their environment which consists of both biotic (living) and abiotic (nonliving) components.

Definitions of Ecosystem

The term of ‘ecosystem’ are defined as follows:

Miller (1990: 80) stated that “Ecosystem is the combination of a community and the chemical and physical factors making up its nonliving environment. It is an ever-changing (dynamic) network of biological, chemical and physical interactions that sustain a community and allow it to respond to changes in environmental conditions.”

Nebel and Richard (1993: 18) said that "Ecosystem may be defined as a group of various species of plants, animals and microbes interacting with each other and with their environment."

Nybakken (2001: 17) defined an ecosystem as a functional unit of variable size composed of living and nonliving parts that interact. The parts and the whole system function through a sequence of operations involving energy and the transfer of energy.

In conclusion, ecosystems are the interactions among organisms or between organisms and their environment in the system.

The Structure of Ecosystems

Ecosystems consist of various nonliving (abiotic) and living (biotic) components. The structure of ecosystems is shown as follows: (Miller. 1990: 80-86); (Nebel and Richard. 1993: 20-34)

1. Abiotic components of ecosystem: The nonliving, or abiotic, components of an ecosystem include various physical and chemicals factors. Important physical factors are sunlight, precipitation, wind, temperature and water currents. The major chemical factors are the nutrient elements and compounds in the atmosphere, hydrosphere, and earth's crust, which are required for the survival, growth and reproduction of organisms.

2. Biotic components of ecosystems: The major types of organisms that make up the living, or biotic, components of an ecosystem are usually classified as producers, consumers, and decomposers.

The major interactions among organisms involve feeding relationships. There are innumerable pathways where one organism is eaten by a second, which is eaten by a third, and so on. Each pathway is called a food chain and the term "food web" is used to denote the complex pattern of interconnected food chains.

Indeed, there are two "sides" in every ecosystem, the organisms (biotic) on one hand and the environmental factors (abiotic) on the other.

The Classification of Ecosystems

Miller (1990: 80) expressed his opinions towards ecosystems that ecosystems can be classified into general types that contain similar types of organisms, as follows:

1. The ecosphere's major land ecosystems such as forests and deserts are called terrestrial ecosystems. The differences among these land ecosystems in various parts of the world are caused mostly by differences in average temperature and average precipitation.

2. Major ecosystems in the hydrosphere are called aquatic ecosystems, for example; ponds, oceans, and coastal areas, etc. The major differences between these ecosystems are the result of differences in the amount of various nutrients dissolved in the water (salinity), differences in the depth of sunlight penetration and differences in average water temperature.

In conclusion, the sandy shores ecosystem is an ecosystem in an aquatic ecosystem. Sandy shores are among the most physically dynamic environments in the sea. Consequently, biodiversity in ecosystems result from sandy shores.

Sandy Shores Ecosystem

The main features and components of sandy shores ecosystem can be concluded as follows: (Nybakken. 2001: 236–304); (Rojchanapraiwong. 2003: 13-31)

The total length of the coast of Thailand is roughly 2,637 kilometers. It is divided into two sides: the side on the Gulf of Thailand extending 1,700 kilometers and covering the area of 17 provinces; and the side of the Andaman Sea spanning 937 kilometers and covering the area of 6 provinces. The area of economic zone in the sea is over 316,000 kilometers. The coastal areas are presently utilized in various ways, by tourist attractions, sea transportation development, industrial development, and agriculture etc.

Sandy shores are located in the intertidal zone or littoral zone, a shore area laying between the extremes of high and low tides. It represents the transitional area from marine to terrestrial conditions. It is a zone of abundant life.

Intertidal exposed sand beaches and protected sand flats are common throughout the world. Exposed sand beaches are subject to more wave action and are usually facing the open sea. The most important physical factor governing life on exposed sand beaches is wave action and its attendant correlation with particle sizes and slope.

A second important physical factor is also the product of wave action. That is wave-induced substrate movement. Light wave action also means that a smaller depth of particles is affected by the passage of a wave, whereas heavy wave action disturbs the substrate to a greater depth.

The final physical factor acting on beaches is oxygen. Oxygen is unlimited in the beach water, because the turbulence of wave action censures constant saturation.

Two main adaptations to continued substrate movement by animals inhabiting open sand beaches are to either burrow deeper than the substrate is displaced or to rapidly reburrow as soon as the wave has passed.

The dominant animals in these areas are polychaete worms, bivalve mollusks, and crustaceans. On the other hand, the types of organisms conspicuous by their absence on open sand beaches are large plants and sessile animals. However, there is little primary productivity in this area, and the animals found there are mainly filter feeders, detritus feeders, and scavengers.

Open sand beaches generally have three zones: an upper supralittoral fringe inhabited by amphipods, a broad midlittoral with sand crabs and isopods, and an infralittoral fringe with many species.

Based on the aforementioned concepts of ecosystems and sandy shores ecosystems, the researcher has chosen sandy shores ecosystem as the subject contents of the e-learning module.

Sandy Shores are located in the intertidal zone or littoral zone, between the extremes of high and low tides. It is a zone of abundant life and ecosystem in the sea.

Measurement and Evaluation

Measurement and evaluation must be congruent with the objectives of the e-learning module, learning objectives, subject contents, learning activities, and instructional media. Measurement and evaluation are as follows:

Student achievement assessment

Student achievement assessment is derived from the results of the pre- and post-assessments. The instrument used is an academic achievement test covering two types of evaluation: formative evaluation and summative evaluation.

Academic achievement is student's abilities on sandy shores ecosystem, which can be measured by an academic achievement test on sandy shores ecosystem, constructed by the researcher. The academic achievement test is designed to measure students' abilities in the following aspects:

Knowledge refers to ability to recall what has been learned about facts, assumptions, terminology, and principles of the sandy shores ecosystem.

Understanding refers to the ability to describe meaning, elaborate, and interpret the basis facts, assumptions, terminology and, principles of the sandy shores ecosystem.

Application refers to the ability to apply the scientific method in new and different situations, especially in daily life situations.

Scientific process skill refers to a person's ability in searching for knowledge through systematic practice and drills until it becomes a skill. Scientific process skills related to the subject contents in this study are observation, classification, and inferring skills.

Information and Communication Technology Skills (ICT skills) assessment

The students' ICT skills are assessed from the results after completing the learning activities in the e-learning module. The instrument used is an evaluation form of ICT skills.

ICT skills are a person's ability in using information and communication technology through systematic practice and drills until it becomes a skill. ICT skills connected with the subject contents of this research are information searching from electronic media skill, organizing data and communication skill, and presentation skill.

Attitudes towards sandy shores environment assessment

The assessment of the students' attitudes towards sandy shores environment can be measured after having completing the learning activities. The instrument used is an attitude inventory form on sandy shores ecosystem.

Attitudes towards sandy shores ecosystem are defined as a person's feelings and opinions towards a certain thing, as well as readiness to behave in any other ways towards sandy shores environment, for instance, like or dislike, agree or disagree, for or against. These attitudes are measured by an attitude inventory form on the sandy shores ecosystem, constructed by the researcher. The attitude test is designed to classify the emotional feelings.

Positive attitudes are emotional feelings expressed as satisfaction, agreement, and favor towards the sandy shores environment.

Negative attitudes are emotional feelings expressed as dissatisfaction, disagreement, and disfavor of towards the sandy shores environment.

Related Research

Recently published papers in the proposed project area include:

Bodzin, Williamson and Price (2002: Online) study on "Learning biology with a web-enhanced curriculum". This is a new basal biology curriculum for ninth and tenth grade students that integrate the World Wide Web with a short topic-oriented textbook. The materials, called Exploring Life, have been developed to directly facilitate student learning by inquiry-based activities and simulations presented over the World Wide Web. It also includes investigative “wet” laboratories, field studies, and a short, concept oriented textbook. There are three chapters in the Exploring Life program, cellular respiration, photosynthesis, and ecology. A concurrent integrative evaluation process was used to evaluate the Exploring Life program. The aim of the research was to discover which factors and issues were important for biology teachers in successfully implementing Exploring Life with their students.

There are many phases in this research. This is the report at the end of the first year. Forty-two high school biology teachers participated in the evaluation of the materials, Exploring Life, during the 1st year. The participants reviewed the Exploring Life Web-based and text materials using the inquiry method in various stages of development at one of three evaluation workshops. And then, eighteen participants tested Exploring Life materials with 783 students. The findings of the classroom field observations will be evaluated and used for developing the next stage. The next stage is to test revised chapters with a larger sample of biology classes.

Krajcik; et.al. (2003: Online) study on “Inquiry based science supported by technology: Achievement among urban middle school students”. The research is making inquiry-based science supported by technology tools and represents a new kind of learning. The researcher worked with teachers to develop a project-based science curriculum and relevant pedagogy and with learners to use technologies to support inquiry. The material was implemented by an innovation comprised of a number of interlocking components, curriculum, technology, and professional development. The researchers have developed a set of computational tools which are called learner-centered design (LCD).

The results are that achievement gains were found in all four curricula across years in overall scores and content-based scores. Scientific process scores improved in most of the curricula as well. Teachers and other factors associated with the schools took several interactions of curriculum development to fine tune the units so they could better engage students in science inquiry and capitalize on the possibilities afforded by new learning technologies.

Kew-Cheol; et.al. (2003: 18-22) study on “Application of virtual reality technology in biology education”. The research was about a learning program for middle school students. It aimed to evaluate the programs’ educational value. Virtual reality (VR) is one of a range of more recent computer-based technologies that may increase the possibilities for interactivity. For example, the potential of virtual reality biology simulations (VRBS) in biology education is enormous, including interactivity, engagement and remote access for learners. Virtual Reality Technology (VRT) may be used as a means of enhancing, motivating and stimulating students' understanding of certain events. VRT focuses students' personal learning and hands-on activities in a virtual environment, and it may be very useful to help them understand otherwise abstract scientific concepts. Virtual Reality Technology (VRT) has many advantages over other learning techniques and as computers have become more prevalent in education, students' familiarity with the technology has enabled the development of more VR learning tools. The findings of this study revealed that VRT could influence student biology learning. VRBS helped students actively participate and immerse in learning activities making it preferable to other multimedia programs.

CHAPTER 3

RESEARCH METHODOLOGIES

The researcher developed an e-learning module on sandy shores ecosystem for Mathayomsuksa 2 Students. The following procedures were used in the development:

1. Population and Sample Groups
2. Research Instruments
3. Experimentation
4. Data Analysis
5. Statistical Devices for Data Analysis

Population and Sample Groups

Population

The population consisted of five classes of Mathayomsuksa 2 students at Sunthonphu Pittaya Secondary School in Klang District, Rayong Province, studying in the second semester of the 2006 academic year.

Sample groups

The sample groups, derived by means of purposive sampling, included three classes of Mathayomsuksa 2 students at Sunthonphu Pittaya Secondary School in Klang District, Rayong Province, studying in the second semester of the academic year 2006.

Research Instruments

The research instruments were classified into two sections. The first describes the types of research instruments, and the second describes constructing and checking the quality and efficiency of research instruments.

Section 1: Types of Research Instrument

1.1 The e-learning module and the e-learning module manuals.

1.1.1 The e-learning module: The module was designed in the form of interactive lessons. The components of the e-learning module in each lesson were divided into five categories: learning objectives, concepts and subject contents, pre-assessment, learning activities, and post-assessment. The 5E Instructional Model was the main model used.

The e-learning module was divided into six lessons as follows:

Lesson 1: Living Organisms and Adaptation of Living Organisms in sandy shores ecosystem

Lesson 2: Components of sandy shores ecosystem

Lesson 3: Food Chains and Food Webs in sandy shores ecosystem

Lesson 4: Mineral Cycles and Water Cycle

Lesson 5: Population

Lesson 6: Conservation in sandy shores ecosystem

1.1.2 The e-learning module handouts: The handouts described how to use the e-learning module for users, both students and teachers, and were also recorded in the CD-Rom.

1.1.3 Instructional media: The instructional material was delivered via computer in form spoken and written form with pictures, such as illustrations, photos and animation.

1.2 Study plans

The researcher composed eight study plans which were relevant to the science curriculum Substance 2: Life and Environment of Key Stage 3, Standard Sc. 2.1 and Standard Sc. 2.2, objectives of the e-learning module, and learning activities. The components of each study plan were divided into five categories as follows:

1.2.1 Learning objectives

1.2.2 Concepts and subject contents

1.2.3 Teaching and learning activities

1.2.4 Instructional media

1.2.5 Measurement and evaluation

1.3 A student academic achievement test

The test was designed to measure students' abilities in four areas: knowledge, understanding, application, and scientific process skills. Scientific process skills related to the subject contents in this research were observation, classification, and inferring skills.

1.4 An evaluation form on ICT skills

The evaluation form was designed to measure students' ability in using information and communication technology (ICT) until they become skills. In this research, ICT skills evaluated were searching from electronic media skill, organizing data and communication skill, and presentation skills.

1.5 An attitude inventory form towards sandy shores environment

The attitude inventory form was designed to classify the students' emotional feelings and opinions towards sandy shores environment in two aspects: positive attitudes and negative attitudes.

Section 2: Constructing and Checking the Quality and Efficiency of Research Instruments

2.1 The e-learning module

The e-learning module was constructed by the researcher and recorded in CD-ROM. The module was developed on with six lessons as described in detail in Section 1.1.1. The quality and efficiency of the e-learning module was checked by means of the following steps:

2.1.1 The e-learning module was checked for its content validity, consistency, and language usage by five experts, one expert for each area: e-learning module development, science teaching and learning, educational measurement and evaluation, educational technology, and marine ecology. The Index of Consistency (IOC) was calculated. Items with an IOC higher or equal to 0.5 were selected and edited according to the experts' comments.

2.1.2 After the e-learning module had been edited according to the comments of the experts, it was test as pilot three times with forty-eight Mathayomsuksa 2 students studying at Sunthonphu Pittaya Secondary School, who were not selected as the sample groups. The first stage was testing the efficiency. The e-learning module was tested with three students at three different levels of learning outcomes: low, medium, and high, and with another fifteen then thirty student, respectively, with learning outcomes at different levels.

2.1.2 The second stage began after the pilot testing; the e-learning module was then revised and investigated for its efficiency. The criterion set for the evaluation of the e-learning module efficiency was 80/80 or higher. Finally, the e-learning module was improved before being used with the sample groups.

2.2 Study plans

The study plans were composed by the researcher and recorded on a CD-Rom. The processes of developing study plans are described as follows:

2.2.1 Studying the science curriculum

The researcher studied the science curriculum of B.E. 2544, Substance 2: Life and Environment, Standard Sc. 2.1 and Standard Sc. 2.2, and then analyzed the contents and developed the e-learning module by dividing the module into six lessons as described in detail in Section 1.1.1. The contents of Substance 2: Life and Environment for Key Stage 3, Standard Sc. 2.1 and Standard Sc. 2.2, related to the study was summarized in Table 2 on Page 51.

2.2.2 Analyzing objectives of the e-learning module

This component is the most important. The objectives of the e-learning module stated what the students will achieve after learning. The objectives must be precise and measurable. The researcher analyzed the objectives of the e-learning module which were relevant to six lessons. These are described in greater detail in Section 2.2 on page 44.

2.2.3 Preparing study plans and constructing instructional media based on the objectives of the e-learning module, the subject contents and learning activities as defined.

2.2.4 Checking study plans for their content validity by five experts, and editing for the suitability of language used.

2.2.5 Revising study plans to implement with the students

The eight study plans for the e-learning module on sandy shores ecosystem, prepared by the researcher, contained ten units, requiring twenty class periods. The summary of the eight study plans is shown in Table 3 on Page 52-53.

2.3 A student academic achievement test

The academic achievement test constructed by the researcher was based on the contents of sandy shores ecosystem. The test consisted of 60 multiple-choice questions evaluating academic achievement in four areas: (1) 5 questions on knowledge (2) 23 questions on understanding (3) 12 questions on application (4) 20 questions on scientific process skills. The testing instrument was checked for quality as follows:

2.3.1 The test was checked for its content validity and the usage of language by five experts in five areas: e-learning module development, science teaching and learning, marine ecology, educational technology, and educational measurement and evaluation, with one expert for each area. The test was calculated for its Index of Consistency (IOC). Questions with an IOC above or equal to 0.5 were selected and the test was then revised according to the experts' comments.

2.3.2 The test was checked of its Difficulty of Index (p) and discrimination Index (r) by administrating the test to forty eight Mathayomsuksa 2 students at Sunthonphu Pittaya Secondary School, who were not selected as the sample group. Each question of the test was selected by considering of the p value between 0.20 and 0.80, and the r value above 0.20.

2.3.3 The whole test paper was calculated for its reliability by means of Kuder Richardson formula 20 (KR-20). The reliability of the test was 0.51.

2.3.4 The final version of the test was administered to the sample group. The test was to assess students' achievement in pilot testing and in the field testing experiment.

2.4 An evaluation form on ICT skills

2.4.1 The evaluation form, constructed by the researcher and written in the diskette, was checked for its content validity, consistency, and language usage by 5 experts in 5 areas: e-learning module development, science teaching and learning, marine ecology, educational technology, and educational measurement and evaluation, with one expert on each particular area. The test was calculated for its Index of Consistency (IOC). The IOC value was selected at above or equal to 0.5, and the test was then revised according to the experts' comments.

2.4.2 The evaluation form on ICT skills was checked for its efficiency. The criterion set for the evaluation of the test efficiency was 80/80. Finally, the test was improved before using with the sample group.

2.5 An attitude inventory form towards sandy shores environment

2.5.1 The attitude inventory form, constructed by the researcher, was designed for assessing students' feelings and opinions towards the sandy shores environment. The form contained twenty statements of a Linkert-scale type consisting of five categories: 5 = strongly agree, 4 = agree, 3 = neither agree nor disagree, 2 = disagree, and 1 = strongly disagree. The item statement was two-tailed with a positive side and a negative side.

2.5.2 The attitude inventory form was checked for its content validity and the usage of language by five experts in five areas: e-learning module development, science teaching and learning, marine ecology, educational technology, and educational measurement and evaluation, with one expert for each area. The form was calculated for its Index of Consistency (IOC). The IOC value was selected at above or equal to 0.5, and the form was then revised according to the experts' comments.

2.5.3 The attitude inventory form was checked for its reliability by administering the form to forty-eight Mathayomsuksa 2 students studying at Sunthonphu Pittaya Secondary School, who were not selected as the sample groups. The students' attitude scores were used to estimate the reliability from the Alpha Coefficient of Cronbach (α-Coefficient) and the reliability of the attitude test was 0.68.

2.5.4 The final version of the attitude test was administered to the sample groups in the field testing experiment.

Table 2 Substance 2: Life and Environment in the science curriculum of B.E. 2544

Substance 2: Life and the Environment

Standard Sc 2.1: The student should be able to understand the local environment, relationship between living things and the environment, interrelationship between living things in different ecosystems, master the investigative processes and scientific thinking, communicate the acquired knowledge for positive use.

Level Standards grade 7 - grade 9

Explore and Analyze status of various local ecosystems, explain relationship between components within the ecosystem, energy transfer, cycles of substance and changes in population size.

Standard Sc 2.2: The student should be able to understand the importance of natural resources, utilization of natural resources at local, national and international levels, master the investigative processes and scientific thinking, communicate the acquired knowledge for positive use and sustainable management of natural resources and local environment.

Level Standards grade 7 - grade 9

Explore and Analyze degree of local environmental problems and natural resources, propose ideas for maintaining balance in the ecosystems, sustainable usage of natural resources based on knowledge of science and technology, also participate in protecting the environment and solving its problems.

Source: Curriculum and Instruction Development, Department. 2002: 3

Table 3 Study Plans: Sandy Shores Ecosystem for Mathayomsuksa 2 Students

Study Plans

Subject: Sandy Shores Ecosystem **Class:** Mathayomsuksa 2 students

Total: 8 study plans /10 units / 20 periods

Unit	**Period**	**Study Plans**		**Activities**	**Instructional Media / Evaluation**
		No.	**Title**		
1	2	-	-	Pre-test	■ A student academic achievement test ■ An evaluation form on ICT skills ■ An attitude test towards sandy shores environment
2	2	1	Introduction to the use of the e-learning module	L & D	■ The e-learning module handouts
3	2	2	Living Organisms and Adaptation of Living Organisms in Sandy Shores Ecosystem	L & D	■ The e-learning module : Lesson 1
4	2	3	Components of Sandy Shores Ecosystem	L & D	■ The e-learning module : Lesson 2
5	2	4	Food Chains and Food Webs in Sandy Shores Ecosystem	L & D	■ The e-learning module : Lesson 3
6	2	5	Mineral Cycles and Water Cycle	L & D	■ The e-learning module : Lesson 4

TABLE 3 (continued)

Unit	Period	Study Plans		Activities	Instructional Media / Evaluation
		No.	Title		
7	2	6	Population	L & D	■ The e-learning module : Lesson 5
8	2	7	Conservation in Sandy Shores Ecosystem	L & D	■ The e-learning module : Lesson 6
9	2	8	Presentation	Presentation	■ Student's slides from lesson 1-6 (3 minutes per person)
10	2	-	-	Post-test	■ A student academic achievement test ■ An evaluation form on ICT skills ■ An attitude test towards sandy Shores Environment

Note:

1. One period is equal to 50 minutes.
2. L & D means learning and doing in the e-learning module.

Experimentation

Experimental design

The experimental design used was One-group pretest-posttest design, as shown in Diagram 1 (Wongrattana. 2001: 383)

Diagram 1

Pre-test	Independent Variable	Post-test
T_1	X	T_2

X refers to treatment

T_1 refers to pre-test

T_2 refers to post-test

Stages in Research

The development of the e-learning module was divided into four stages, with details below:

Stage 1 Studying and Analyzing Basic Information

This stage was to prepare of necessary information for developing the e-learning module. The researcher studied information from the following resources:

1. Documents, textbooks and related studies.

1.1 Concepts and theories about developing e-learning modules, based on Piaget's Developmental Psychology, Concepts of psychology of learning, namely Jerome S. Brurer's discovery approach and constructionism approach, and Gange's learning theory.

1.2 5E instructional model.

1.3 Concepts and student outcomes of the science curriculum of B.E. 2544 on Substance 2: Life and Environment for Key Stage 3, Standard Sc. 2.1 and Standard Sc. 2.2.

1.4 Research on e-learning module development, environment, ecology, and the sandy shores ecosystem.

2. Science teachers' opinions

2.1 The questionnaire, constructed by the researcher, was designed for assessing secondary science teachers' opinions towards teaching and learning science by means of e-learning, including problems, and solutions.

2.2 The questionnaire was divided into the following sections:

Section 1: General information of the respondents

Section 2: Problems and needs for teaching and learning in Substance 2: Life and Environment, Standard Sc. 2.1 and Standard Sc. 2.2

Section 3: Problems and needs for using computers in teaching and learning science.

Section 4: Problems and needs for using e-learning in teaching and learning science.

2.3 The respondents were twenty-four secondary science teachers who taught science in Chonburi, Rayong, Chantaburi, and Trat, with six science teachers from each province.

Stage 2 Developing the E-Learning Module and Investigating Its Efficiency

This stage was to construct the e-learning module based on the results of the studies in the first stage. Four steps were carried out in this stage: Step 1 Creating the e-learning module objectives and framework; Step 2 Checking the e-learning module framework; Step 3 Revising the e-learning module according to the experts' comments; and Step 4 Test piloting the e-learning module and investigating its efficiency

Step 1 Creating the e-learning module objectives and framework

The concepts and theories for developing the e-learning module, and the results of the studies in the first stage, were applied in developing the e-learning module. It included these components:

1. E-learning module components

1.1 Rationale

1.2 Objectives

1.3 Pre-assessment

1.4 Learning Activities

1.5 Post-assessment

2. Defining the subject contents in each component

2.1 Rationale: Stating the background, the framework of the module, and a summary of the basic knowledge necessary for the teaching and learning process to help the students understand what they have learned.

Stating the rationale was based on necessity, by considering the information gained from studying related research, as well as information from the questionnaire on opinions of the science teachers teaching in Substance 2: Life and Environment, Standard Sc 2.1 and Standard Sc. 2.2. The information collected would be used to specify the lessons of the e-learning module and as guidelines to define the objectives of the module.

Defining the basic concepts in developing the e-learning module was based on the philosophy of providing instruction congruent with the necessity of Basic Education Curriculum, Science Learning Substances, including the learning principles in sandy shores ecosystem which could be applied in developing learning activities by means of the 5E instructional model.

2.2 Objectives of the e-learning module: The objectives stated in the e-learning module must be in accordance with necessity. In this research, the objectives stated were to develop the e-learning module on sandy shores ecosystem for Mathayomsuksa 2 students, and to expect that after having followed the objectives of the e-learning module, the students were able to solve problems and that the module lessons could serve the needs of the learners and their communities.

The objectives of the e-learning module were defined in relation and relevance to the six lessons. The objectives of the e-learning module were defined as follows:

2.2.1 Students can explain species and adaptation of living organisms in sandy shores.

2.2.2 Students can explain components of the sandy shores ecosystem.

2.2.3 Students can explain food chains and food webs in the sandy shores ecosystem.

2.2.4 Students can explain mineral cycles and water cycle.

2.2.5 Students can define populations and communities in the sandy shores ecosystem.

2.2.6 Students can explain the conservation methods for the sandy shores ecosystem.

2.3 Creating the module framework: The module framework created must be in congruence with the objectives of the e-learning module. The framework of the e-learning module was divided into the six lessons as described in Section 1.1.1, Page 47. The components of the e-learning module in each lesson were then divided into five categories as described in detail in Step 1, Page 57.

2.3.1 Learning objectives: The learning objectives stated what the students will achieve after learning. They were to specify the desirable behavior intended to develop in the students themselves.

2.3.2 Concepts and subject contents: Concepts and subject contents described in the module concept and summary of basic knowledge necessary and be used as guidelines for students.

2.3.3 Pre-assessment: Pre-assessment was to investigate the students before learning to determine whether they have enough necessary knowledge and skills specified in the learning objectives. The learning activities were selected to suit the students' learning stage.

2.3.4 Learning activities: Learning activities must be arranged in line with the stated learning objectives. The learning activities were based mainly on the 5E instructional model, which included engagement, explorations, explanation, elaboration, and evaluation.

2.3.5 Post-assessment: Post-assessment was provided after learning and included four aspects evaluated in the pre-assessment.

2.4 Writing the subject contents: The subject contents were written in accordance with Learning Standards of Key Stage 3, secondary education Mathayomsuksa 1-3, and with the content specified in Substance 2: Life and Environment, Standard Sc 2.1 and Standard Sc. 2.2. The e-learning module was composed of six lessons with details of the subject contents as in each lesson, developed by the researcher.

2.5 Instructional media: Instructional media were congruent with the subject contents and learning activities. The instructional media, constructed by the researcher, were in the form of educational games, simulations, and multimedia contained in the e-learning module.

2.6 Measurement and evaluation: Measurement and evaluation must be congruent with the objectives of the e-learning module, learning objectives, subject contents, learning activities, and instructional media. The measurement and evaluation systems were:

2.6.1 Student achievement assessment: Student achievement assessment was evaluated from the results of pre-assessment and post-assessment. The instrument used was an academic achievement test covering both formative and summative evaluations.

2.6.2 ICT skills assessment: The students' ICT skills were assessed from the results of before and after instruction. The instrument used was an evaluation form of ICT skills.

2.6.3 Attitude assessment: The assessment of the students' attitudes towards sandy shores ecosystem could be measured before and after instruction. The instrument used was an attitude inventory.

Step 2 Checking the e-learning module framework

After the construction of the e-learning module framework, it was evaluated for its efficiency by eliciting experts' comments in the following areas:

1. Criteria of the experts

The e-learning module framework was checked by five experts, one expert for each area, as described in Section 2.1.1, Page 49.

2. Instruments and methods of their construction

2.1 The e-learning module framework was checked for its content validity, consistency, and language usage by five experts. The experts checked the e-learning module framework by a questionnaire with the following details:

2.1.1 Checking the consistency among the components of the e-learning module with a 3-point level as follows:

+1	refers to	consistent
0	refers to	uncertain
-1	refers to	inconsistent

2.1.2 The evaluation form used was checked for consistency of subject contents, characteristics of question items, and language suitability. The evaluation form was then calculated for its Index of Consistency (IOC).

Step 3 Revising the e-learning module according to the experts' comments

1. Collecting the data

In the process of checking the e-learning module framework, official letters were requested from the Graduate School of Srinakarinwirot University. The researcher herself contacted experts and gave them the e-learning module framework and evaluation form.

2. Analyzing the data

The data was analyzed using these steps:

2.1 Ensuring the evaluation form was complete

2.2 Defining the criteria for considering

The scores of the consistency and content validity were collected from the evaluation form. The scores were placed in the formula for calculating Index of Consistency (Saiyot & Saiyot. 1995: 248-249). Index of Consistency scores of 0.5 or more were considered acceptable.

3. Evaluating the e-learning module framework

The data gained from the evaluating the e-learning module framework by the experts was used to establish criteria for revising the e-learning module. The criteria included:

3.1 An Index of Consistency score of 0.5 upwards was acceptable with no need of revision.

3.2 Apart from the comments for question items, any suggestions being of consistency from five experts were added up in the e-learning module.

Step 4 Test piloting the e-learning module and investigating its efficiency

The e-learning module was test piloted with students, who were not members of the sample groups, to investigate the module's efficiency. The procedure had two steps:

1. Test piloting the module

The e-learning module was edited based on experts' comments and by following Step 3. The revised module then was tested three times with forty-eight Mathayomsuksa 2 students, who were not in the sample groups. The first stage was testing for the efficiency. The e-learning module was tested with three students of three different learning outcome levels: low, medium, and high, and with another fifteen then thirty student, respectively, with learning outcomes at all different levels. After each testing, the e-learning module was improved and revised before being used with the sample groups.

2. Improving the module

After each testing, the e-learning module was revised and integrated for the efficiency. The criterion set for the evaluation of the e-learning module efficiency was 80/80.

Stage 3 Field Testing the E-Learning Module

After the e-learning module was test piloted, it was evaluated. The results obtained were used for improving the module by making it more correct and consistent for the next stage of field testing:

1. Experimentation Procedure

The experimentation consisted of the following steps:

1.1 Setting the time period for experimentation based on the study plans of sandy shores ecosystem for three classes of Mathayomsuksa 2 students, studying in the second semester of the academic year 2006, at Sunthonphu Pittaya Secondary School, Klang District, Rayong Province. Two periods, of fifty minutes each, was spent for teaching each unit. Ten units were used, which covered eight study plans in twenty periods. The teaching ran from November to December, 2006.

1.2 Preparation before implementing the module

Before implementing the module, the researcher prepared the following:

1.2.1 Constructing supplementary documents for the e-learning module, e.g. the e-learning module handouts and study plans.

1.2.2 Preparing the instructional media. This included educational games, simulations, and multimedia in a CD-ROM contained in the module.

1.2.3 Preparing training materials. These materials were used for training science teachers before the field testing. Because sandy shores ecosystem is a new subject, the researcher must organize the training for the science teacher in both subject matter and teaching process by using the e-learning module. After the training, it was expected that the teachers were able to teach it and to effectively achieve the module's objectives.

1.2.4 Preparing classrooms and teaching equipment and asking for cooperation from school directors to encourage students to attend class regularly.

1.3 Experimentation

The experimentation process was divided into the following steps:

1.3.1 Purposive sampling of three classes of Mathayomsuksa 2 students at Sunthonphu Pittaya Secondary School, Klang District, Rayong Province, as the sample groups.

1.3.2 Three classes of sample groups were taught through the e-learning module by a teacher who attended the training as stated in 1.2.3. The students completed the learning activities as specified in the e-learning module. The results of the field testing experiment were collected as well.

1.3.3 In administering the academic achievement test, the ICT skills evaluation form, and the attitude inventory form on the sandy shores environment were administered to students in three classes of the sample groups before and after the experimentation of implementing the e-learning module.

1.3.4 The students' academic achievement, students' ICT skills, and attitudes towards sandy shores environment before and after learning with the module were compared.

1.3.5 Investigating the relationship between the students' academic achievement after learning with the module and learning outcomes of the science, which were divided into three levels: good, fair, and low. The students' learning outcomes in studying science used in the comparison were their grades from studying science while in the first semester of Mathayomsuksa 2, in the 2006 academic year. The criteria considered were as follows:

A science learning outcome with the grade higher than 2.50 was considered as good.

A science learning outcome with the grade higher than 2.50 was considered good

A science learning outcome with the grade between 2.00-2.50 was considered fair.

A science learning outcome with the grade lower than 2.00 was considered low.

1.3.6 Examining the relationship between students' ICT skills after using the e-learning module and their science learning outcomes, which were divided into three levels: good, fair, and low, according to the criteria in 1.3.5.

1.3.7 Comparing the students' academic achievement and their ICT skills on the three sample groups after using the module.

Stage 4 Improving the E-Learning Module

After the e-learning module was field tested and evaluated, the data analysis results were used for improving the module to make it more complete and appropriate so it could be developed into e-learning module prototype on sandy shores ecosystem for Mathayomsuksa 2 students.

Data Analysis

1. Analyzing the data collected from the academic achievement test, the evaluation form on ICT skills, and the attitude inventory form on sandy shores environment by means of descriptive statistical devices. The data were processed by computer through SPSS for Windows Program.

2. Comparing the students' academic achievement test score, ICT skills, and attitudes towards sandy shores environment before and after learning through the module, in each sample group, by means of a dependent t-test.

3. Investigating the relationships among students' academic achievement test score, ICT skills of the three sample groups, and their science learning outcomes were divided into three levels as stated, by means of Pearson's product moment correlation coefficient. (Wongrattana. 2001: 314)

4. Comparing the students' academic achievement test score and ICT skills after using the module with the three sample groups by means of One-way analysis of variance (ANOVA).

Statistical Devices for Data Analysis

The statistical devices employed for data analysis were:

1. Basic statistical devices, for instance, mean ($\overline{X}$), and standard deviation (SD).
2. Statistical devices for checking the quality of the instruments.

2.1 The academic achievement test

2.1.1 The Difficulty of Index (p) and Discrimination Index (r) of each item of the tests were calculated by the following formulas: (Saiyot & Saiyot. 1995: 210-211)

$$p = \frac{(R_H + R_L)}{(n_H + n_L)}$$

$$r = \frac{(R_H - R_L)}{n_H} \quad \text{or} \quad r = \frac{(R_H - R_L)}{n_L}$$

p	represents the difficulty level value
r	represents the discrimination power value
R_H	represents the number of students answering correctly in the high academic achievement score group
R_L	represents the number of students answering correctly in the low academic achievement score group
n_H	represents the number of students in the high academic achievement score group
n_L	represents the number of students in the low academic achievement score group

2.1.2 Reliability of the whole test by means of Kuder Richardson (KR-20) (Saiyot & Saiyot. 1995: 197-198)

$$r_{tt} = \frac{n}{n-1}\left\{1 - \frac{\sum pq}{S_t^2}\right\}$$

r_{tt}	represents the reliability coefficient
n	represents the number of test items
p	represents the proportion of students answering each item correctly, i.e. proportion of students answering correctly to the total number of students
q	represents the proportion of students making answering incorrectly each item or I-p
r_{xy}	represents the variance of the whole test
S_t^2	represents the variable score of whole test

2.2 The quality of the attitude inventory form towards sandy shores environment.

The reliability of the whole test was calculated by means of Cronbach's Alpha Coefficient (α – Coefficient) (Saiyot & Saiyot. 1995: 210-213)

$$\alpha = \frac{n}{n-1}\left\{1 - \frac{\sum S_i^2}{S_t^2}\right\}$$

α	represents the test's reliability
n	represents the number of test items
$\sum S_i^2$	represents the variance of each item

2.3 The efficiency of the e-learning module and the evaluation form on ICT skills.

2.3.1 The content validity was calculated by means of Index of Consistency (IOC). (Saiyot & Saiyot. 1995: 248 – 249)

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

IOC	represents Index of Consistency between the test and learning objectives
$\sum R$	represents summation of experts' consideration
N	represents number of experts

2.3.2 Calculating for the efficiency of the module and the evaluation form on ICT skills according to the standard criterion 80/80.

E_1 refers to efficiency of the process, calculated in percentage of the mean score from doing exercises and learning activities.

E_2 refers to efficiency of the outcomes or behavior changed in the students themselves after learning, calculated in percentage of the post test score.

Calculating for E_1 and E_2 of the e-learning module the evaluation form on ICT skills could be done by using the following formulas: (Saiyot & Saiyot. 1995: 220-221)

$$E_1 = \frac{\left[\Sigma x / n \right]}{A} \times 100$$

E_1	represents the efficiency of the process
Σx	represents the summation score students gained from doing the learning activities
A	represents the total score of exercises in the learning activities
n	represents the number of students

$$E_2 = \frac{[\Sigma x/n]}{B} \times 100$$

E_2 represents the outcomes' efficiency

Σx represents the summation of score students gained from doing the learning activities

B represents the total score of posttest

n represents the number of students

3. Statistics for hypotheses testing.

3.1 Comparing the students' academic achievement test score, their ICT skills, and attitudes towards sandy shores environment before and after learning with the module, in each sample group, by means of a dependent t-test.

3.2 Investigating the relationships among students' academic achievement test score, their ICT skills of the three sample groups, and their science learning outcomes divided into three levels as stated, by means of Pearson's product moment correlation coefficient. (Wongrattana. 2001: 314)

3.3 Comparing the students' academic achievement test score, their ICT skills after learning with the e-learning module of the three sample groups by means of One-way analysis of variance (ANOVA).

CHAPTER 4

FINDINGS

The main objective of the research was to develop an e-learning module on the sandy shores ecosystem for Mathayomsuksa 2 Students. The module's development was divided into four stages: Stage 1 Studying and analyzing basic information, Stage 2 Developing the e-learning module and investigating its efficiency, Stage 3 Pilot testing the e-learning module, Stage 4 Improving the e-learning module. The findings are summarized into two sections as follows:

Section 1: E-Learning Module Development

Stage 1 Studying and Analyzing Basic Information

The researcher studied and collected basic information from research studies and opinions from science teachers. The results were as follows:

1. Documents on e-learning module development

The study revealed that the sandy shores ecosystem has been part of the science learning substance, Substance 2: Life and environment, according to the Standard Sc. 2.1 and Standard Sc. 2.2. (Curriculum and Instruction. 2002: 25) The 5E instructional model was chosen as the core model of learning in each lesson of the e-learning module. The study showed that the collected information was used to specify the lessons of the e-learning module and as guidelines to define the module's objectives.

2. A study of science teachers' opinions

The study revealed useful information, problems and needs as well as recommendations from the teachers, which were taken into consideration during the development and improvement of the module. The information obtained from the respondents can be summarized as follows.

Section 1: General Information

Of all twenty-four Science teachers, 21 percent were male and 79 percent were female. Approximately 37.50% were between 20–29, 16.68% were 30-39, 29.26% were 40–49 and 16.66% were over 50 years old. Bachelor degree holders made up 91.67%, and while 8.33% held master's degrees. In terms of teaching load, 61.99% taught less than 20 hours per week, while 38.51% had load between 20-24 hours per week. All respondents had other responsibilities apart from teaching.

Section 2: Problems and needs for teaching and learning in Substance 2: Life and Environment, Standard Sc. 2.1 and Standard 2.2

The model of learning most frequently used by the respondents was the lecture method, (83.33% of them). The second and the third most popular methods were the 5E instructional model and cooperative learning, with 58.33% and 58.30% of the respondents, respectively.

Concerning the topic of sandy shores ecosystem, it was found that only 25% of the respondents taught this topic. The problems arising from teaching this topic were lack of knowledge about it and an inability to take students on a field trip. Instead they had to select topics in other ecosystems, for instance, Fresh Water Ecosystem. With regards to teaching about the sandy shores ecosystem, it was found that they needed the following types of support: instructional media, additional knowledge, and instructional methods, calculated into percentage this represented 62.50%, 54.17%, and 41.67% of the respondents, respectively.

Section 3: Problems and needs for using computers in teaching and learning science

The respondents used computer in teaching and learning science in the following ways: 66.67% used it for information searching, 20.83% used it for test preparation, and 20.83% used it for data calculations and analysis.

Problems arising from using computers in teaching and learning science were availability and inconvenient infrastructure.

The respondents needed support in terms of quantity and quality of computer availability, convenience of the infrastructure provision, including the addition of a computer room for teaching and learning non-computer subjects.

Section 4: Problems and needs for using e-learning in teaching and learning science

When asked about using e-learning in teaching and learning science, 66.67% said they used CAI, 20.83% used CD-ROM, and 20.80% used e-learning packages.

The topics taught were the Blue Planet, the Earth's Atmosphere, and Force and Mobility. E-learning packages on Sandy Shores Ecosystem had never been found.

The respondents perceived the usefulness of e-learning in teaching and learning science as supplementary media (91.67%) for learning, self-study (70.83%), and (66.67%) remedial teaching.

The problems arising from using e-learning in teaching and learning science were difficulty of learning lessons, incompatibility of time and activities, and lack of variety in subject contents.

The respondents needed changes in the following aspects: the learning mode of e-learning, compatibility of time and activities, learners' learning development, including a wide variety of subject contents.

Stage 2 Developing the E-Learning Module and Investigating Its Efficiency

Three steps were conducted in this stage, as follows:

Step 1 Creating the e-learning module objectives and framework

The outcome was as follows:

1. The e-learning module was divided into six lessons as described in detail in Section 1.1.1, Page 47.

Each lesson had the following components as described in detail in Stage2 (Step1), Page 57.

1.1 Rationale: The rationale was based on information from studying related research and the questionnaire given to the relevant science teachers.

1.2 Objectives of the e-learning module: Six objectives were determined.

1.3 Pre-assessment: The measurement and evaluation, for both pre-assessment and post-assessment, for the students were linked to the learning objectives, subject contents, learning activities, and instructional media.

1.4 Learning activities: The main learning activities in each lesson were mainly based on the 5E instructional model. The module was designed in the form of interactive lessons. The instructional media was delivered via computer using text and visuals as well as multimedia.

1.5 Post-assessment: Post-assessment covered the same four areas that were in the pre-assessment.

Step 2 Checking and revising the e-learning module framework and study plans

The e-learning module framework was evaluated for its efficiency by obtaining feedback from experts as follows:

2.1 The e-learning module framework was checked for its content validity, consistency, and language usage by five experts as describe in detail in Section 2.1.1, Page 49. The results of evaluating the quality of the e-learning module framework are shown in Table 4.

Table 4 The results of evaluating the appropriateness of the e-learning module framework according to experts' opinions

No.	Evaluation topic list	No. of items	N=5 Mean	S.D.	Results
1.	content and content development	5	4.80	0.14	Appropriate
2.	measurement and evaluation	5	4.64	0.43	Appropriate
3.	organization of instructional materials	5	4.56	0.26	Appropriate
	Total	15	4.66	0.12	

From Table 4, the results show that the framework on was appropriate in all areas; therefore, this e-learning module was ready for the next step.

2.2 The study plans were checked for content validity and edited for language suitability by five experts as describe in detail in Section 2.1.1, Page 49. The results show eight study plans for ten of the learning units as describe in detail in Table 3, Page 53-54. The results of evaluating the quality of the e-learning module framework are shown in Table 5, on Page 70.

Table 5 The results of evaluating the congruence of item-objectives (IOC) with the study plans

No.	The item consideration	N = 5 Mean	S.D.	Interpretation
1.	Learning objectives of the study plans with the objectives of the e-learning module	4.8	0.44	Appropriate
2.	content of the study plans congruent with focus on the sandy shores ecosystem	4.8	0.44	Appropriate
3.	content of the study plans congruent with the method of using the 5E instructional model	4.6	0.54	Appropriate
4.	content of the study plans congruent with the instructional media	5.0	0.00	Appropriate
5.	content of the study plans congruent with the measurement and evaluation	4.4	0.54	Appropriate

From Table 5, the results of each evaluation list showed that the study plans were appropriate in all areas.

2.3 Other research instruments were used in both the pilot testing and field testing experiment were divided into three categories as follows:

2.3.1 A student academic achievement test: The testing instrument was checked for its content validity and language usage by five experts as describe in detail in Section 2.1.1, Page 49. The results of each evaluation showed that the student academic achievement test was appropriate in all areas.

2.3.2 An evaluation form on ICT skills: The evaluation form was checked for content validity, consistency, and language usage by five experts as describe in detail in

Section 2.1.1, Page 47. The results of each evaluation showed that the evaluation form on ICT skills was appropriate in all areas.

2.3.3 An attitude test towards sandy shores environment: The test was checked for its content validity and the usage of language by five experts as describe in detail in Section 2.1.1, Page 49. The results of each evaluation list showed that the attitude test was appropriate in all areas.

Step 3 Implementing the e-learning module as a pilot testing experiment and investigating its efficiency

The results are, as follows:

1. Problems found in the pilot testing experiment included a misunderstanding of language in some parts, time limitations for some activities, and technical problems with some computers.

2. The e-learning module efficiency was examined at this stage. The findings showed that the e-learning module efficiency was 80.50 / 84.04**,** as shown in Table 6, on Page 72.

3. Other research instruments were used both in the pilot testing and the field testing experiment were divided into three categories as follows:

3.1 A student academic achievement test: The reliability of the test was 0.51, which indicate that the student academic achievement test had enough quality to assess students' achievement.

3.2 An evaluation form on ICT skills: The efficiency of the evaluation form on ICT skills was greater than 80/80. The result showed that the evaluation form on ICT skills had enough quality to use for measuring ICT skills of students.

3.3 An attitude inventory form towards sandy shores environment: The reliability of the attitude inventory form was 0.68, showing that the attitude test had enough quality to use for classifying the student's emotional feelings towards sandy shores ecosystem.

Stage 3 Implementing the E-Learning Module as Field Testing Experiment

The results of this stage were shown in the Section 2: Data Analysis.

Stage 4 Improving the E-Learning Module

The e-learning module was then developed into an e-learning module prototype for sandy shores ecosystem for Mathayomsuksa 2 students.

Section 2: Data Analysis

The results of the e-learning module development were tested for the six research hypotheses.

The first hypothesis stated that “The e-learning module efficiency is 80/80 or higher”.

To test this hypothesis, the e-learning module was calculated for the efficiency. The findings showed that the e-learning module efficiency was higher than 80/80. The results are shown in Table 6 as follows:

Table 6 The e-learning module efficiency in the pilot testing experiment

Sample groups	E_1	E_2	Efficiency E_1 / E_2
Classroom 1	80.56	84.78	80.56 / 84.78
Classroom 2	80.83	84.11	80.83 / 84.11
Classroom 3	80.11	83.22	80.11 / 83.22
Mean	**80.50**	**84.04**	**80.50 / 84.04**

The efficiency value of the e-learning module in all classrooms was 80.50/84.04.

The results of the first hypothesis testing for efficiency of the e-learning module revealed higher efficiency than the standard criterion set, which was at 80/80. Therefore, the results supported this hypothesis.

The second hypothesis stated that “The students’ academic achievement in each sample group, after learning by using the e-learning module, would be higher than before using the e-learning module”.

To test this hypothesis, Students’ scores were used to test the hypothesis by means of t-test dependent. The results are shown in Table 7, on Page73.

Table 7 The comparison of students' academic achievement before and after learning by using the e-learning module

Students' academic achievement	n	Mean	S.D.	t	df	p-value
Class 1						
Pre-test	30	30.20	4.99			
				-26.71	29	0.00*
Post-test	30	50.86	5.69			
Class 2						
Pre-test	30	30.63	4.82			
				-26.92	29	0.00*
Post-test	30	50.46	4.65			
Class 3						
Pre-test	30	30.40	5.10			
				-19.69	29	0.00*
Post-test	30	49.93	5.45			

*p < .05

T-test statistical results indicate that the students' academic achievement in classroom 1, classroom 2, and classroom 3 after using the e-learning module were significantly higher than that of before using the e-learning module at the .05 level.

The results of the second hypothesis testing were represented by score points gained from the academic achievement test of the three classes of students who learned with the e-learning module. The students' academic achievement scores in all sample groups after using the e-learning module were found to be significantly higher than before using the e-learning module at the .05 level. Consequently, the results support this hypothesis.

The third hypothesis stated that "The students' ICT skills in each sample group after using the e-learning module would be higher than that of before learning by using the e-learning module".

To test this hypothesis, students' points were used for hypothesis testing by means of a t-test dependent. The results are shown in Table 8.

Table 8 The comparison of students' ICT skills before and after using the e-learning module

Students' ICT skills	n	Mean	S.D.	t	df	p-value
Class 1						
Pre-test	30	13.63	0.96			
				-20.94	29	0.00*
Post-test	30	16.76	1.22			
Class 2						
Pre-test	30	14.33	0.75			
				-21.48	29	0.00*
Post-test	30	16.80	1.06			
Class 3						
Pre-test	30	14.26	0.73			
				-16.52	29	0.02*
Post-test	30	16.93	.86834			

* $p < .05$

T-test statistical results indicate that the students' ICT skills in classroom 1, classroom 2, and classroom 3 after using the e-learning module were significantly higher than before using the e-learning module at the .05 level.

The results of the third hypothesis testing were represented by ICT skills of three classes of students who used the e-learning module. These students' ICT skills were found to be significantly higher than before learning using the e-learning module at the .05 level. Accordingly, the results supported this hypothesis.

The fourth hypothesis stated that "The students' attitude towards sandy shores environment in each sample group after using the e-learning module would be higher than before using the e-learning module".

To test this hypothesis, students' mean scores were used for hypothesis testing by means of a t-test dependent. The results are shown in Table 9, on Page 75.

Table 9 The comparison of student's attitudes towards sandy shores environment before and after using the e-learning module

Students' attitudes towards Sandy Shores Environment	N	Mean	S.D.	t	df	p-value
Class 1						
Pre-test	30	81.96	6.33			
				-1.14	29	.16
Post-test	30	84.53	9.04			
Class 2						
Pre-test	30	82.00	6.10			
				-1.41	29	.15
Post-test	30	85.06	8.72			
Class 3						
Pre-test	30	81.80	5.80			
				-1.74	29	.21
Post-test	30	85.40	8.42			

*p < .05

T-test statistical results indicated that the attitudes towards sandy shores environment in classroom 1, classroom 2, and classroom 3 after learning by using the e-learning module were found to be no higher than before using the e-learning module.

The results of the fourth hypothesis testing, the students' attitudes towards sandy shores environment in each sample group after using the e-learning module were found not to be higher than before using the e-learning module. The results did not support this hypothesis.

The fifth hypothesis stated that "The students' academic achievement and ICT skills after using the e-learning module are related to their different levels of science learning outcomes".

To test this hypothesis, students' mean scores of academic achievement and students' science learning outcomes were used for hypothesis testing by means of the Pearson's product moment correlation coefficient. The results are shown in Table 10.

Table 10 The relationship between the students' academic achievement and the science learning outcomes, divided into three levels, after using the e-learning module

Details		Levels of science learning outcomes	Achievement scores after learning
Levels…	Pearson Correlation	1	.69*
	Sig. (2tailed)		.00
	N	90	90
Score…	Pearson Correlation	.69*	1
	Sig. (2tailed)	.00	
	N	90	90

* p<.05

Pearson's product moment correlation coefficient statistical results indicated that their academic achievement after using the module were not related to their science learning outcomes in all levels.

To test this hypothesis, students' mean scores of the students' ICT skills and science learning outcomes were used for hypothesis testing by means of the Pearson's product moment correlation coefficient. The results are shown in Table 11, on Page 79.

Table 11 The relationship between the students' ICT skills and science learning outcomes, divided into three levels, after using the e-learning module

Details		Levels of science learning outcomes	ICT skills scores after learning
Levels…	Pearson Correlation	1	.14
	Sig. (2tailed)		.16
	N	90	90
Scores…	Pearson Correlation	.14	1
	Sig. (2tailed)	.16	
	N	90	90

*p<.05

Pearson's product moment correlation coefficient statistical results indicate that their ICT skills after using the module were not related to their science learning outcomes in all levels.

The results of the fifth hypothesis, the students' ICT skills in each sample group after using the e-learning module were not found to be related to their science learning outcomes. Consequently, the results do not support this hypothesis.

The sixth hypothesis stated that "The students' academic achievement and ICT skills of the three sample groups after using the e-learning module would be different".

To test this hypothesis, the mean scores of the students' academic achievement on the three classes of students after using the e-learning module were used for hypothesis testing by means of One-way analysis of variance (ANOVA). The results are shown in Table 12.

Table 12 The comparison of the students' academic achievement on the three sample groups after using the e-learning module

Details	Sum of Squares	df	Mean Square	F	p-value
Between Groups	13.15	2	6.57	.23	.79
Within Groups	2428.80	87	27.91		
Total	2441.95	89			

*p < .05

ANOVA statistical results indicated that the students' academic achievement on the classroom 1, classroom 2, and classroom 3 after using the e-learning module were found to have no difference.

The results of the sixth hypothesis testing, the students' academic achievement of the three sample groups after using the e-learning module were found to have no difference. Thus, the results did not support this hypothesis.

To test this hypothesis, the mean scores of the students' ICT skills on the three classes of students after using the e-learning module were used for hypothesis testing by means of One-way analysis of variance (ANOVA). The results are shown in Table 13.

Table 13 The comparison of the students' ICT skills on the three sample groups after using the e-learning module

Details	**Sum of Squares**	**df**	**Mean Square**	**F**	**p-value**
Between Groups	.46	2	.23	.207	.81
Within Groups	98.03	87	1.12		
Total	98.50	89			

*p < .05

ANOVA statistical results indicate that the students' ICT skills in the classroom 1, classroom 2, and classroom 3 after using the e-learning module were found to not to be different.

The results of the sixth hypothesis testing, the students' ICT skills of the three sample groups after using the e-learning module were found not to be different. Thus, the results do not support this hypothesis.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

This research was to develop an e-learning module on sandy shores ecosystem for Mathayomsuksa 2 Students. The summary, research findings, discussions, and recommendations are summarized below:

Summary

Research objectives

The objective of the research was to develop an e-learning module on sandy shores ecosystem for Mathayomsuksa 2 students.

Scope of the study

Sample groups

The sample groups, derived by means of purposive sampling, included three classes of Mathayomsuksa 2 students at Sunthonphu Pittaya Secondary School in Klang District, Rayong Province, studying in the second semester of the academic year 2006.

Variables

1. Treatment variable: Treatment variable was the e-learning module.

2. Dependent variables: Dependent variables were: 1) academic achievement 2) ICT skills 3) attitudes towards sandy shores environment

Contents of the Research

To meet the objectives of this research, the e-learning module was developed. There were five phases of the 5E instructional model: engagement, exploration, explanation, elaboration, and evaluation. The e-learning module was written in the CD-Rom. The framework of the e-learning module was divided into the following six lessons, as shown:

Module: sandy shores ecosystem

Lesson 1: Living Organisms and their Adaptation in the sandy shores ecosystem.

Lesson 2: Components of the sandy shores ecosystem

Lesson 3: Food Chains and Food Webs in the sandy shores ecosystem

Lesson 4: Mineral Cycles and Water Cycle

Lesson 5: Population

Lesson 6: Conservation in the sandy shores ecosystem

The components of the e-learning module in each lesson were divided into five categories: learning objectives, concepts and subject contents, pre-assessment, learning activities, and post-assessment.

Hypotheses

The researcher generated hypotheses as follows:

1. The e-learning module efficiency is 80/80 or higher.

2. The students' academic achievement in each sample group after using the e-learning module would be higher than before using the e-learning module.

3. The students' ICT skills in each sample group after using the e-learning module would be higher than before using the e-learning module.

4. The students' attitude towards the sandy shores environment in each sample group after using the e-learning module would be higher than before using the e-learning module.

5. The students' academic achievement and ICT skills after using the e-learning module would be related to their different levels in learning science.

6. The students' academic achievement and ICT skills for the three samples after using the e-learning module would be different.

Research Methodologies

The development of the e-learning module was divided into four stages. The details of each stage are as follows:

Stage 1 Studying and Analyzing Basic Information

The researcher studied and collected information from the following resources: 1) documents on e-learning module development 2) opinions from science teachers

Stage 2 Developing the E-Learning Module and Investigating Its Efficiency

This stage was to construct the e-learning module based on the results of the studies in the first stage. Four steps were carried out in this stage: Step 1 creating the e-learning module objectives and framework, Step 2 checking the e-learning module framework, Step 3 revising the e-learning module according to the experts' comments, Step 4 test piloting the e-learning module and investigating its efficiency.

. Stage 3 Field Testing the E-Learning Module

The time period for experimentation is relevant to the study plans on sandy shores ecosystem for three classes of Mathayomsuksa 2 students, as the sample groups. In administering the academic achievement test, the ICT skills evaluation form, and the attitude test on sandy shores environment were administered to students before and after the using the e-learning module.

Stage 4 Improving the E-Learning Module

After the e-learning module was field tested and evaluated, the results of the data analysis were used for improving the e-learning module by making it more complete and appropriate to be developed as an e-learning module prototype for sandy shores ecosystem for Mathayomsuksa 2 students.

Research Findings

The e-learning module was tested for the following six research hypotheses:

1. The results of the first hypothesis testing for efficiency of the e-learning module revealed higher efficiency than the standard criterion set, which was 80/80. Therefore, the results supported this hypothesis.

2. The results of the second hypothesis testing were represented by the score points gained from the academic achievement test of the three classes of students using the e-learning module. Their academic achievement in all sample groups after using the e-learning module was found to be significantly higher than before using the module at the .05 level. Consequently, the results supported this hypothesis.

3. The results of the third hypothesis testing were represented by ICT skills of three classes of students using the e-learning module. Their ICT skills in all sample groups after using the e-learning module were found to be significantly higher than before using the module at the .05 level. Accordingly, the results supported this hypothesis.

4. The results of the fourth hypothesis testing were represented by the scores obtained from the attitude inventory form of three classes of students who used the e-learning module. Their attitudes towards sandy shores environment in all sample groups after using the e-learning module were found not to be higher than before learning by using the module. Consequently, the results did not support this hypothesis.

5. The results of the fifth hypothesis testing, represented by the score points obtained from the students' academic achievement and their ICT skills after using the e-

learning module, were not related to their science learning outcomes. Consequently, the results did not support this hypothesis.

6. The results of the sixth hypothesis testing, represented by the score points obtained from the students' academic achievement and their ICT skills, of the three sample groups after using the e-learning module were found having no difference. Thus, the results did not support this hypothesis.

Discussion

Section 1: The development of the e-learning module

The discussion of the e-learning module is divided into two stages:

Stage 1 Studying and Analyzing Basic Information

The researcher studied and collected basic information from both research related documents and the opinions of science teachers. This idea is supported by Smaldino & Russell. (2005: 182) who stated that a full process of instructional development would begin with a needs assessment. It is the appropriate solution to a performance problem. The discussion of results follows below:

1. Documents on e-learning module development

1.1 Concepts and theories concerning: The module's development started with studying and analyzing concepts and theories about the development of e-learning module, the concepts of the 5E instructional model, research studies, and the learning standards of Thailand's Basic Education Curriculum, B.E. 2544. (Curriculum and Instruction. 2001: 8) These documents were used as guidelines for selecting appropriate contents and learning activities as related to local communities. The Sandy Shores ecosystem was classified as a environmental study and part of science learning substance 2: Life and environment, according to the Standard Sc. 2.1 and Standard Sc. 2.2. (Curriculum and Instruction. 2002: 25). Similarly, Department of Curriculum and Instruction Development (2002: 4) which stipulated that environmental study in Thailand is a requirement in the Basic Education Curriculum of B.E. 2544 and in many substances of subject groups, especially the science subject group.

1.2 The model of learning: The 5E instructional model was a central model of learning in the e-learning module. It is an effective way to engage students in learning and to encourage inquiry skills. This idea is supported by Trowbridge & Bybee. (1996: 213) who stated that the 5E instructional model has five phases: engagement, exploration, explanation, elaboration, and evaluation. According to the 5E instructional model, students can learn scientific concepts and principles faster and develop good attitudes towards teaching and learning science. Similarly, Weld. (2004: 381-382) suggested that the use of the 5E instructional model enables students to build up their knowledge from their past experiences and to teach them the skills of problem solving, which will certainly be useful in other areas of life. Practice within artificially structured situations can allow the more rapid application of these skills in real life.

2. A study of opinions from science teachers

The questionnaire was designed for the assessment of secondary science teachers' opinions towards teaching and learning science by means of e-learning, including problems, and solutions in order to gather information for the development of the e-learning module. Problems and needs according to the opinions of science teachers can be summarized as follows:

2.1 Concerning the topic of the sandy shores ecosystem, it was found that only 25 percent of the respondents used to teach this topic. The problems they stated that arose from teaching this topic were lack of topic knowledge on the teachers' part and an inability to take students for field trips. Instead, they selected topics in other ecosystems. This problem can be solved by using the simulations in the instructional media to replace fieldtrips. This idea is supported by Reynolds & Robertta (1996: 30) who stated that simulations have the advantage of regulating the number of variables in the environment so that intended patterns and relationships become easier to grasp.

2.2 The problems arising from using e-learning in teaching and learning science were the degree of difficulty in learning the subject, incompatibility of time and activities, and lack of variety in subject contents. In designing and developing the e-learning module, the developer should refer to educational theories, cognitive psychology and models of learning to create something which is optimally useful for students. This idea is supported by Newton & Laurence. (2001: 7) who suggested that one of the most important factors of software design that makes programs easy to use and understand depends upon intrinsic properties. The effective application of software in the classroom requires a range of teachers' skills related to their understanding of the curriculum and their own students' needs.

2.3 Problems arising from using computers in teaching and learning science were their unavailability and cumbersome infrastructure. Teachers are capable of obtaining background information on the topic and preparing instructional materials in computer and internet use, so school administrators should provide users both the quantity and the quality of computers, including a convenient infrastructure. This idea is supported by Suktrisul (n.d.: Online) who suggested that the purchase of computers and peripheral equipment will require a major investment from the school and the government.

Stage 2 Developing the E-Learning Module and Investigating Its Efficiency

The concepts and theories concerning the development of the e-learning module, and the results of the studies in the first stage were applied in developing the e-learning module as follows:

1. The e-learning module

The e-learning module had five categories: rational, objectives, pre-assessment, learning activities, and post-assessment. The module was a kind of instructional tool which was complete in it and student-centered. The module's aim was to help students gain knowledge and meet the stated learning objectives. This idea is supported by Moon. (2002: 151-153) who said that "Modules are complete in themselves and are assessed." Similarly, Virginia. (1990: Online) stated that "A learning module is a competency-based tool focused on what a learner will know or be able to do as a result of using the tool."

2. The objectives of the e-learning module

The objectives of the e-learning module were to develop the e-learning module on sandy shores ecosystem for Mathayomsuksa 2 students and prepare them to learning with the module and that the module could effectively serve the needs of the learners and their communities. The researcher defined the module's six objectives so they are relevant to the curriculum. The idea is supported by Houston; et.al. (1972: 15-20) who suggested that objectives are the most important aspect of the module. The objectives state what the learners will achieve after learning.

3. The e-learning module framework

3.1 The framework of the e-learning module was designed in the form of six interactive lessons, as described in detail in Section 1.1.1.

3.2 The components of each lesson were divided into five categories: learning objectives, concepts and subject contents, pre–assessment, learning activities, and post–assessment. It was evident that the e-learning module on sandy shores ecosystem had continual learning steps. Each step was related to the others and also provided a feedback mechanism to the learning activity steps. This idea is supported by Virginia. (1990: Online) who suggested that congruence must be evident between learners' needs and the module's content. Special attention should be directed to outcomes, activities, and evaluation procedures. Similarly, Parson; et.al. (2001: 256-258) who described that Gagne's research revealed that well-designed lessons begin with the arousal of students' interest and then move on to present new material, involve students in practice with feedback, assess their understanding, and go on to follow up activities. The e-learning module incorporated these instructional steps. The components of each lesson are discussed below:

3.2.1 Learning objectives were relevant to the objectives of the e-learning module and actually measurable. This idea is supported by Smaldino & Russell. (2005: 101) who suggested that objectives stated in performance terms as what the learner is expected to gain from studying the module.

3.2.2 Concepts and the subject contents were designed in accordance with Learning Standards of Key Stage 3, and with the contents specified in Substance 2: Life and Environment, Standard Sc 2.1 and Standard Sc. 2.2.

3.2.3 Pre-assessment assessed students before using the e-learning module. Students could do the assessment on screen and check their answers, as well as get immediate feedback by themselves. This idea was supported by Smaldino & Russell. (2005: 104) who suggested that the entry-test determined whether students have mastered the prerequisite skills needed to enter the module.

3.2.4 The learning activities: Learning activities were based on the 5E instructional model in each lesson. The e-learning module took the form of interactive lessons that the students could do on screen. Students had a chance to review information and check their own progress with feedback. This idea was supported by Reynolds & Robertta. (1996: 40) who stated that computers have endless patience in tutorial situations; they have the ability to present information and feedback over and over again. The instructional media were delivered via computer using oral and written texts and pictures visuals, such as illustrations, photos and animation, educational games, simulations; and multimedia were also contained in the e-learning. Smaldino & Russell. (2005: 104) suggested that teachers need to be able to select the best technology and media to help their students learn. The e-learning developers use a variety of media to involve students actively and to utilize a number of their senses. Having a variety of learning methods and media increases students' interest and meet their needs.

3.2.5 Post-assessment: Post-assessment assessed students after using the e-learning module. The processes were similar to the pre-assessment stage. This idea was supported by Smaldino & Russell (2005: 104), who suggested that posttest assess what students have mastered and review and check their own progress.

3.3 The learning activities: The e-learning module had a variety of activities in each phase of the 5E instructional model. This idea is supported by Clark & Richard. (2003: 30) who suggested that for knowledge construction to occur most effectively, instructional methods must support the cognitive process of learning. The details of learning activities in the e-learning module are as follows:

3.3.1 Engagement Phase: In this phase, students were engaged in the concepts through a short activity or relevant discussion. The researcher selected educational games, simulations, and multimedia to engage students. This idea was supported by Smaldino & Russell. (2005: 104) who suggested that educational games can incorporate the common features of behaviorism, cognitivism, constructivism, and social psychology, and provide attractive frameworks for learning activities. Similarly, Alessi & Stanley (2001: 298) who suggested that games are powerful educational tools and good for integrating learning across a number of subject areas, if used appropriately. Educational games must satisfy three basic requirements; they must have worthwhile learning objectives, they must be fun, and the game's goal must reinforce the learning goals. For simulations, this idea was supported by Alessi & Stanley. (2001: 263) who suggested that simulations are useful for giving learners experiences that are not otherwise possible. Simulations improve on tutorials and drills with enhanced motivation, transfer of learning, efficiency and flexibility. Similarly, Smaldino & Russell. (2005: 104) who suggested that instructional simulation games are found in curriculum applications that require both repetitive skills practice associated with games and the reality context associated with a simulation. The excitement of playing stimulates interest in the subject matter, and the holistic treatment of the game gives students a feel for the total process before they approach parts of it in a more linear way. For multimedia, this idea is supported by Smaldino & Russell (2005: 215) who suggested that using a variety of media involves students actively and utilizes a number of their senses. Most media formats lend themselves to use in the modules.

3.3.2 Explorations phase: In this phase, students explored the concepts to develop a common set of experiences. The researcher provided relevant information from websites for each lesson. Students should search and investigate information from this source in the module instead of reading books for learning in each lesson. This idea is supported by Poole. (2000: 215) who stated that computers offer students an opportunity for investigation and discovery of information from sources far beyond the scale available in the normal school library. Students develop not only their subject knowledge but also the skills needed to deal with the speed and flexibility of information retrieval available electronically. Similarly, Leask &

Norbert. (1999: 55) who suggested that the advantages of Web-related worksheets, developed by teachers, are that they help steer students away from unsuitable material and wasting time searching the web.

3.3.3 Explanation phase: In this phase, students developed an explanation for the concepts they had been exploring. Exercises relevant to the subject contents were provided. Students completed the drills with feed-back on screen. This idea is supported by Alessi & Stanley. (2001: 209-210) who suggested that drills are useful and perhaps even essential to efficient learning, Similarly, Clark & Richard. (2003: 13) suggested that using instructional methods, such as practice, can improve learning.

3.3.4 Elaboration phase: In this phase, students extended their understanding by applying what they have learned in a new setting. Relevant exercises were provided. Students completed the exercises with feed-back on screen. The process in this phase was the same as in the former, but used different contents.

3.3.5 Evaluation phase: In this phase, students and teachers had an opportunity to evaluate their students' understanding. Students expressed their ideas from their investigation in the form of slides. They produced and presented slides by using Microsoft PowerPoint from a computer. Teachers evaluated their slides, as a formative assessment. This idea is supported by Reynolds & Robertta. (1996: 9) who said that production level is the top level of the mutual interactivity. Production level is a two-way interaction between the learner and the program which results in a new product or information. Also, Smaldino & Russell. (2005: 215) suggested that PowerPoint presentation software is user friendly. Their high quality, ease of production, and flexibility of use have made computer-produced slides popular. Students can make slide shows with a variety of styles. Similarly, Ross. (2000: 133) who stated that by producing slides from computer, students can create a draft then adjust it for a final presentation saving a lot of time. This is particularly valuable for the weaker students.

4. Writing the CD-ROM: The researcher collected all information in the former steps, and then wrote the CD-ROM. The e-learning module was first test piloted. This idea is supported by Smaldino & Russell (2005: 215) who suggested that CD-ROM has the capacity to handle not only quality sound but also large quantities of digital information, including text, photographs, animation and audio. They are popular in classrooms of all sorts. A single disc is inexpensive to purchase and easy to store and maintain. Similarly, Clark & Richard (2003: 54-55) who stated that multimedia presentations encourage students to engage in active learning by mentally representing the material in words and pictures and by mentally making

connections between the pictorial and verbal representations. Providing relevant graphics to the text is a proven method of fostering deeper cognitive processing in students.

Section 2: The results of the hypotheses testing

The results of the hypotheses testing are, as follows:

The first hypothesis testing: The E-learning module on sandy shores ecosystem was implemented for Mathayomsuksa 2 students. The findings indicated that the efficiency value of the e-learning module was 80.50/84.04. The e-learning module had higher efficiency than the standard criterion set (80/80). Even though the efficiency gained is higher than the criterion set, E_1 and E_2 are not much different and not higher than 5% Accordingly, there is no error. (Promwong 2003: Interview) It was considered appropriate to be used with Mathayomsuksa 2 students because the development of the e-learning module was well planned at all stages: students' needs and educational theories, a variety of learning activities, and appropriateness of the learning processes. The development of the e-learning module on sandy shores ecosystem began with studying the necessary basic information, for instance, relevant concepts and theories and the opinions of science teachers. The indicated relationships were used as guidelines for selecting appropriate contents and learning activities as related to local communities. The e-learning module was designed in the form of text and visuals, as interactive lessons. Students could learn and do exercises on screen with feedback. A variety of learning activities were provided in each phase of the 5E instructional model. This idea is supported by Newton & Laurence (2001: 7) who suggested that, "The effective application of software in the classroom requires a range of teachers' skills related to their understanding of the curriculum and their students' need. The process of software design also demands knowledge of the learning process, an appreciation of students' learning needs and expectations about their responses to the tasks involved". Similarly, Alessi & Stanley (2001: 525) stated that, "The processes of developing multimedia include document design, matching the contents with the needs and characteristics of the learners, and balancing ideas against the available budget".

From the statements mentioned above, it is evident that the e-learning module also improved the quality of science teaching and learning processes, and provided other learning experiences. The e-learning module could really serve the needs of Mathayomsuksa 2 students and the local community. Consequently, the e-learning module on sandy shores ecosystem had efficiency to use in teaching science as an instructional tool.

The second hypothesis testing: The findings indicated that the students' academic achievement improved by using the e-learning module for learning. The results were analyzed as follows:

1. The learning processes: The e-learning module focused on a student-centered approach. The 5E model was the central model of learning in the e-learning module with several interactive learning activities. The module enabled students to recognize the prior knowledge students bring into the learning process. This idea is fit well with many educational theories, for instance, Discovery Learning Approach, Parsons; et.al. (2001: 60-63) who said that Jerome S. Bruner also expressed his opinion towards discovery learning in that students can develop their own knowledge by learning from anything around themselves. Consequently, teachers should arrange learning experiences for students by providing a variety of activities for their learning. The Inquiry Approach, suggested by Trowbridge & Bybee. (1996: 175-199), said that it would help students know how to find ways of explaining all events reasonably with supported principles. The Constructivism Approach, recommended by the Department of Curriculum and Instruction. (2002: 146) states that science learning in Thailand should be based on a process which requires students to inquire, to seek, to investigate and check, to search for knowledge by various means. It is obvious that students are able to build up the body of knowledge when they have to pass various learning processes. The Inquiry Cycle, confirmed by Jennifer Tang (1996: 45) suggested the inquiry process plays upon natural human curiosity and engages the students to stop parroting what they learned in textbooks, develops scientific knowledge, understanding of scientific idea and explanations for what they observed. Finally, the 5E instructional model, supported by Trowbridge & Bybee (1996: 213) is one of the important models of learning in science subject. Students can learn scientific concepts and principles faster and have foster good attitudes towards teaching and learning science. From the above statements, it shows that the learning processes in the e-learning module engage students to gain knowledge and develop their curiosity.

2. The learning activities: The e-learning module has a variety of activities for each phase of the 5E instructional model. This idea is supported by Smaldino & Russell (2005: 183) who stated that e-learning is not just accessing information but guiding students to specific outcomes and stimulating curiosity. The approach in the learning activities increased students' ability in different four ways as follows:

2.1 Knowledge: Students gain the concepts and knowledge from many learning activities in the e-learning module, for example, educational games, simulations, and multimedia (Smaldino & Russell. 2005: 104, 215); (Alessi & Stanley. 2001: 263, 298), and searching the information from websites, as electronic media in the e-learning module. (Poole. 2000: 215)

2.2 Understanding: Students expressed their understanding of the concepts and knowledge that they explored and the exercises they have completed. These learning activities were useful and improved students' learning, and perhaps even essential to efficient learning. (Alessi & Stanley. 2001: 209-210); (Clark & Richard. 2003: 13)

2.3 Scientific processes skills: With the e-learning module students learned about living organisms through pictures or other instructional media in the learning module. Students expressed their understanding from their investigation through written via the PowerPoint slides. Thus they could improve their scientific processes skills, for instance, observation skills, classifying skill, and inferring skills. (Reynolds & Robertta. 1996: 9); (Smaldino & Russell. 2005: 215); (Ross. 2000: 133) This idea is supported by Newton & Lawrence (2001: 11) who stated that the computer technology exploits new ways of working, thinking and learning. Also, Clark & Richard (2003: 13) who stated that e-learning as instruction delivered by a CD-ROM, Internet and intranet can enable students to build new knowledge and skills linked to individual learning goals or improved performance. Similarly, Clark & Richard (2003: 54-55) stated that multimedia presentations encourage students to engage in active learning by mentally representing the material in words and in pictures and by mentally making connections between the pictorial and verbal representations. Providing relevant graphics to text is a proven method of fostering deeper cognitive processing in students.

3. Students' background: Students in the sample groups have never studied ecology or the sandy shores ecosystem. Moreover, they have never studied the science through computers. Their learning was confined to the classroom and laboratory and delivered by lecture and practical work. Not surprisingly, students were excited, and took an active role in studying with the e-learning module. Similarly, the research of Suanpang (2006: Abstract); Chan; et.al. (2002: 7); Education Review. (2005: 8) who concluded that e-learning is one type of active learning. Students enjoyed e-learning activities, and prefer the e-learning approach than the traditional approach.

From Table 7, on Page 73, it shows a high range of standard deviation (S.D.). It thus signifies that the students gain higher scores in the post-test than in the pre-test. This may be because the test papers in the pre-test and the post-test are in parallel forms and the subjects' contents of the test papers are congruent with the learning activities in the e-learning module. Further, the period of time for the pre-test and the post-test is not very distant; consequently, the students can still remember the characteristics of the questions and answers. However, the learning processes and the learning activities in the e-learning module can effectively guide the students to achieve the specific outcomes.

From what was mentioned above, it is evident that the e-learning module could also be used for developing students' cognitive abilities. Consequently, the students' academic achievement improved through the use of the e-learning module on sandy shores ecosystem.

The third hypothesis testing: The findings of the third hypothesis indicated that the e-learning module was able to be used for improving ICT skills of Mathayomsuksa 2 students. The results are analyzed as follows:

1. Characteristics of the e-learning module: The discussion has already been mentioned in Section 2. Therefore, the e-learning module was appropriate for students with a range of abilities.

2. The learning activities: The e-learning module was written in a CD-ROM requiring all learning activities in each lesson to be done on the computer. At the beginning, students were not familiar with these learning activities, so they spent more time doing the learning activities and exercises on screen. However, in later on, they could complete the tasks quicker and easier because the activities in every lesson used the same type, but with different contents. This idea is supported by Reynolds & Robertta (1996: 6) who said who said "Students who become technology users are empowered to produce their own creative works. Technology allows students to focus on the process rather than products. The opportunity is a highly motivating factor for children". The approach in the learning activities increased students' ICT skills in three aspects as follows:

2.1 Information searching from electronic media skill: In the Explorations phase of each lesson, students were required to search and investigate information from electronic media by clicking on a link. This process engaged and increased their skills in exploring the concepts and developing a common set of experiences. This idea is supported by Poole. (2000: 215); Leask & Norbert. (1999: 55)

2.2 Organizing data and communication skills: In the Explanation phase, students developed an explanation for the concepts they had explored. Students learned and did exercises with feedback on screen. They also organized the information and practiced with the feedback on screen. Moreover, in the Elaboration phase, they extended their understanding or applied what they had learned in a new setting. In conclusion, they did the learning activities following the same process as in previous one but with a different content. This repetition helped increase their organizing data and communication skills. This idea is supported by Alessi & Stanley. (2001: 209-210); Clark & Richard. (2003: 13)

2.3 Presentation skills: In the Evaluation phase, students expressed their ideas from their investigation in the form of slides as proof of their understanding of the concepts. They produced and presented slides with Microsoft PowerPoint. By following the same pattern of all lessons, they were trained in making presentation skills. This idea is supported by Reynolds & Robertta. (1996: 9); Smaldino & Russell. (2005: 215); Ross. (2000: 133)

In short, the learning activities enabled all students to increase ICT skills by learning with the e-learning module. This is supported by Reynolds & Robertta (1996: 6) who said, “New technology motivates students and contributes to their learning in the affective domain as well as the cognitive domain.”

The fourth hypothesis testing: The findings of this hypothesis indicate that the e-learning module is an electronic instructional tool used for learning about conservation of the sandy shores environment. The results were analyzed as follows:

1. The learning activities: The e-learning module contained contents and learning activities related to the sandy shores environment. The sandy shores ecosystem was classified according to the scope of environmental study as a basic environmental study and placed in the part of science learning substance, Substance 2: Life and environment, according to the Standard Sc. 2.1 and Standard Sc. 2.2. In reality, students encountered the problems of the sandy shores environment in their real-life situations and they could find the solution of the environmental problems. The e-learning module focused on an environment which is part of the students’ community. They could apply the environment information to solve local environmental problems and conserve their local environment for sustainable development. This idea is supported by Parsons; et.al. (2001: 60-63); Trowbridge & Bybee. (1996: 175-199, 213)**;** Jennifer Tang (1996: 45).

2. Students’ background: Most students in three sample groups were familiar with the sandy shores environment because the school is near by one. They had already realized the values and benefits of sandy shores very well. The study’s findings revealed that students’ attitudes towards the sandy shores ecosystem were satisfactory and positive. Therefore, the development of the e-learning module and other materials on environmental study were

necessary to be used to develop students' awareness and concerns of the importance of environment and the causes of environmental problems. This idea is supported by Habibi (n.d.: Online) who suggested that the major causes of environmental problems in Afghanistan were 1) Not enough awareness of people about environment importance 2) No media or publication about the environment. The solutions were 1) Environmental awareness development 2) Increased media awareness.

From the above, the e-learning module is appropriate for use in developing students' awareness and concerns in conservation of the sandy shores environment for sustainable development.

The fifth and the sixth hypotheses testing: The findings of both hypotheses indicated that the e-learning module was able to be used with all Mathayomsuksa 2 students, including students with different levels science background. The results were analyzed as follows:

1. Characteristics of the e-learning module: The e-learning module was written in a CD-ROM format, so students could use it individually through a computer. Some students, who finished earlier than others, could go on to the next section. While other students who took more time to complete each section could repeat them without embarrassment. During the study time, students could collaborate with peers on exploring the lessons' topics, scoring from exercise, and producing slide presentations. Indeed, the e-learning module was appropriate for students with varied ability ranges. This idea is supported by Smaldino & Russell. (2005: 35) who stated that to make an efficient use of instructional media and technology, there must be a match between the students' characteristics and the content of the methods, media, and materials. Similarly, Reynolds & Robertta (1996: 42) described successful instructional packages as being 1) appropriate for multicultural classrooms and students with a wide range of abilities 2) have motivating topics 3) fitting the curriculum's objectives 4) Flexible by being linked to several topics, and can be used by both beginners and advanced students, and fit several logistical settings (independent, small group, whole class).

2. The learning activities: In the evaluation phase, students expressed their ideas and understanding of the concepts from their investigation in the form of slides presentation. They were interested in their own work as well as their friends' in both design and content. Students could share their experiences, develop their creative skills and be satisfied with their own work. This process enabled all students to construct their knowledge from their

experiences. This idea is supported by Ross. (2000: 133) who stated that producing slides from computer; students can create draft and then adjust them for final presentation saving a lot of time. This is particularly valuable for the weaker students. Similarly, Reynolds & Robertta (1996: 6) suggested that students gain a sense of satisfaction from their own academic achievement and the products they produced. Also, Newton & Lawrence. (2001: 11) who said that the purposes of using software relevant to science education are: 1) providing new knowledge 2) revision of previous knowledge 3) practice of basic skills 4) presenting information 5) exploring, evaluating, and applying ideas.

3. Students' background: Most students in three sample groups have grown up in the sandy shores surroundings because Sunthonphu Pittaya Secondary School is located nearby sandy shores at Laem Mae Phim, Klang District, Rayong Province. From their everyday life, they learned that sandy shores are an area of academic, economic, tourism, and fishery resources, but they didn't realize that sandy shores is a good learning resource in their community. This ecosystem was the theme all students were already experienced was and relevant to themselves. This idea is supported by Parsons; et.al. (2001: 60-63); Trowbridge & Bybee. (1996: 175-199, 213)**;** Jennifer Tang (1996: 45).

4. Students' background on ICT: Students had studied computers from Matthayomsuksa 1, according to what has been stated in the National Curriculum in the aspect of expected learning outcomes. "Students have computer literacy and basic computer skills, for instance, word processor, slide presentation, and using the Internet." It can thus be assumed that all students were familiar with using computers for learning. These computer skills benefited their learning while completing the e-learning module. This idea is supported by Parsons; et.al. (2001: 60-63); Trowbridge & Bybee. (1996: 175-199, 213)**;** Jennifer Tang (1996: 45).

From the above, it is evident that the e-learning module on the sandy shore ecosystem was appropriate to all students at all levels of science learning as a way of developing their cognitive abilities and ICT skills. In other words, it could be used with any person, at anytime, and anywhere (at any point) of the learning process within this age group and community.

Recommendations

This section consists of suggestions for future studies focusing on the development of e-learning module for secondary students. The following recommendations might be useful for teaching and learning science with e-learning modules.

1. Recommendations for school administrators

1.1 The use of ICT and e-learning should be employed in teaching and learning in all subjects to encourage teachers and students to learn and use ICT for enhancing their teaching and learning skills. The purchase of computers and peripheral equipment will require a major investment from schools and the government, but it will yield a great benefit to both teachers and students.

1.2 E-learning and the use of ICT should be integrated into the school curriculum, especially in science education, at all educational levels.

1.3 Support and help should be provided to all teachers to create their own electronic materials, such as the e-learning module, by arranging training courses and seminars for them.

2. Recommendations for using the results of this research study

2.1 The effective application of ICT and the e-learning module in the classroom requires a range of teachers' skills related to their understanding of the curriculum and their own students' needs. All teachers should be equipped with basic skills in ICT use.

2.2 Teachers should prepare themselves by studying the 5E instructional model. They should understand their roles as mentors or facilitators and to use the study plans effectively.

2.3 The use of the study plans will help teachers know and plan how to monitor and access all students in the class so that the students can be engaged in and follow the lessons step by step. Teachers should monitor the students' learning process to be certain that there is a continuing through learning period in all students.

2.4 The e-learning module contains information from electronic media. It is easily accessible and the contents can be quickly copied to produce students' slides. Thus, these contents are not from their own idea. In any assessment, students can find an answer-key or feed-back immediately before doing the test. Consequently, the result of assessment might not reflect real achievements. Teachers must know how to evaluate the students' work.

3. Recommendations for further study

The results of the e-learning module development on sandy shores ecosystem in field testing indicated that students had achieved more academically and in terms of their ICT skills after using the e-learning module. Similarly, the positive effects were found in this study. The recommendations for future studies are as follows:

3.1 The e-learning focusing on a student-centered approach and the 5E instructional model should be applied for developing e-learning modules in all educational levels, according to the results of this research.

3.2 The e-learning module approaches allow more relevant interactions with the local community, and its problems. This e-learning module can also serve as a model in e-learning module development for other science contents.

3.3 The study should be implemented into a larger sample and other schools in the eastern region of Thailand.

3.4 The study should be focused on learning about the environment and students' thinking abilities, especially problem solving skills and creative thinking.

3.5 The e-learning module should be accessed via the Internet.

3.6 The e-learning module should allow students to present their data and ideas using variety of ICT software in the learning activity section.

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APPENDIX

Appendix 1

Related Persons and Schools in This Study

1. Experienced persons for research instruments

1.1 Associate Professor Dr. Vorawit Chivaporn	Faculty of Science, Burapha University
1.2 Assistant Professor Dr. Seree Chinodom	Computer Center, Burapha University
1.3 Associate Professor Dr. Chalong Tubsri	Faculty of Education, Burapha University
1.4 Associate Professor Ravivan Angkananurakpan	Satit Piboon Bampen School, Burapha University
1.5 Ajarn Surapong Ngamsom	Director, Sunthonphu Pittaya Secondary, School

Appendix 2

Statistical Analysis

The first hypothesis

The e-learning module efficiency was 80/80

		E1	E2
Efficiency	classroom1	80.56	84.78
	classroom2	80.83	84.11
	classroom3	80.11	83.22

…………………………………………………………………………………………..

The ICT skills evaluation form efficiency was 80/80

		E1	E2
Efficiency	classroom1	80.56	83.85
	classroom2	80.83	83.85
	classroom3	80.11	83.85

The second hypothesis

t-test (Achievement score before and after learning)

Classroom 1

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	before	30.2000	30	4.99241	.91148
	after	50.8667	30	5.69170	1.03916

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	before & after	30	.693	.000

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		Mean	Std. Deviation	Std. Error Mean
		Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
Pair 1	before - after	-20.66667	4.23722	.77361	-22.24887	-19.08446	-26.715	29	.000

Classroom 2 (The second hypothesis)

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	before	30.6333	30	4.82439	.88081
	after	50.4667	30	4.65154	.84925

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	before & after	30	.638	.000

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		Mean	Std. Deviation	Std. Error Mean
		Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
Pair 1	before - after	-19.83333	4.03505	.73670	-21.34004	-18.32662	-26.922	29	.000

Classroom 3 (The second hypothesis)

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	before	30.4000	30	5.10983	.93292
	after	49.9333	30	5.45156	.99531

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	before & after	30	.473	.008

Paired Samples Test

		Paired Differences				t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference			
						Mean	Std. Deviation	Std. Error Mean
		Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
Pair 1	before - after	-19.53333	5.43128	.99161	-21.56141	-17.50526	-19.699	29	.000

The third hypothesis

The ICT skills scores before and after learning in each classroom (t-test)

Classroom 1

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	before	13.6333	30	.96431	.17606
	after	16.7667	30	1.22287	.22326

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	before & after	30	.744	.000

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		Mean	Std. Deviation	Std. Error Mean
		Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
Pair 1	before - after	-3.13333	.81931	.14958	-3.43927	-2.82740	-20.947	29	.000

Classroom 2 (The third hypothesis)

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	before	14.3333	30	.75810	.13841
	after	16.8000	30	1.06350	.19417

Paired Samples Correlations

	N	Correlation	Sig.
Pair 1 before & after	30	.813	.000

Paired Samples Test

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		Mean	Std. Deviation	Std. Error Mean
	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
Pair 1 before - after	-2.46667	.62881	.11480	-2.70147	-2.23187	-21.486	29	.000

Classroom 3 (The third hypothesis)

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	before	14.2667	30	.73968	.13505
	after	16.9333	30	.86834	.15854

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	before & after	30	.404	.027

Paired Samples Test

		Paired Differences				t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference	Mean	Std. Deviation	Std. Error Mean
		Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
Pair 1	before - after	-2.66667	.88409	.16141	-2.99679	-2.33654	-16.521	29	.000

The forth hypothesis

The attitude scores before and after learning in each classroom (t-test)

Classroom 1

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	before	81.9667	30	6.33808	1.15717
	after	84.5333	30	9.04675	1.65170

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	before & after	30	-.263	.160

Paired Samples Test

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		Mean	Std. Deviation	Std. Error Mean
	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
Pair 1 before - after	-2.56667	12.33633	2.25230	-7.17313	2.03979	-1.140	29	.264

Classroom 2 (The forth hypothesis)

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	before	82.0000	30	6.10257	1.11417
	after	85.0667	30	8.72149	1.59232

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	before & after	30	-.270	.150

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		Mean	Std. Deviation	Std. Error Mean
		Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
Pair 1	before - after	-3.06667	11.91618	2.17559	-7.51624	1.38291	-1.410	29	.169

Classroom 3 (The forth hypothesis)

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	before	81.8000	30	5.80368	1.05960
	after	85.4000	30	8.42247	1.53772

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	before & after	30	-.232	.218

Paired Samples Test

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		Mean	Std. Deviation	Std. Error Mean
	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
Pair 1 before - after	-3.60000	11.28197	2.05980	-7.81276	.61276	-1.748	29	.091

The fifth hypothesis

The relationship between achievement scores after learning and level of science learning outcomes

Descriptive Statistics

	Mean	Std. Deviation	N
grade	2.3222	.63295	90
After score	50.4222	5.23810	90

Correlations

		grade	afterscore
grade	Pearson Correlation	1	.691(**)
	Sig. (2-tailed)		.000
	N	90	90
After score	Pearson Correlation	.691(**)	1
	Sig. (2-tailed)	.000	
	N	90	90

** Correlation is significant at the 0.01 level (2-tailed).

The relationship between ICT skills scores after learning and level of science learning outcomes

Descriptive Statistics

	Mean	Std. Deviation	N
grade	2.3222	.63295	90
After score	16.8333	1.05202	90

Correlations

		grade	After score
grade	Pearson Correlation	1	.149
	Sig. (2-tailed)		.161
	N	90	90
After score	Pearson Correlation	.149	1
	Sig. (2-tailed)	.161	
	N	90	90

The sixth hypothesis

The comparison of achievement scores after learning on the three classrooms (ANOVA)

Descriptive

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
	Lower Bound	Upper Bound	Lower Bound	Upper Bound	Lower Bound	Upper Bound	Lower Bound	Upper Bound
1.00	30	50.8667	5.69170	1.03916	48.7414	52.9920	41.00	60.00
2.00	30	50.4667	4.65154	.84925	48.7298	52.2036	36.00	56.00
3.00	30	49.9333	5.45156	.99531	47.8977	51.9690	38.00	59.00
Total	90	50.4222	5.23810	.55214	49.3251	51.5193	36.00	60.00

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	13.156	2	6.578	.236	.791
Within Groups	2428.800	87	27.917		
Total	2441.956	89			

The sixth hypothesis

The comparison of ICT skills scores after learning on the three classrooms (ANOVA)

Descriptive

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
	Lower Bound	Upper Bound	Lower Bound	Upper Bound	Lower Bound	Upper Bound	Lower Bound	Upper Bound
1.00	30	16.7667	1.22287	.22326	16.3100	17.2233	14.00	19.00
2.00	30	16.8000	1.06350	.19417	16.4029	17.1971	15.00	19.00
3.00	30	16.9333	.86834	.15854	16.6091	17.2576	15.00	18.00
Total	90	16.8333	1.05202	.11089	16.6130	17.0537	14.00	19.00

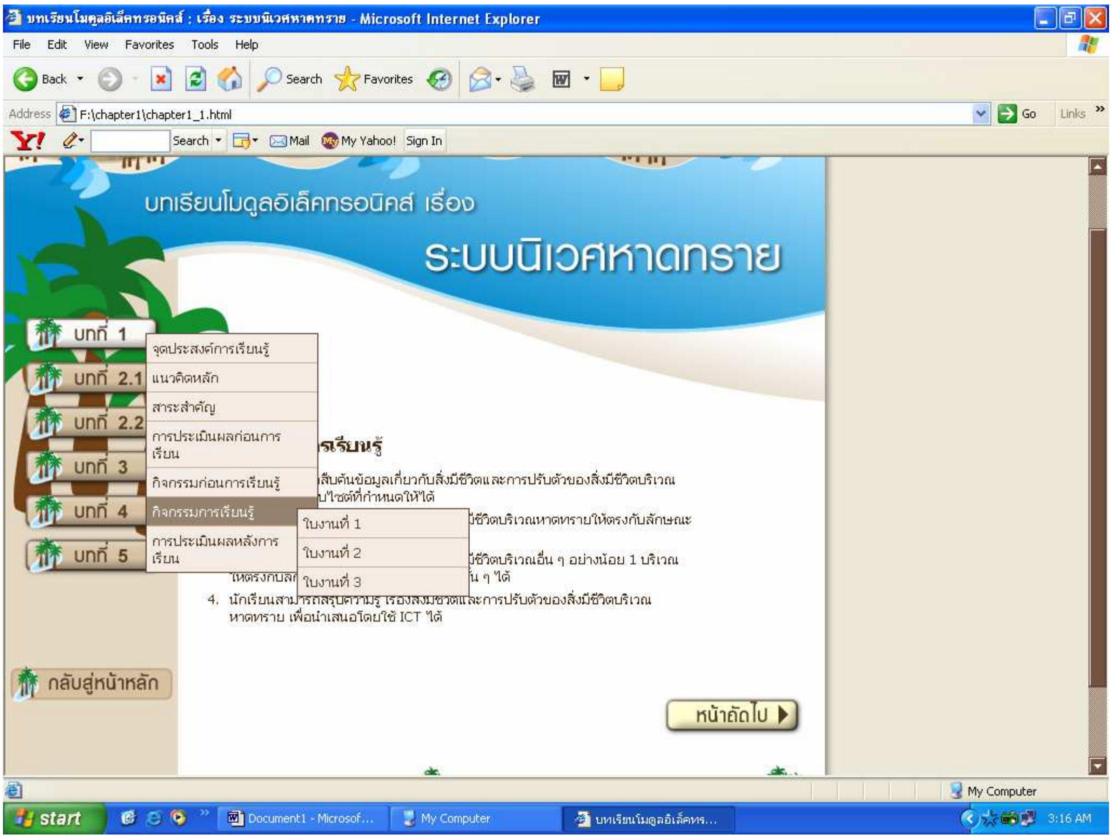
ANOVA (ICT skill scores)

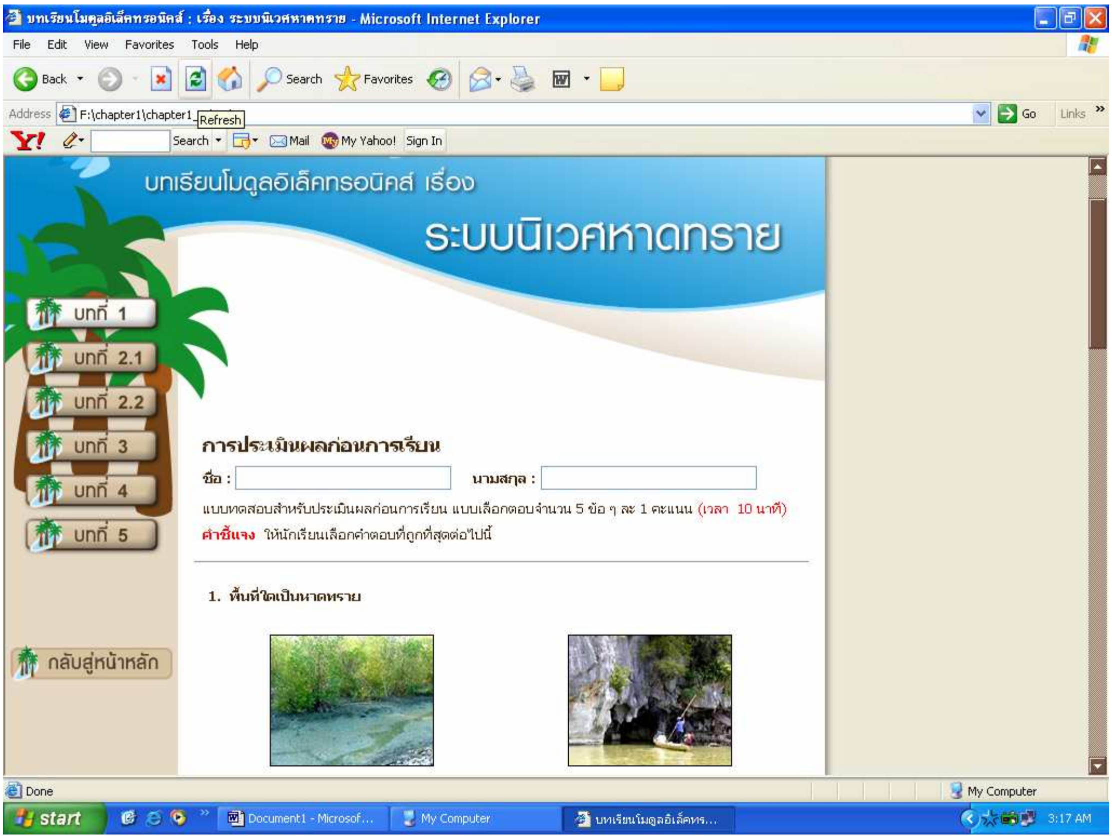
After score	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.467	2	.233	.207	.813
Within Groups	98.033	87	1.127		
Total	98.500	89			

Appendix 3

The E-Learning Module on Sandy Shores Ecosystem for Mathayonsuksa 2 Students

(If interest, please contact directly to the researcher)





Appendix 4

Study Plan

แผนการจัดการเรียนรู้
บทเรียนโมดูลอิเล็กทรอนิกส์

บทเรียนโมดูลอิเล็กทรอนิกส์ เรื่อง ระบบนิเวศหาดทราย ชั้นมัธยมศึกษาปีที่ 2
บทเรียนที่ 1 เรื่อง สิ่งมีชีวิตและการปรับตัวของสิ่งมีชีวิตบริเวณหาดทราย

เวลา 2 คาบเรียน (100 นาที)

จุดประสงค์การเรียนรู้

1. นักเรียนสามารถสืบค้นข้อมูลเกี่ยวกับสิ่งมีชีวิตและการปรับตัวของสิ่งมีชีวิตบริเวณหาดทรายจากเว็บไซต์ที่กำหนดให้ได้
2. นักเรียนสามารถเลือกภาพและเขียนชื่อ สิ่งมีชีวิตบริเวณหาดทรายให้ตรงกับลักษณะการปรับตัวของสิ่งมีชีวิตนั้น ๆ ได้
3. นักเรียนสามารถเลือกภาพและเขียนชื่อ สิ่งมีชีวิตบริเวณอื่น ๆ อย่างน้อย 1 บริเวณให้ตรงกับลักษณะการปรับตัวของสิ่งมีชีวิตนั้น ๆ ได้
4. นักเรียนสามารถสรุปความรู้ เรื่องสิ่งมีชีวิตและการปรับตัวของสิ่งมีชีวิตบริเวณหาดทราย เพื่อนำเสนอโดยใช้ ICT ได้

แนวคิดหลัก

สิ่งมีชีวิตที่อาศัยอยู่บริเวณหาดทรายมีการปรับตัวเพื่อให้เหมาะสมกับสภาพแวดล้อม

สาระสำคัญ

สิ่งมีชีวิตที่อาศัยในบริเวณหาดทราย เช่น ปลากระบาง หอยเสียบ ปูลมและปูเสฉวน เป็นต้น มีการปรับตัว ได้แก่ มีลำตัวแบนราบกับพื้นทราย ชอบฝังตัวหรือขุดรูอยู่ในพื้นทรายหรือเคลื่อนไหวได้อย่างรวดเร็ว

การประเมินผลก่อนการเรียน

แบบทดสอบสำหรับประเมินผลก่อนการเรียน แบบเลือกตอบจำนวน 5 ข้อ ๆ ละ 1 คะแนน (เวลา 10 นาที)

คำชี้แจง ให้นักเรียนเลือกคำตอบที่ถูกที่สุดต่อไปนี้

1. พื้นที่ใดเป็นหาดทราย

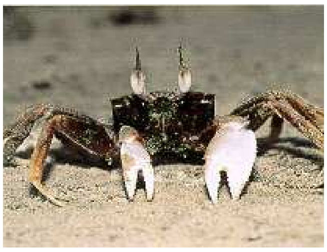
ก. 

ข. 

ค. 

ง. 

2. ข้อใดเป็นสิ่งมีชีวิตประเภทสัตว์ที่พบบริเวณหาดทราย

ก. 

ปูลม

ข. 

ปลาตีน

ค. 

ปูแสม

ง. 

ฉลามครีบเงิน

3. ข้อใดเป็นสิ่งมีชีวิตประเภทพืชที่พบบริเวณหาดทราย

ก. 

ต้นตาตุ่มทะเล

ข. 

โคพีพอด

ค. 

ปะการังอ่อน

ง. 

แพลงก์ตอนพืช

4. ข้อใดเป็นการปรับตัวของสิ่งมีชีวิต ประเภทของสัตว์ที่อาศัยในบริเวณหาดทราย

ก. มีเปลือกบาง สีสันสวยงาม

ข. สามารถอพยพย้ายถิ่นขึ้นลงตามน้ำทะเลได้

ค. มีถุงลมขนาดใหญ่ เพื่อพยุงตัวให้ลอยน้ำ

ง. สามารถอาศัยตามรากต้นไม้ได้

5. ข้อใดเป็นการปรับตัวของสิ่งมีชีวิต ประเภทพืชทีอาศัยในบริเวณหาดทราย

ก. มีรากค้ำจุน เพื่อพยุงลำต้นมิให้ล้ม

ข. มีรากอากาศเป็นจำนวนมาก เพื่อแลกเปลี่ยนก๊าซ

ค. ใบเป็นหนามแหลม

ง. ดำรงชีวิตเป็นแพลงก์ตอนพืชล่องลอยในน้ำ

เกณฑ์การประเมินแบบทดสอบการประเมินผลก่อนการเรียน

ประเด็นที่ประเมิน	คะแนน
เลือกตอบคำตอบได้ถูกต้อง	1
เลือกตอบคำตอบไม่ได้ถูกต้อง	0

กิจกรรมการเรียนรู้

1. **ขั้นสร้างความสนใจ**

ให้นักเรียนเล่นเกมต่อภาพจิ๊กซอว์ “หาดทราย” ที่กำหนดให้ต่อไปนี้ (เวลา 5 นาที)

2. ขั้นสำรวจและค้นหา

นักเรียนสืบค้นข้อมูลเกี่ยวกับสิ่งมีชีวิต และการปรับตัวของสิ่งมีชีวิตบริเวณหาดทราย ตามเว็บไซต์ที่กำหนดต่อไปนี้ (ใบงานที่ 1 ข้อ 1)

http://www.marinepcd.org/seastory/coastal.html

http://us.geocities.com/metscience/sea/beach/beach.html

http://us.geocities.com/metscience/sea/beach/beach_life.html

http://techno.obec.go.th/content/www.seaanimal.com/page4.html

http://www.arri.chula.ac.th/Cholatassathan/zone5.htm

http://www.doae.go.th/library/html/detail/KUmagazine/december_43/kung/crab.htm

3. ขั้นอธิบายและลงข้อสรุป

ให้นักเรียนเลือกภาพและชื่อสิ่งมีชีวิตที่อาศัยบริเวณหาดทรายมา 5 ชนิด จากภาพและชื่อของสิ่งมีชีวิตที่กำหนดให้ แล้วนำไปใส่ในตารางให้ตรงกับลักษณะการปรับตัวของสิ่งมีชีวิตนั้น ๆ (จำนวน 10 ข้อ ๆ ละ 1 คะแนน) (ใบงานที่ 1 ข้อ 2)

4. ขั้นขยายความรู้

ให้นักเรียนเลือกภาพและชื่อสิ่งมีชีวิตที่อาศัยบริเวณป่าชายเลน มา 5 ชนิด จากภาพและชื่อของสิ่งมีชีวิตที่กำหนดให้ แล้วนำไปใส่ในตารางให้ตรงกับลักษณะการปรับตัวของสิ่งมีชีวิตนั้น ๆ (จำนวน 10 ข้อ ๆ ละ 1 คะแนน) (ใบงานที่ 2)

5. ขั้นประเมิน

5.1 ให้นักเรียนยกตัวอย่างสิ่งมีชีวิตที่พบบริเวณหาดทรายมา 2 ชนิด แล้วเขียนชื่อและอธิบายลักษณะการปรับตัวของสิ่งมีชีวิตนั้น ๆ เพื่อนำเสนอเป็นสไลด์ จำนวน 2 สไลด์โดยใช้โปรแกรม PowerPoint (ใบงานที่ 3 ข้อ 1)

5.2 ให้นักเรียนรวบรวมผลงานทั้งหมด แล้วนำมาใส่ในแฟ้มผลงาน (ใบงานที่ 3 ข้อ 2)

สื่อประกอบการประกอบการเรียนรู้

บทเรียนโมดูลอิเล็กทรอนิกส์ เรื่องระบบนิเวศหาดทราย บทเรียนที่ 1 เรื่อง สิ่งมีชีวิตและการปรับตัวของสิ่งมีชีวิตบริเวณหาดทราย

การประเมินผลหลังการเรียน

แบบทดสอบสำหรับประเมินผลหลังการเรียน เป็นแบบเลือกตอบ จำนวน 5 ข้อ ๆ ละ 1 คะแนน (เวลา 10 นาที)

คำชี้แจง ให้นักเรียนตอบคำถามต่อไปนี้

1. พื้นที่ใดเป็นหาดทราย

ก. 

ข. 

ค. 

ง. 

2. ข้อใดเป็นสิ่งมีชีวิตประเภทสัตว์ที่ไม่พบบริเวณหาดทราย

ก. 

ดาวทราย

ข. 

ปูเสฉวน

ค.  ง. 

หอยทับทิม ฉลามครีบเงิน

3. ข้อใดเป็นสิ่งมีชีวิตประเภทพืช ที่พบบริเวณหาดทราย

ก.  ข. 

แมงกระพรุน ต้นโกงกาง

ค.  ง. 

แพลงก์ตอนพืช ต้นแสม

4. ข้อใดเป็นการปรับตัวของสิ่งมีชีวิต ประเภทสัตว์ที่อาศัยบริเวณหาดทราย

ก. ขุดรูอยู่ในทราย เพื่อใช้เป็นที่หลบซ่อนตัว

ข. มีขนาดใหญ่ อาศัยอยู่ตามพื้นหิน หรือทรายได้

ค. มีหนวดยาว เพื่อยึดเกาะตามรากต้นไม้

ง. สามารถอาศัยอยู่กับดอกไม้ทะเลได้

5. ข้อใดเป็นการปรับตัวของสิ่งมีชีวิตประเภทพืช ที่อาศัยบริเวณหาดทราย

ก. มีรากเป็นจำนวนมากเพื่ออุ้มน้ำได้ดี

ข. พืชที่มีลำต้นขนาดใหญ่ ไม่สามารถปรับตัวได้

ค. ใบเรียวเล็ก เพื่อลดแรงต้านของน้ำ

ง. สามารถยึดเกาะกับก้อนหิน ได้อย่างแน่นหนา

เกณฑ์การประเมินแบบทดสอบการประเมินผลหลังการเรียน

ประเด็นที่ประเมิน	คะแนน
เลือกตอบคำตอบได้ถูกต้อง	1
เลือกตอบคำตอบไม่ได้ถูกต้อง	0

ใบงาน บทที่ 1

ใบงานที่ 1

บทเรียนโมดูลอิเล็กทรอนิกส์ เรื่อง ระบบนิเวศหาดทราย ชั้นมัธยมศึกษาปีที่ 2
บทเรียนที่ 1 เรื่อง สิ่งมีชีวิตและการปรับตัวของสิ่งมีชีวิตบริเวณหาดทราย เวลา 30 นาที

----

1. นักเรียนสืบค้นข้อมูลเกี่ยวกับสิ่งมีชีวิต และการปรับตัวของสิ่งมีชีวิตบริเวณหาดทรายตามเว็บไซต์ที่กำหนดต่อไปนี้

http://www.marinepcd.org/seastory/coastal.html

http://us.geocities.com/metscience/sea/beach/beach.html

http://us.geocities.com/metscience/sea/beach/beach_life.html

http://techno.obec.go.th/content/www.seaanimal.com/page4.html

http://www.arri.chula.ac.th/Cholatassathan/zone5.htm

http://www.doae.go.th/library/html/detail/KUmagazine/december_43/kung/crab.htm

2. ให้นักเรียนเลือกภาพและชื่อสิ่งมีชีวิตที่อาศัยบริเวณหาดทรายมา 5 ชนิด จากภาพและชื่อของสิ่งมีชีวิตที่กำหนดให้ แล้วนำไปใส่ในตารางให้ตรงกับลักษณะการปรับตัวของสิ่งมีชีวิตนั้น ๆ (จำนวน 10 ข้อ ๆ ละ 1 คะแนน)

ภาพสิ่งมีชีวิตที่กำหนดให้







ชื่อสิ่งมีชีวิตที่กำหนดให้

ปะการังอ่อน	แมงกะพรุน	ปลากระบาง	แพลงก์ตอนพืช	หอยเสียบ
ปูลม	ปูเสฉวน	ปูทะเล	ปลาตีน	ปลาการ์ตูน

ภาพที่	สิ่งมีชีวิตที่อาศัยบริเวณหาดทราย		
	ภาพ	ชื่อ	ลักษณะการปรับตัว
1	1. ________________	2. ________________	เคลื่อนที่เร็ว หลบซ่อนตัวอยู่ในรู ตามพื้นทราย
2	3. ________________	4. ________________	อาศัยเปลือกหอย หลบซ่อนตัว
3	5. ________________	6. ________________	ดำรงชีวิต เป็นแพลงก์ตอนพืช
4	7. ________________	8. ________________	อพยพย้ายถิ่นขึ้นลง ตามน้ำทะเล กินอาหาร จะเปิดฝา ทั้งสองฝาออก
5	9. ________________	10. ________________	ลำตัวแบนราบ กับพื้นทราย

เกณฑ์การประเมินใบงานที่ 1 ข้อ 2

ประเด็นที่ประเมิน	คะแนน
เลือกตอบคำตอบได้ถูกต้อง	1
เลือกตอบคำตอบไม่ได้ถูกต้อง	0

เฉลยใบงานที่ 1

บทเรียนโมดูลอิเล็กทรอนิกส์ เรื่อง ระบบนิเวศหาดทราย ชั้นมัธยมศึกษาปีที่ 2
บทเรียนที่ 1 เรื่อง สิ่งมีชีวิตและการปรับตัวของสิ่งมีชีวิตบริเวณหาดทราย เวลา 30 นาที

ภาพที่	**สิ่งมีชีวิตที่อาศัยบริเวณหาดทราย**		
	ภาพ	ชื่อ	ลักษณะการปรับตัว
1	 1. ____________	2. **ปูลม**	เคลื่อนที่เร็วหลบซ่อนตัวอยู่ในรูตามพื้นทราย
2	 3. ____________	4. **ปูเสฉวน**	อาศัยเปลือกหอยหลบซ่อนตัว
3	 5. ____________	6. **แพลงก์ตอนพืช**	ดำรงชีวิตเป็นแพลงก์ตอนพืช

4	 7. ______________	8. **หอยเสียบ**	อพยพย้ายถิ่นขึ้นลง ตามน้ำทะเล กินอาหาร จะเปิดฝา ทั้งสองฝาออก
5	 9. ______________	10. **ปลากระบาง**	ลำตัวแบนราบ กับพื้นทราย

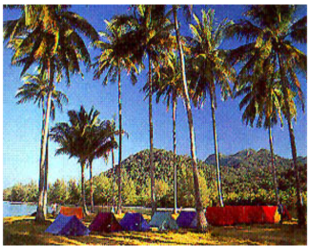
ใบงานที่ 2

บทเรียนโมดูลอิเล็กทรอนิกส์ เรื่อง ระบบนิเวศหาดทราย ชั้นมัธยมศึกษาปีที่ 2
บทเรียนที่ 1 เรื่อง สิ่งมีชีวิตและการปรับตัวของสิ่งมีชีวิตบริเวณหาดทราย เวลา 20 นาที

ให้นักเรียนเลือกภาพและชื่อสิ่งมีชีวิตที่อาศัยบริเวณป่าชายเลน มา 5 ชนิด จากภาพและชื่อของสิ่งมีชีวิตที่กำหนดให้ แล้วนำไปใส่ในตารางให้ตรงกับลักษณะการปรับตัวของสิ่งมีชีวิตนั้น ๆ (จำนวน 10 ข้อ ๆ ละ 1 คะแนน)

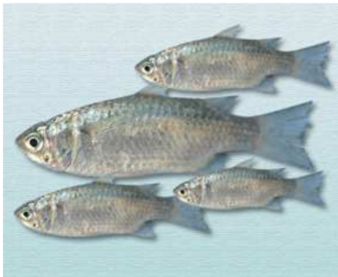
ภาพสิ่งมีชีวิตที่กำหนดให้











ชื่อสิ่งมีชีวิตที่กำหนดให้

ลิงแสม	ต้นแสม	ต้นมะพร้าว	ต้นโกงกาง	หอยทับทิม
กัลปังหา	ปูแสม	หอยขมทะเล	ปลากระบอก	ปลาตีน

ภาพที่	สิ่งมีชีวิตที่อาศัยบริเวณป่าชายเลน		
	ภาพ	ชื่อ	ลักษณะการปรับตัว
1	1. ____________________	2. ____________________	มีรากค้ำจุน
2	3. ____________________	4. ____________________	มีรากอากาศ
3	5. ____________________	6. ____________________	เป็นปลา ที่มีครีบหูแข็งแรงมาก สามารถใช้เดินบนเลนได้
4	7. ____________________	8. ____________________	มีกระดองแข็ง อาศัยตามหน้าดิน กินซากพืช ซากสัตว์ เป็นอาหาร
5	9. ____________________	10. ____________________	อยู่รวมเป็นกลุ่มตามราก และลำต้นของพืช ในป่าชายเลน

เกณฑ์การประเมินใบงานที่ 2

ประเด็นที่ประเมิน	**คะแนน**
เลือกตอบคำตอบได้ถูกต้อง	1
เลือกตอบคำตอบไม่ได้ถูกต้อง	0

เฉลยใบงานที่ 2

บทเรียนโมดูลอิเล็กทรอนิกส์ เรื่อง ระบบนิเวศหาดทราย ชั้นมัธยมศึกษาปีที่ 2
บทเรียนที่ 1 เรื่อง สิ่งมีชีวิตและการปรับตัวของสิ่งมีชีวิตบริเวณหาดทราย เวลา 20 นาที

ภาพที่	สิ่งมีชีวิตที่อาศัยบริเวณป่าชายเลน		
	ภาพ	ชื่อ	ลักษณะการปรับตัว
1	 1. ____________	2. โกงกาง	มีรากค้ำจุน
2	 3. ____________	4. แสม	มีรากอากาศ
3	 5. ____________	6. ปลาตีน	เป็นปลาที่มีครีบหู แข็งแรงมาก สามารถใช้เดินบนเลนได้

4	 7. ____________________	8. **ปูแสม**	มีกระดองแข็ง อาศัยตามหน้าดิน กินซากพืช ซากสัตว์ เป็นอาหาร
5	 9. ____________________	10. **หอยขมทะเล**	อยู่รวมเป็นกลุ่มตามราก และลำต้นของพืช ในป่าชายเลน

ใบงานที่ 3

บทเรียนโมดูลอิเล็กทรอนิกส์ เรื่อง ระบบนิเวศหาดทราย ชั้นมัธยมศึกษาปีที่ 2
บทเรียนที่ 1 เรื่อง สิ่งมีชีวิตและการปรับตัวของสิ่งมีชีวิตบริเวณหาดทราย เวลา 25 นาที

----

1. ให้นักเรียนยกตัวอย่างสิ่งมีชีวิตที่พบบริเวณหาดทรายมา 2 ชนิด แล้วเขียนชื่อและอธิบายลักษณะการปรับตัวของสิ่งมีชีวิตนั้น ๆ เพื่อนำเสนอเป็นสไลด์ จำนวน 2 สไลด์โดยใช้โปรแกรม Power Point

2. ให้นักเรียนรวบรวมผลงานทั้งหมด แล้วนำมาใส่ในแฟ้มผลงาน

เฉลยการประเมินผลก่อนการเรียน

แบบทดสอบสำหรับประเมินผลก่อนการเรียน แบบเลือกตอบ จำนวน 5 ข้อ ๆ ละ 1 คะแนน (เวลา 10 นาที)

คำชี้แจง ให้นักเรียนเลือกคำตอบที่ถูกที่สุดต่อไปนี้

1. พื้นที่ใดเป็นหาดทราย

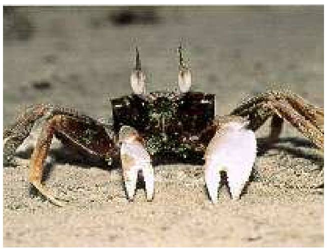
ก. 

ข. 

/ค. 

ง. 

2. ข้อใดเป็นสิ่งมีชีวิตประเภทสัตว์ที่พบบริเวณหาดทราย

ก. 

ปูลม

ข. 

ปลาตีน

ค. 

ปูแสม

/ง. 

ฉลามครีบเงิน

3. ข้อใดเป็นสิ่งมีชีวิตประเภทพืชที่พบบริเวณหาดทราย

ก. 

ต้นตาตุ่มทะเล

ข. 

โคพีพอด

ค. 

ปะการังอ่อน

/ง. 

แพลงก์ตอนพืช

4. ข้อใดเป็นการปรับตัวของสิ่งมีชีวิต ประเภทของสัตว์ที่อาศัยในบริเวณหาดทราย

ก. มีเปลือกบาง สีสันสวยงาม

/ข. สามารถอพยพย้ายถิ่นขึ้นลงตามน้ำทะเลได้

ค. มีถุงลมขนาดใหญ่ เพื่อพยุงตัวให้ลอยน้ำ

ง. สามารถอาศัยตามรากต้นไม้ได้

5.ข้อใดเป็นการปรับตัวของสิ่งมีชีวิต ประเภทพืชที่อาศัยในบริเวณหาดทราย

ก. มีรากค้ำจุน เพื่อพยุงลำต้นมิให้ล้ม

ข. มีรากอากาศเป็นจำนวนมาก เพื่อแลกเปลี่ยนก๊าซ

ค. ใบเป็นหนามแหลม

/ง. ดำรงชีวิตเป็นแพลงก์ตอนพืช ล่องลอยในน้ำ

เฉลยการประเมินผลหลังการเรียน

แบบทดสอบสำหรับประเมินผลหลังการเรียน เป็นแบบเลือกตอบ จำนวน 5 ข้อ ๆ ละ 1 คะแนน (เวลา 10 นาที)

คำชี้แจง ให้นักเรียนตอบคำถามต่อไปนี้

1. พื้นที่ใดเป็นหาดทราย

/ก. 

ข. 

ค. 

ง. 

2. ข้อใดเป็นสิ่งมีชีวิตประเภทสัตว์ที่ไม่พบบริเวณหาดทราย

ก. 

ดาวทราย

ข. 

ปูเสฉวน

ค. 

หอยทับทิม

/ง. 

ฉลามครีบเงิน

3. ข้อใดเป็นสิ่งมีชีวิตประเภทพืช ที่พบบริเวณหาดทราย

ก. 

แมงกระพรุน

ข. 

ต้นโกงกาง

/ค. 

แพลงก์ตอนพืช

ง. 

ต้นแสม

4. ข้อใดเป็นการปรับตัวของสิ่งมีชีวิต ประเภทสัตว์ที่อาศัยบริเวณหาดทราย

/ก. ขุดรูอยู่ในทราย เพื่อใช้เป็นที่หลบซ่อนตัว

ข. มีขนาดใหญ่ อาศัยอยู่ตามพื้นหิน หรือทรายได้

ค. มีหนวดยาว เพื่อยึดเกาะตามรากต้นไม้

ง. สามารถอาศัยอยู่กับดอกไม้ทะเลได้

5. ข้อใดเป็นการปรับตัวของสิ่งมีชีวิตประเภทพืช ที่อาศัยบริเวณหาดทราย

ก. มีรากเป็นจำนวนมากเพื่ออุ้มน้ำได้ดี

/ข. พืชที่มีลำต้นขนาดใหญ่ ไม่สามารถปรับตัวได้

ค. ใบเรียวเล็ก เพื่อลดแรงต้านของน้ำ

ง. สามารถยึดเกาะกับก้อนหิน ได้อย่างแน่นหนา

Appendix 5

Examples of students' work

ปูเสฉวน

เรามักพบปูเสฉวนได้ทั่วไป โดยเฉพาะชายหาดทราย บางครั้งที่น้ำทะเลลดลงอย่างรวดเร็ว ปูเสฉวนบางตัวยังตกค้างอยู่บนชายหาด จึงต้องรีบคลานลงสู่ทะเล เพื่อให้รอดพ้นอันตรายจากการถูกล่า ปูเสฉวนส่วนใหญ่จำเป็นต้องอาศัยเปลือกหอยขนาดเล็กเป็นเกราะกำบังตัว ด้วยเหตุนี้ หากหอยถูกเก็บมาทำเครื่องประดับ เช่น สร้อย กรอบรูป จนเหลืออยู่น้อยลูกปูเสฉวนก็จะไม่มีที่อยู่อาศัย

วัฏจักรคาร์บอน (ในระบบนิเวศหาดทราย)


องค์ประกอบของระบบนิเวศนาข้าว
องค์ประกอบที่มีชีวิต
ผู้ผลิต
ผู้บริโภค
ผู้ย่อยสลาย
ผู้บริโภคพืช
ผู้บริโภคสัตว์
ผู้บริโภคทั้ง
พืชและสัตว์
ต้นข้าว
ควาย
งู
นก
เห็ด


ห่วงโซ่อาหารในระบบทุ่งนา
ต้นข้าว
ตั๊กแตน
นก
งู
ต้นข้าว
หนู
นกเค้าแมว
งู

VITAE

VITAE

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2007 Doctor of Education (Science Education), Srinakharinwirot University.