A DEVELOPMENT OF SCIENCE LEARNING MODEL ON LIFE AND LIVING FOR LEVEL 3 USING PROBLEM-BASED LEARNING AND TUTORIALS

A DISSERTATION

By

SURAPOL PAHOLPAK

Presented in Partial Fulfillment of the Requirements for the

Doctoral of Education degree in Science Education

at Srinakharinwirot University

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Surapol Paholpak. (2006). ***A Development of Science Learning Model on Life and Living for Level 3 using Problem-Based Learning and tutorials.*** **Dissertation, Ed.D. (Science Education). Bangkok. Graduate School, Srinakhariwirot University. Advisor Committee: Dr. Manat Boonprakob, Assoc.Prof.Dr. Weerawan Sithigorngul, Assist.Prof.Dr. Dilok Dilakanont.**

The objectives of this study were to develop a science learning model on life and living for level 3 using problem-based learning and tutorials, and to study the effects of the science learning model on student's critical thinking, understanding of science, science achievement, and satisfaction are with the model. The study based on the hypothesis that a problem-based learning and tutorial courses had the positive effects more than the others did. A randomized control group pretest-posttest design was used to compare the three lower secondary science classrooms of Matthayom Sanggit Wittaya Bangkok School, Pathumthani province, which were the sample groups followed by the problem-based learning and tutorial approach, problem-based learning approach, and the traditional approach respectively. Research instruments consisted of: critical thinking test, understanding of science test, and science achievement test. The level of difficulty, item discrimination and reliability coefficient ($r_{tt\ (KR\text{-}20)}$) of the critical thinking test were 0.46-0.63, 0.24-0.61, and 0.52 respectively. The Cronbach' s alpha coefficient of the understanding of science test and science achievement test were 0.925, 0.996, and construct validity were 0.70 and 0.70 respectively. The tests were administered to individual student of all groups.

It was found that, students who were trained by the problem-based learning and tutorial approach received higher scores of all tests than in the other two approaches. The data was analyzed using ANCOVA and ANOVA. The results showed that there were significant differences among the three groups ($p < .05$), particularly students' critical thinking skills and students' science achievement. Welch Statistics was used to determine the equality of understanding of science means and found that there was no significant difference among the three approaches ($p > .05$).

Additionally, a classroom observation and the findings from the questionnaires revealed that the students were satisfied with problem-based learning and tutorials rather than the problem-based learning only. The study results indicated that problem-based learning and tutorial approach was an effective approach for students to achieve schools' learning objectives.

การพัฒนารูปแบบการเรียนรู้วิทยาศาสตร์เรื่อง ชีวิตและการดำรงชีวิต สำหรับช่วงชั้นที่ 3 โดยใช้ปัญหาเป็นฐานร่วมกับการสอนทบทวน

บทคัดย่อ

ของ

สุรพล พหลภาคย์

เสนอต่อบัณฑิตวิทยาลัย มหาวิทยาลัยศรีนครินทรวิโรฒ เพื่อเป็นส่วนหนึ่ง

ของการศึกษาตามหลักสูตรปริญญาการศึกษาดุษฎีบัณฑิต

สาขาวิทยาศาสตรศึกษา

พฤษภาคม 2549

สุรพล พหลภาคย์. (2549). ***การการพัฒนารูปแบบการเรียนรู้วิทยาศาสตร์เรื่อง ชีวิตและการดำรงชีวิต สำหรับช่วงชั้นที่ 3 โดยใช้ปัญหาเป็นฐานร่วมกับการสอนทบทวน.*** **ปริญญานิพนธ์ กศ.ด. (สาขาวิทยาศาสตรศึกษา). กรุงเทพฯ : บัณฑิตวิทยาลัย มหาวิทยาลัยศรีนครินทรวิโรฒ. คณะกรรมการควบคุม : ดร. มนัส บุญประกอบ, รองศาสตราจารย์ ดร. วีระวรรณ สิทธิกรกุล, และ ผู้ช่วยศาสตราจารย์ ดร. ดิลก ดิลกานนท์**

การวิจัยนี้มีวัตถุประสงค์เพื่อพัฒนารูปแบบการเรียนรู้วิทยาศาสตร์เรื่อง ชีวิตและการดำรงชีวิต สำหรับช่วงชั้นที่ 3 โดยใช้ปัญหาเป็นฐานร่วมกับการสอนทบทวน และศึกษาผลต่อความคิดวิจารณญาณ ความเข้าใจทางวิทยาศาสตร์ และผลสัมฤทธิ์ทางวิทยาศาสตร์ การวิจัยนี้ตั้งอยู่บนสมมติฐานที่ว่า รูปแบบการเรียนรู้วิทยาศาสตร์โดยใช้ปัญหาเป็นฐานร่วมกับการสอนทบทวนมีผลเป็นบวกในทุกด้านมากกว่าการสอนด้วยรูปแบบการสอนโดยใช้ปัญหาเป็นฐาน และรูปแบบการสอนปกติ โดยมีแบบแผนการวิจัยเป็นแบบสุ่มมีกลุ่มควบคุมและการทดสอบก่อนเรียนและหลังเรียน เพื่อเปรียบเทียบผลในกลุ่มนักเรียนวิทยาศาสตร์ช่วงชั้นที่ 3 โรงเรียนมัธยมสังคีตวิทยา กรุงเทพมหานคร จังหวัดปทุมธานี จำนวน 3 ห้อง ซึ่งเรียนด้วยรูปแบบการเรียนรู้วิทยาศาสตร์โดยใช้ปัญหาเป็นฐานร่วมกับการสอนทบทวน รูปแบบการสอนโดยใช้ปัญหาเป็นฐาน และรูปแบบการสอนปกติ เครื่องมือวิจัยประกอบด้วยแบบทดสอบการคิดวิจารณญาณ มีค่าความยากง่าย ค่าอำนาจจำแนกและ ค่าความเชื่อมั่น ($r_{tt-KR\ 20}$)เท่ากับ 0.46-0.63, 0.24-0.61, และ 0.52 ตามลำดับ แบบทดสอบความเข้าใจทางวิทยาศาสตร์ และ แบบทดสอบผลสัมฤทธิ์ทางวิทยาศาสตร์ มีค่าความเชื่อมั่นโดยใช้การหาสัมประสิทธิ์แอลฟ่าของครอนบาค เท่ากับ0.925 และ 0.996 ตามลำดับ และ ค่าความตรงตามโครงสร้าง เท่ากับ 0.70 และ 0.70 ตามลำดับ

ผลการศึกษาพบว่า นักเรียนในกลุ่มทดลองที่เรียนด้วยรูปแบบการเรียนรู้วิทยาศาสตร์โดยใช้ปัญหาเป็นฐานร่วมกับการสอนทบทวนมีคะแนนการคิดวิจารณญาณและผลสัมฤทธิ์ทางวิทยาศาสตร์หลังเรียนสูงกว่านักเรียนในกลุ่มที่เรียนด้วยแบบเรียนอื่นอย่างมีนัยสำคัญทางสถิติที่ระดับน้อยกว่า .05 โดยการวิเคราะห์ความแปรปรวนร่วมและการวิเคราะห์ความแปรปรวน แต่ไม่พบความแตกต่างระหว่างคะแนนความเข้าใจทางวิทยาศาสตร์หลังเรียนอย่างมีนัยสำคัญทางสถิติที่ระดับมากกว่า .05 โดยการวิเคราะห์ด้วยสถิติเวลช์

นักเรียนที่เรียนด้วยรูปแบบการเรียนรู้วิทยาศาสตร์โดยใช้ปัญหาเป็นฐานร่วมกับการสอนทบทวนมีความพึงพอใจต่อแบบการเรียนรู้นี้มากกว่าแบบการเรียนรู้โดยใช้ปัญหาเป็นฐาน ผลการศึกษาชี้ให้เห็นว่ารูปแบบการเรียนรู้โดยโดยใช้ปัญหาเป็นฐานร่วมกับการสอนทบทวนเป็นแบบการเรียนรู้ที่ทำให้นักเรียนเรียนรู้บรรลุจุดประสงค์ได้ดี

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The dissertation titled

A Development of Science Learning Model on Life and Living for

Level 3 Science Using Problem-Based Learning and Tutorials

By

Surapol Paholpak

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Surapol Paholpak

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Chapter 1
Introduction

Background

Research on science education in Thailand reveals that different teaching and learning approaches have been developed, but to a limited extent. The reports indicated that there needed to be improved in both content and teaching approach of science in Thailand. Most schools lacked scientific instructional materials, which enabled students to construct knowledge themselves. It negatively affected students' performance in science (Soydhurum. 2001:10-19). A lack of sufficient knowledge and a scientific attitude were also the causes for most students why they can not apply some scientific knowledge to their daily life (Wattanakeeree. 1993: 87; Sagnuanwong. 1994: 45-46; Wongyai. 2542 : 2 ; Kaewdang. 1998: 35-47). This also had negative affect on scientific learning, shown by the results of an assessment of the quality of education by the Department of Curriculum and Instruction Development in 1997. It was found that test scores of most students were rated as a median down to poor (Office of the National Education Commission. 2001). The test revealed that the average science score of primary level students' was 50%, and the lower secondary level students' science score was less than 50% (Soydhurum. 2001:42-43). Also the statistical analysis reported by the U.S. Department of Education (2000) showed that the average score of Thai eight-grade students in science contents especially in earth science, physics, chemistry, science inquiry and the nature of science were lower than that of 38 nations listed. The results indicated that those students had biology scores better than that of physics, chemistry, and the nature of science. However they received the lowest score in the nature of science. The students in this group also received lower scores than the other groups from countries all over the world in the Third International Mathematics and Science Study (TIMSS) conducted by The International Association for the Evaluation Achievement (IEA). During the 1995-1999 competitions of the Academic Olympics, the overall competition records of Thai students were always ranked the lowest among the 5 Asian countries, which were Thailand, Taiwan, Korea, Vietnam and Singapore. Also the students' National Test scores 2000 indicated that learning abilities of students still fall short of expectation particularly in thinking process and a problem-solving skill (Office of the National Education Commission. 2001). This indicated that Thai students lack scientific thinking skills. They failed to develop analytical and critical thinking abilities and could not make a connection between science and other disciplines (Maneesiri. 1994; Tunwattakul. 1995; Thongma.1997; Gnamagsorn. 1998; Office of the National Education Commission. 2001; MEO. 2540 : 6; Wongyai. 2542 : 2; Kaewdang. 2543 : 35-47). With respect to those problems mentioned, the educational reform was needed as a tool to solve the problems.

In Thailand, The Office of the National Commission was an initiator in reforming Thai education, which began in1992. At the time of the first educational reform, Thailand was in the period of adjustment that needed people who were familiar with a civil working system. The stresses caused by the reform were at teacher education, teacher development, and educational personnel development. This included higher education and teaching and learning system were reformed in 1996. According to the reform, Thai people have had an equal opportunity in education, as a result, quality of teaching and learning have been improved and developed more appropriately for Thai students. Furthermore, the National Educational Development plan was implemented successfully, and had been packed in the 8th of The National Educational Development plan (1997-2001). Currently, education has been raised to be the Thailand principal policy (Office of the National Education Commission. 2001).

The affords for raising Thailand educational quality are included in The Thai National Education Act of 1999, which emphasizes that learning process must promote students critical thinking abilities in order to prepare them for the global world (Section 23 (2) (3)). The provision in section 24 of The Act focuses on education institutes that classroom organization must be rearranged and learning activities are designed to develop students' cognition upon their individual capacity. The Act conducted to the Basic Education Curriculum (BEC) 0f 2001. The emphasis of the BEC is to enhance Thai students to think critically which is an essential tool for people on how to live, work, and tackle problems logically in their daily basis. The expectation is that Thai students should be able to make choices, evaluate and judge things. Therefore, classroom management and a content of subject matter must be changed for supporting students to develop their own critical thinking as well as to construct their own knowledge. Particular, teaching and learning style is considered as one of the important parts of the reform achievement. The education goal is to allow all students to develop at their own pace and at their maximum potential. This was supported by The Promotion of Teaching

Science and Technology who stated that science instruction must help students reach the education goals through a scientific approach which is included in many instructional methods, in which case, the problem-based learning method is adopted as an instructional strategy to assist the students on their critical thinking development.

The Promotion of Teaching Science and Technology (IPST) has been the organization that is responsible for introducing various teaching and learning methods to Thai science teachers. The IPST has developed the science curriculum and learning materials for helping all science teachers. The objectives are to promote students to learn with scientific processes and students centered learning. After The National Education Act of 1999 was announced, all schools have their tasks on the development of school curriculum that improve student’s critical thinking skill based on student’s capabilities. The IPST has developed the national science stand, which has been used as a stand for local school science. The school science curriculum is developed based on the science stand, which consists of 8 substands: 1) living things and living processes, 2) Life and environment, 3) Matters and properties of the matters, 4) Forces and motion, 5) Energy, 6) Processes that shapes the earth, 7) Astronomy and space, and 8) Nature of science and technology. Within the science substand 1.1.1 and 1.1.7, the content relates to a human body and its function, drugs and drug addiction.

The topic of a human body and its function is closely related to drugs and drug addiction. For level 3, students must learn and understand digestive system, circulatory system, respiratory system, nervous system, and muscle and skeletal system. Manopichetwattana (2004 : 4) stated that students must learn and understand human body and its function because it is an important matter for students to understand this subject. But the substance itself is rather. Even worse, appropriately instructional methods can negatively affect students’ learning of the subject. This makes it difficult foe students to make a connection between the substance and other substances. The recent studies revealed that most of the students had misconceptions about the human body. Teaching and learning style was inappropriate for students to learn complicated human bodies and its function. Although human body and its function is closely related to drugs and drug addiction, students learn the contents contained in health education separately from the science subject. These affected students could not integrate and connect their knowledge to other disciplines (Cuthbert. 2000 ; Sander. 1993 : 919-934; Prapaisri Hinsui. 2538 B.E.; Taweedej Sanchom. 2540 B.E.). For this research, the instructional method about human body and its function, drugs and drug addiction should not only increase students' understanding of science knowledge, but also enhance students to think critically and integrate their knowledge to daily living.

Using problem-based learning strategy was based on psychologists' advocates that better cognitive development process lead student to better achievement at school (Department for Education and Skills, UK (2002). Mishoe and Welch (2002) suggest that the effectively instructional intervention for developing students' critical thinking skills is problem-based learning. It is a process in which students learn through situations similar to the one that they face in the real world. It is useful for development of student' s critical thinking skills and a thorough understanding of the knowledge. The students will discuss and analyze the problems based on their prior knowledge and existed learning resources. When they discuss and analyze the problem together, they use their cognitive skills for solving problems and self-monitoring skills to identify their learning needs as well as questioning skills to find related facts (School of Education, Stanford University. 2003). In this learning environment, the teacher will act as a monitor who motivates students organizing in learning. The monitor is active in planning a problem-based learning content and organizing the projects, discussing with the students, and evaluating students' progression. With the necessary experiences and guidances, the students will gain benefit from the course and start to build the new knowledge (Bolhuis. 1996; Temple and Rodero. 1995). These ideas are expanded by many researchers (Russell and Chiappetta. 1981; Chang and Barufaldi. 1999; Chistine et al. 2000) that a problem-based learning approach is worth for secondary science students in improving students' achievement and has positive effects on students active learning style. Using problem-based learning and an appropriate tutorial as an instructional approach will help students achieve in science achievement as well as improve their critical thinking skills to enable a higher standard of living.

In addressing these issues, a science learning model using problem–based learning and tutorials was developed for raising student` critical thinking skills, understanding of science, and science achievement. The contents of the research were focused on life and living for level 3, particularly human body and its function, and drugs and drug addiction.

Research Questions

The research questions are as follows:

1. Are the students' critical thinking skills, understanding of science, and students' science achievement who were trained by problem based learning followed by tutorial approach better than that of who trained by a problem-based learning approach, and a conventional approach?

2. Are the students satisfied with the science learning model using problem-based learning and tutorial approach?

Objectives of the study

The objectives of this study were:

1. To develop a science learning model on life and living for level 3 using problem-based learning and tutorial approach.

2. To compare among the effects of the science learning model using problem-based learning and tutorial approach, a conventional course using problem-based learning approach, and a conventional approach on students' critical thinking, understanding of science, and science achievement.

3. To determine the students satisfaction of the science learning model using problem-based learning and tutorial approach and the same course using problem-based learning approach.

Scope of the study

Design and methodology

The subject of this study is lower secondary school science using a problem-based learning strategy for grade 7 only. The contents were emphasized on human body and its function, drugs and drug addiction followed by the substrand 1.1.1 and 1.1.7. The curriculum was tested in the second semester, academic year of 2004, for 8 weeks with 16 class periods (24 hours) in total. The instructional strategies were given to grade 8 science teachers.

In this study, the learning science model was a science core course for the lower secondary school. The model consists of 4 sections. The first theses three sections include 3 problem scenarios related to alcohol and health effects, paracetamol and health effects, and amphetamine and health effects. And the last section is made up of keynote lectures and practical workshops containing all contents and learning activities of the human body and its function, and drugs and drug addiction provided in the National Science Standard. Problem-based learning and tutorials were used as an instructional strategy for an application of this research.

Participants of the study

The learning science model was implemented at Mathayom Sangkit Wittaya Bangkok School. The participant teachers were two science teachers. Both of them had twenty-year experiences in lower secondary science teaching. They were trained in the participant teachers' meeting before implementing the model in an actual science classroom.

MS 1 students in three different classrooms were participants in this study. With the Randomized Control Group Pretest-Posttest Design, 41 students of the MS 1/5 were taught with the developed learning science model using problem-based learning and tutorial approach, 43 students of the MS 1/4 with a problem based learning approach, and 35 students of the MS 1/1 with a conventional approach. The implementing procedure was from December 2004 to February 2005.

Variables of the study

In this study, the science learning model was independent variables and four dependent variables would be concerned. They were the following:

Independent variable The science learning model was science teaching approaches, which consisted of:

1. A problem-based learning and tutorial approach
2. A problem-based learning approach
3. A conventional learning approach

Dependent variables The four concerned effects of the model consisted of:

1. Student's critical thinking skills
2. Student's understanding of science
3. Student's science achievement
4. Student's satisfaction of the science learning model

Definition of terms

1. Science learning model: The developed science learning model was an instructional strategy for level 3 science. There were three teaching approaches used in the science learning model for increasing students critical thinking skills, understanding of science, science achievement and student's satisfaction. These were a problem-based learning and tutorial approach, problem-based learning approach, and conventional approach. The model consisted of four sections: 1) Alcohol and health effects, 2) Paracetamol and health effects, 3) Amphetamine and health effects, and 4) keynote lectures and practical workshop. The achievement target in each section was developed around The National Science standard particularly substrand 1.1.1 (human physiology, anatomy) and 1.1.7 (drugs and drug misuses).

2. Problem-based learning approach: The developed instructional strategy was used as a tool to promote student centred learning by using real world problems to drive students motivation in learning. The problems were the social issues outside the classroom that encourage students to learn by themselves. A group of six students were formed and they try to find out solutions to problems. The teacher facilitates the learning environment without tutorials. The instructional strategy consisted of three learning activities as follows:

1. Problems scenarios were presented to motivate students to learn.

2. Students learned in-groups to identify the given problems, select the related information, deduct the information, interpret the data, and explain solutions to problems. They used their critical thinking skills as an important thinking process to solve the given problems.

3. Teacher acted as a facilitator who supported the students' learning by motivating questions without tutorials.

3. Tutorials: Tutorials was one of the important factors of the developed science learning model for teacher to motivate students learning without being directed, and to help the students in the difficult tasks. The strategy was structured based on the core content and achievement goal. It included a list of concepts for identifying the given problems and exploring the related information, learning objectives that are applicable concepts to the solutions, and guiding students with stimulus materials (such as information sheets and tutorial guides).

4. Problem-based learning and tutorial approach: The developed instructional approach was used as a tool to that promote student centered learning by using real world problems to drive students' motivation in learning. The problems were the social issues outside the classroom that encouraged students to learn by themselves. A group of six students were formed and they tried to find out solutions to the problems. The teacher would help them in difficult tasks by using the developed tutorial guides. This approach consisted of five learning activities as follows:

1. Problem scenarios were presented to motivate students to learn.
2. Students learned in-groups of six and found out solutions to given problems.
3. Teacher acted as a monitor who supported the students by motivating them to learn and guiding them with the developed tutorial guides contained of science core concepts, learning objectives, information sheets, as well as providing the feedback in order to help them with some related science concepts.
4. Critical thinking skills included problem identification, selection of useful information, deduction, interpretation, and explanations were used as an important thinking process to solve the problems.
5. Students learned in class with lectures and practical workshop in accordance with the National Science Standard before ending the course.

5. Conventional approach: The conventional approach was a type of teaching provisions suggested by The Institute of Promotion of Teaching Science and Technology (2542). It consists of three steps:

1. Discussion. The students discuss about learning objectives, issues or the problems.
2. Experimentation. The students carry out the experiments as explained in the practical handbook.
3. Conclusion. The students discuss the results and answers of the provided questions and express their deep understanding of science through various passages.

6. Students' critical thinking skills: The critical thinking skills were a human ability to think rationally, which were used in problem-solving processes. Critical thinking skills were emphasised on the five ability components as the followings: 1) problem identification, 2) selection of useful information, 3) deduction, 4) interpretation, and 5) explanation. The skills were used as an important thinking process when the students were situated in problem-based learning and in tutorial approach.

7. Students' understanding of science: Understanding of science was an active process in which students were capable of organizing and elaborating the information with different ideas in a designed task. The variety of instructional strategies used in the courses affected an individual student of how he or she understood science.

8. Students' science achievement: Student science achievement was the student use cognitive skills when approaching science. Science achievement involved student science knowledge, understanding of science and ability to think critically. Students expressed their cognition through modified short essay questions, which were constructed around the standard core contents for level 3 science, particularly in the substand 1.1.1 and 1.1.7.

9. Students' satisfaction: Students' satisfaction was students' feedback after learning with developed problem-based learning and tutorial course. It was an important information for knowing students' learning process. Students expressed their experiences covered the following: satisfaction with the course format, classroom management information, and the student's opinions about the course.

Significance of the study

The principal outcomes from the study comprised of:

1. The science learning model using problem-based learning and tutorials appropriated for level 3 science students.

2. A set of evaluation instrument for measuring the student's progression, which consisted of a critical thinking test, an understanding of science test, and a science achievement test.

3. A basic knowledge for further studying on using of problem-based learning and tutorial approach. The approach was a student centred learning activities oriented strategy.

Conceptual framework

The science learning model using problem-based learning and tutorial approach was developed from a conceptual framework that was drawn from a social constructivist and cognitivist philosophy. In particular, the science learning model recognized that tutorials from more knowledgeable peers (teachers) were useful for students to construct their own knowledge in the context of problem-based activity.

Using problem-based learning approach was adopted as an effectively instructional intervention for developing students' critical thinking skills (Mishoe and Welch. 2002). Russell and Chiappetta (1981); Chang and Barufaldi (1999); and Chistine et al (2000) found that a problem-based learning approach was worth for secondary science students in improving students' achievement and had positive effects on students active learning style. Nowyenphon (2001) and Thongsooknok (2003) found that students who had low problem-solving abilities gradually improved to higher levels after learning with the open-ended problems, which were important parts in problem-based learning approach. As Bolhuis (1996); Temple and Rodero (1995); and Das, Mpofu, Hasan and Stewart (2002) suggested that the necessary experiences and appropriate guidances were important to assist students gaining more benefit from the problem-based learning approach.

In addition, a goal of using the developed science learning model was students' critical thinking skills, understanding of science and science achievement were investigated. The report of a meta-analysis investigation by Gijbels et al (2005: 27-61) was the basis for studying in the assessment congruency with problem-based learning that guided this study efforts. An outline of the conceptual framework of this study is shown in figure 1.

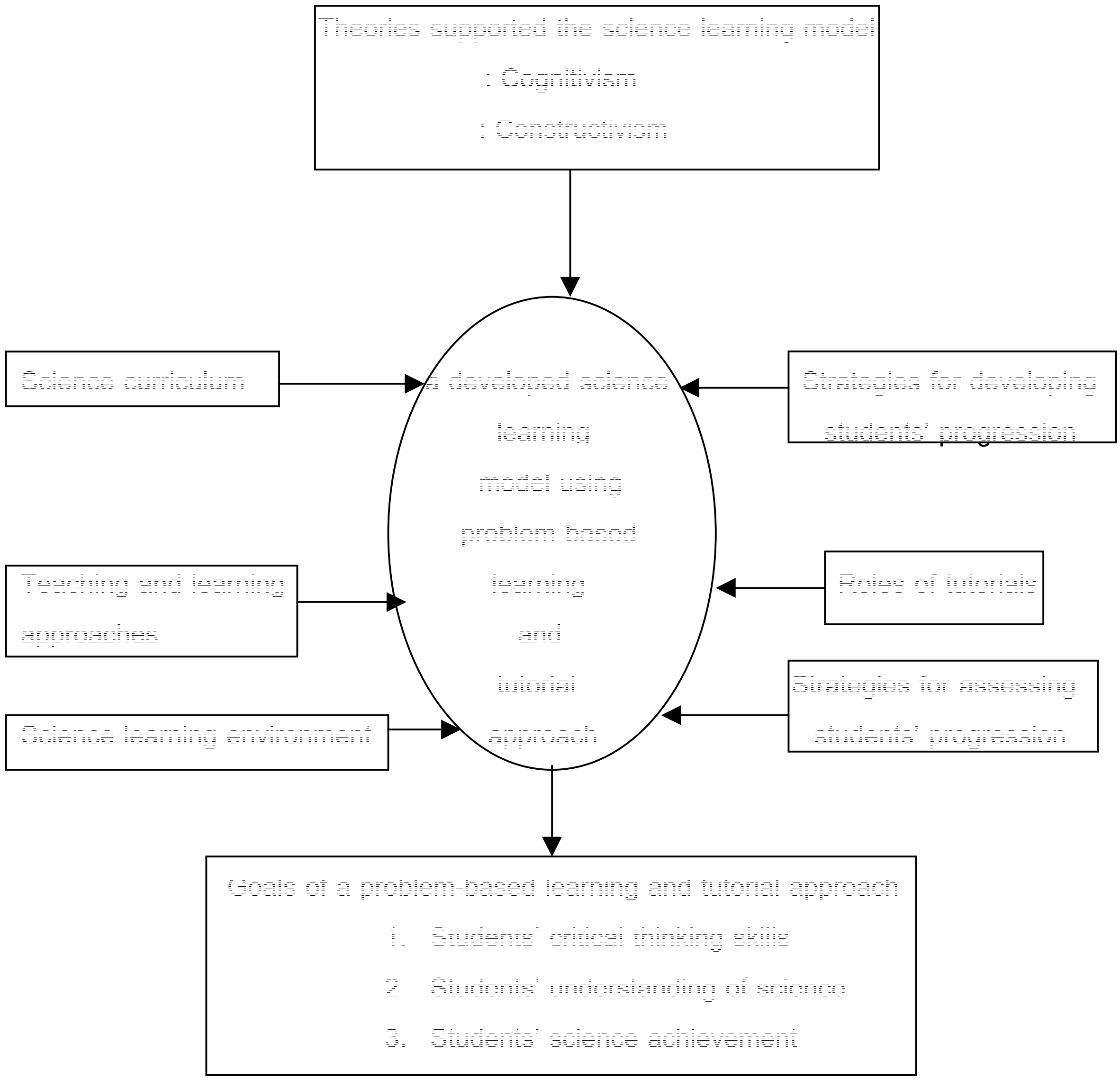

Figure 1 The conceptual framework of this study

Chapter 2

Literature Review

This literature review comprised of six sections, which were relevant to this study.

Section 1: Problem-based learning and development of problem-based learning and tutorial courses

Section 2: Research related to problem-based learning

Section 3: Steps of development of problem-based learning and tutorial courses

Section 4: Definitions of thinking, critical thinking and process of thinking development

Section 5: Understanding of Science

Section 6: Cognitivism and constructivism

Section 1: Problem-based learning and tutorial approach

Problem-based learning

Problem-Based learning aims at gaining knowledge, information, and learning techniques while solving problems. The main point of this study was that problem-based learning was one of the effective teaching and learning strategies. It was in line with Constructivism that students are able to learn and construct knowledge themselves through real life problems and through collaborative task designed.

There are many types of teaching and learning methods considered as active teaching and learning approaches, but the most well-known significant approach which supports active learning and promote student critical thinking is problem-based learning or PBL. Problem-based learning is based on ideas that have a long history and have been studied by many researchers (Gijbels, Dochy, Bossche, and Segers. (2005:28). Although it is originally developed for McMaster Medical School in Canada, the McMaster version of PBL has been applied widely in various fields, for instance, architecture, business administration, engineering study, economics, and others (Gijbels, Dochy, Bossche, and Segers citing Donaldson, Maitland, Merchant, Garland, cawley, and Boud. 2005:28-29).

Barrows and Tamblyn (1980) defined problem based learning as the learning that results from the process of working toward the understanding or solution of a problem. They pointed out that students encountered problems first. Which the problems serve as stimulus in students problem-solving task. Then they look for relevant information to help them understand the problem and how it can be solved. Barrows (1986) pointed out that possible permutations and combinations of designed variables in problem based learning is endless and can come about by challenging the role of subjects, group learning, teachers and schools. For Barrows, the problem of PBL is a learning material rather than curriculum. PBL motivates students to learn and gain knowledge when they work on their problem-solving task.

Barrows (1996) also developed a model of problem-based learning that included six characteristics of:

1. Learning is student-centered.
2. Students learn in small groups.
3. A teacher acts as a facilitator.
4. Students are presented with authentic problems before learning has occurred.
5. The problems are used as learning instruments to achieve their learning goals.
6. New knowledge is acquired through self-directed learning.

Boud (1997) noted that a problem or a puzzle, which the learners wish to solve at the beginning of problem-based learning course, is a stimulus for student learning. There are some problems in problem-based learning in which they should be analyzed in terms of the types of problem, teaching learning sequences, and autonomous learning and assessment methods (Barrows, 1986). Therefore, when using PBL, one should consider on following factors, such as, course objectives, expectations, including developmental psychology. This implied that PBL derives from various objectives of a course and some particular skills that drive self-learning abilities. Students who trained by a problem-based learning course are expected to use a variety of methods to construct new knowledge by themselves. Charlin et al (1998) supported that problem-based learning are based on different educational principals and approaches.

Gallagher et al (1995) stated that the order of learning in PBL is inverted to reflect real life learning and problem solving. Learning begins after students are presented with an ill-structured problem that challenges thoughts, habits of mind and actions. An ill-structured problem is defined as little or no information provided on the initial stage, the goal-stage, or some combination of these two stages. The way to approach ill-structured problems is to identify multiple goals in objective terms so that a variety of solutions can be considered (Halpern, 1989). When facing a real life problem, students are not capable of tackling the problem due to the insufficient information. There is no single correct answer to the problem. Finally, students are not certain about their solutions because some information is still missing. This is a characteristic of science. This is described as a process of thinking about problems, then finding ways how to approach them, asking what further approaches can be used to solve this problem (Gallagher, 1995). This coincides with American Association for the Advancement of Science (1989) and National Science Teachers Association (1992) that the theme of science education is to understand science as thinking processes and implementing them.

Mishoe and Welch-Jr. (2002:1-5) viewed that there are at least three variations of problem-based learning: 1) student directed PBL (full PBL), 2) modified PBL (partial PBL) and 3) introduction to PBL (minimal PBL). They defined problem-based learning as a process which learners learn through situations when solving problems. It is a student-directed approach and its objective is to help learners develop higher order thinking. The teachers' role is to facilitate a learning process by giving opportunities for learners to independently learn by themselves through group discussions and research. The PBL focuses on development of cognitive strategies and professional skills including teamwork, communication, and decision making. This is consistent with Bruner's theory that cognitive strategies are very important factors for students to learn new knowledge. In a PBL course, students express their abilities to think critically through various methods. For examples, the critical thinking test is designed to test specific critical thinking skills. Students' presentations reflect their cooperative ideas from group work, while the facilitator helps students gain knowledge during their discussions and assess students' abilities on their critical thinking skills.

In teacher-centered learning or lecture-centered learning, the teachers are mainly responsible for selecting subject content and skills that the students are expected to learn. The teachers also set the standard for assessment, evaluation, and demonstration. Students are less directly responsible for what they learn and for their own education. This leads them to be passive learners. By this approach, quality of the teachings depends on teachers' background, presentation styles and their expertise. Glasgow (1997: 30-34) suggested that this approach does not involve in helping students develop their cognitive skills and their learning experience.

Mishoe and Welch,Jr. (2002) also supported Glasgow's idea and illustrated the differences among PBL and conventional approach as shown in Table 1.

TABLE 1 The differences among PBL and conventional approach

PBL	Lecture
1. Student directed	1. Teacher directed
2. Active learning	2. Passive learning
3. Centered on cases	3. Centered on lecture notes
4. Emphasis on cognitive skills	4. Emphasis on knowledge acquisition
5. Curriculum organized around problem	5. Curriculum organized around disciplines
6. Centered on group discussions, communication and skills, problem solving skills	6. Centered on listening, independent reading, testing to assess knowledge
7. Focused on biological and psychosocial issues	7. Focused on separated subjects

Adapted from Mishoe and Welch (2002; 7)

Learning process in problem-based learning in science classrooms

As mentioned above, students are placed as a center in a problem-based learning course. The students work in-groups of between 5-12 persons to look at the problems. Students act as a scientist. The problems are designed to capture students' interest and to motivate them to search for more knowledge about science concepts.

Learning process in problem-based learning includes:

1. Problems are presented to the students and examined by the group members.
2. Students discuss in-group and identify the problem. Woods (1994) stated that successful problem-solvers spend most of their time deciding what to do. Gallagher, Rosenthal, and Stepien (1992) suggested that successful problem-solvers tend to spend their time in the problem-based learning

course to identify the problem first in which they called “problem finding” or problem identification (Adams, 1979), while unsuccessful problem-solvers spend most of their time doing something irrelevant to the problem. At this step, students identify what they think the problems are.

3. Students identify their learning needs in order to prove hypotheses. They agree on the learning objectives that they will have to seek more knowledge. At this step, students gather information to generate the answers. They decide whether they should use acquired information or not.
4. Students generate a solution. At this step, student individually learns depending on the selected information and individual’s background knowledge and understanding.
5. Students present the solution. They share their research findings to the class. Students give comments during discussion.

Teachers minimize their teaching roles to be facilitators of the learning process. After delivering the problem, teachers motivate students’ learning by asking questions, such as, What do you need to know more about? What is your evidence? Teachers do not pose direct questions about the problem. Consequently, students become self-directed learners, which they are capable of questioning and identifying their learning needs.

In a science classroom, teachers use inquiry as an instructional method to develop students understanding of science. The students also use the inquiry technique to build up new knowledge and gain more experiences. This is in line with the science educators and educational researchers who attempt to foster the inquiry skills in students for finding and extending knowledge. Szesze (cited by Tanaprayothsak. 2005: 23) states that inquiry is a process of questioning scientifically to find out whether answers are valid. Students in all levels in a science course should be provided opportunities to use scientific inquiry to develop their thinking abilities that include questioning, planning, conducting investigation, gathering information, thinking critically, and communicating scientifically (The National Research Council. 1996 cited by Tanaprayothsak. 2005: 23).

Apparently, science inquiry method is an important part of the problem-based learning approach that has been adopted as an effective inquiry learning model for science course. Which Kain (2003) presents a basic version of problem-based learning integrated with a basic structure of inquiry as an exploring tool for students. The students ask, what they know, what they need to know, and how they find out more information in order to come up with solution (Stepien & Gallagher. 1993 cited by Kain. 2003: 2-3). The tutors then guide the students how to question and where to seek for further information. The inquiry process makes students learn more. Finally, the students present a solution.

The use of problem-based learning in secondary schools

Kain (2003: 5) stated " In recent years, problem-based learning has been promoted by a number of scholars and practitioners for use in the public schools. There is a Center for Problem-Based Learning in The Illinois Math and Science Academy, with a website that features samples of the approach and a discussion of issues related to PBL. Indeed, many schools are incorporating the practice. The research into the effects of PBL on learning in the public schools is still emerging. However, initial results are encouraging".

Christine and Chia (2000) indicated that PBL for secondary school students is based on what students are interested in. Students learn new knowledge through the process of problem solving and apply skill to finding out solutions to problems. Then scientific skills are necessary to be integrated in secondary school curriculum. Chang (2002) advocated that science instructions in secondary school should put more emphasis on developing the science process skills in student. This is important input for successful problem solving in real life science problems. Solving a problem requires student to understand the problem, make accurate observations, interpret data, formulate a valid hypothesis and find solution to the problem. In order to do such things, students need problem-solving abilities or skills. American Association for the Advancement of Science (1993) defined problem solving ability as the ability to think critically, to reason analytically, and to create productivity, which all involve quantitative, communicative, manual and critical response skills. These abilities are transferable to students through the active teaching and learning approach, not conventional approach that students are passive knowledge receivers. Presently, most of science curricula for secondary schools foster students to be critical thinkers by using problem solving approach rather than other approaches.

Chistine and Chia (2000); Chiu (2002); and Kain (2003) all advocated that several studies of problem-based learning were succeeded at higher education level, especially at medical schools, but there are very few studies at a secondary school level. Since problem-based learning approach is considered as an effective approach in helping students learn by themselves. It is worth considering as another tool to engage students in secondary school level.

Tutorials

The tutorial is an early exposure to the students' working and function as they are learning in problem-based learning course (Boud. 1996). They will use it as a guideline for learning or building up new knowledge. Little (1998) suggested that tutorial should include learning objectives, evaluation and assessment.

In project-based learning and problem-based learning, the role of a tutor is more important than the conventional approach. The tutor is expected to face more challenges students' discussion when ill-structured problem is presented. Facilitator should psychologically support students. The facilitator motivates students to give feedbacks on a small-group work. Facilitator should act as a part of the group but not dominating discussion, encourage the learners to go on, ask them to explain their thinking, and clarify meaning (Harlen. 1988: 91-92 cited by Ian W. and Carson S.2002). The facilitators' roles in problem-based learning course are to ask questions and to lead the discussions. In addition, the facilitators encourage students to participate by giving support and praise to them.

The roles of the teachers in problem-based learning are as a facilitator, a tutor, a mentor or a monitor. The teachers serve as a resource for students. The facilitators plan the problem-based learning contents and are sequence of the projects organization, include giving feedback immediately to the students, having discussions with them, and evaluating their performances. Norman and Shamidt (1992) agreed that teachers' feedback that cooperate into students learning activities help students gain more benefit from instructors so that students will be provided a chance to discuss what they may not understand, so that misconceptions can be discussed before. Stepien and Gallagher (1993) suggested that teachers should act as metacognitive coaches and serve as models. Learning with teachers and peers is aimed at helping students be aware of connection between school knowledge and real-world problems (Bolhuis. 1996; Temple and Rodero. 1995; Guthric, Solomon and Rinchart: 1997).

In this science model, the monitor worked with groups of student and facilitated the learning process. Particularly in the initial section, the facilitator took more active role while students were learning how to identify problems and to set goals and objectives. The students were given a developed tutorial guide to help them understand the learning objectives, find learning resources, and collect information around them. Students began their learning activities with a tutorial guide to clarify relevant concepts or issues because they were confronted with the problem for the first time. Teacher used the developed tutorial guide to support students for verifying and finding solutions of the provided problems.

The problem-based learning and tutorials in this study

The science learning model using problem-based learning and tutorials for the lower secondary school science was developed based on the ideas mentioned above. The model included four sections of problem 1: Alcohol and health effects, problem 2: Paracetamol and its effects, problem 3: Amphetamines and its effects, and the last section is lectures and discussions.

The structure of the developed science learning model started from students encountered ill-structured problems before they received any information in the relevant contents. The students brainstormed using 5 components of critical thinking skills including the following: identify problems, select useful information, deduce cause and effects, interpret data, and explanations the solution. Students worked in-group of six which they exchanged information. The teacher's role acted as a monitor. The monitor guided students by providing the information sheets followed by a tutorial guide. The students set their own pace and directions when solving a given problem in a form of a series of health data. The monitor encouraged and guided the students to learn without directing.

As for the tutorials, the facilitator would assist students developed critical thinking skills to become self-directed learners, and to be able to apply what they have learnt to find solutions. In this study, the teacher acted as a monitor by using tutorials guide for motivating students to develop their critical thinking skills. The students used the 5 critical thinking components to extend knowledge for deeper understanding science. At the end of the learning process, students expressed their ideas through solutions, and the paper tests.

The structure of problem-based learning and tutorial approach in this science learning model is shown in figure 2.

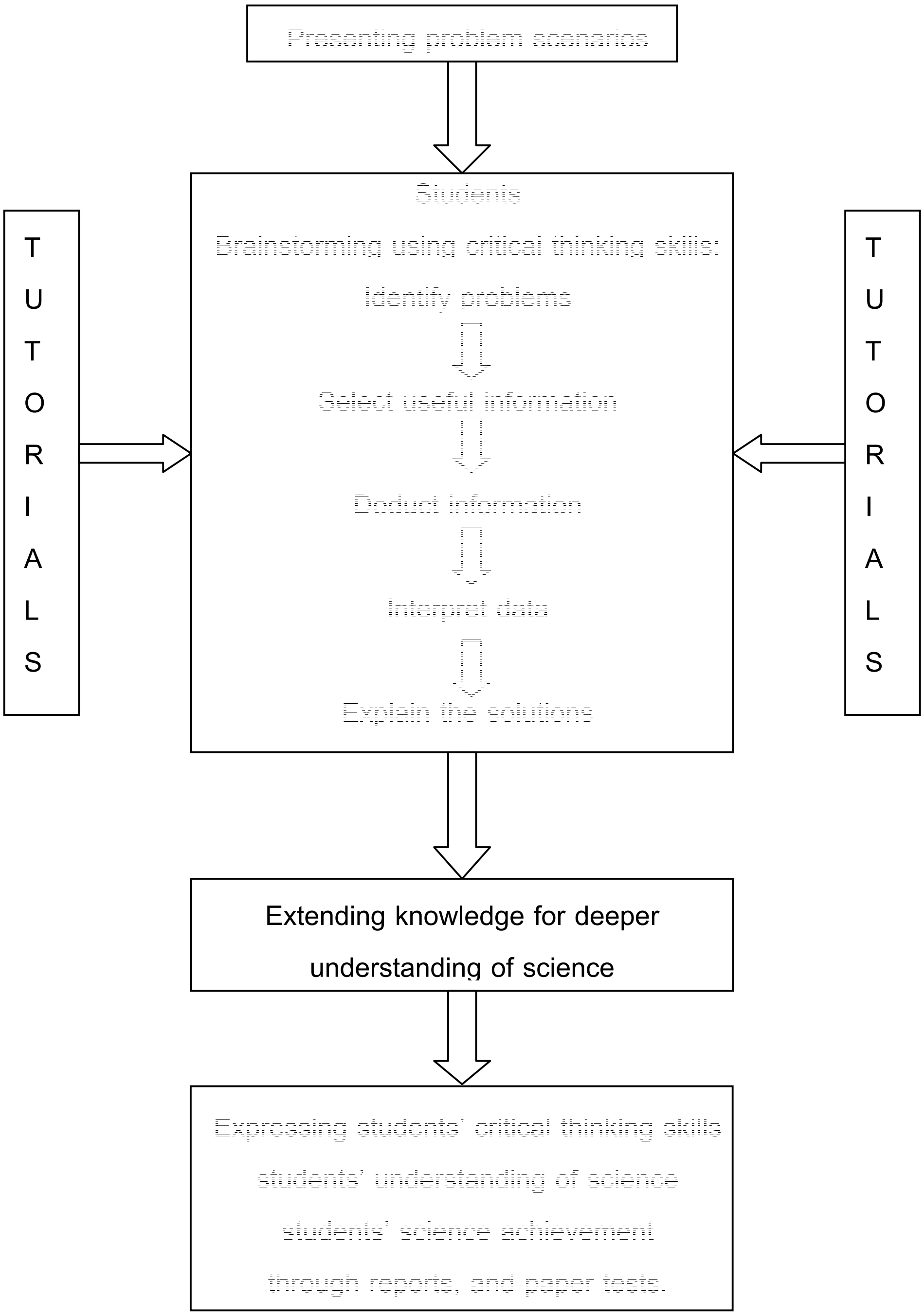

Figure 2 The structure of Problem-based learning and tutorial approach in the science learning model

The science learning model for level 3 was developed mainly based on the Piaget's theory and Vygotsky's theory. The students who received the science learning model directed themselves in many ways for developing new knowledge. This was supported by the Piaget's theory that students between the ages of 11-14 are able to develop their abstract thinking and reasonable thinking. The Vygotsky's theory supported this study as well that students in these ages can make progress by thinking hard about their prior knowledge and establish understanding with a solution on their own. They can work with teacher and other pupils and learn from the discussion they are working on. When students are learning to solve problems, they require to understand the problems rather than to make use of their existing knowledge.

Although a survey study by Shayer revealed that less than 30 percent of secondary students between the ages of 11-16 were in Piaget's formal operational stage (cited by Amos, 2002:156-157), but tutorials in this model would help students achieved the learning goals. Therefore, this model started with the familiar problems about alcohol and its effects for motivating students to learn. Students were encouraged to learn from their facilitators as well as their peers. It was a valuable strategy for helping students achieve science standards and develop social skills at the same time.

Section 2: Research related to problem-based learning and tutorials

Research related to problem-based learning and tutorials

Chin and Li-Gek (2000) studied on how problem-based learning was incorporated into the biology curriculum in three classes from secondary level. The study focused on how students generated ideas for their problems, the types of question they asked, and how the teachers presented these activities. The study results showed that the students had difficulties in generating questions and forming their own problems at the beginning. After spending time to think, the students understood the problem-finding process. The problems then became a focus of subsequent inquiries and the students worked collaboratively in-groups and have been supported by the facilitator. Several of the students' misconceptions on science related to social issues were discussed and being cleared up during the learning process. The study indicated that students could take control of their problems, and intended to solve their problems from real-life experiences. The students learned new knowledge through the process of problem solving. The researchers suggested that the implementing of problem-based learning in the classroom might be purposeful and supported by appropriate learning materials. The most interesting points of the study were those students' questions and problems came from three main areas; 1) cultural beliefs and native tales, 2) advertisement and media, and 3) encounters or family members' concerns. This learning method is called “a search of the problem space” (Apleton. 1995: 383), which was an initial phase of problem solving involving the construction of an internal, mental representation of the problem. Some students required validating information that they had found out from various sources which was the step of analysis in Bloom' s taxonomy. Finally, the student could achieve science goal. This indicated that the students were motivated to continue to solve the problem and build up the knowledge themselves by learning though a problem-based learning course.

Chang and Weng (2002: 441-451) explored the interrelationship between secondary school students’ problem solving ability and their science-process skills in the area of earth science. The results indicated that science process skills serve as important inputs for students in solving the problems successfully in earth science. Bonnie (1984) and Bayer (1985) supported the study results that understanding the problem, making accurate observations, interpreting data, formulating a valid hypothesis, and finding solution to the problem are important characteristics of critical thinking abilities. The abilities were essential for students and could come handy when students solve a problem. The findings suggested that science instruction in the secondary schools should put more emphasis on developing students’ science process skills or critical thinking skills. The researcher expected that development of critical thinking skills helped students improved their problem-solving abilities.

Chang (2001) explored the effects of a problem-based computer-assisted instruction (PBCAI) on students’ earth science achievement in grade 10 students in Taiwan. The results indicated that the PBCAI produced more positive outcomes on students’ achievement than did the directed-interactive teaching approach. The results also viewed the success of the PBCAI that it had positive effects on students’ knowledge and comprehension levels of Bloom’s cognitive domain. The researcher suggested that incorporating models of PBL into CAI promoted students to see real-life science problems in situation, to understand the natural hazard problems, to identify scientific facts, to collect relevant data and information, and to elaborate on their solution. Students were able to construct their own methods of acquiring knowledge and understanding concepts in earth sciences. The research results supported Russell and Chiappetta (1981) that problem-based approach improved the overall achievement of eighth-grade earth sciences students. In additional, Chang and Barufaldi (1999) found that a problem-based instruction model significantly improved students' achievement and had positive influences on students learning.

Panarat Chamchoen (2005) studied the results of the laboratory activity packages focussed on patterns and relations for enhancing Mathayom 1 students' mathematical problem solving skills. One-group pretest-posttest design was used for the study to compare students' mathematical achievement after using the developed laboratory activity packages. The finding showed that those students' mathematical problem solving skills and reasoning skills on patterns and relations was higher significantly at the .10 level. The packages using a problem-solving approach had positive effects on students' mathematical achievement.

Peecah Nowyenphon (2001) studied the effects of open-ended problems in Mathematics for lower secondary school students. The study found that the students (60% of participants) who had low problem-solving abilities gradually improved to higher levels after learning with the open-ended problem solving technique. The findings suggested that problem solving instruction should be put in learning processes for secondary schools students in all subjects for fostering students' problem-solving abilities.

Rangson Thongsooknok (2003) studied the effects of problem-based learning approach in Theory of number for secondary school students. The results showed that 50% of the students achieved more than 60% of the mathematics score. The open-ended problems motivated the students to learn on their own with teachers' assistance at the early stage. The assistance was gradually needed less lately. The researcher suggested that most of the secondary school students, particular the Mathayom 4 students, had their abilities to learn Theory of numbers using problem-based learning approach. The important issue found in the study was that the open-ended problems used as a stimulus tends follow the National Standard Contents, as well as included the mathematical process skills that could promote the PBL in class. Also, students learned Logical Theory prior to exposing to problem-based learning.

There were several studies at a undergraduate level particularly in basic science in medical students, dental students, and other bio-medical sciences. They compared two different approaches: conventional and PBL, and examined whether students' performance were different in their learning outcomes. Shelton and Smith (1998) used the problem-based learning approach with the first year undergraduate biomedical science students at Sheffield

Hallam University. The study found that students were very positive about PBL. The students were able to relate theory to practical workshops. They gained the benefits of group-work and improved their problem-solving skills but negatively effects on taking responsibility for their own learning and examining revision notes. The students' achievements were slightly higher than the previous year students who took the course with conventional didactic approach. These results were similar to the study of the effects of problem-based learning and conventional course on basic science knowledge of dental students at Liverpool by Last et al (2001). The results showed that there was no significant difference in the total scores when negatively marked between the conventional and problem-based learning course group but there were higher total scores in the problem-based learning groups when positively marked. Students' performances in anatomy, oral biology and physiology did not differ between the groups when negatively marked but the scores of the conventional course groups in biochemistry were significantly lower than the others. Positive marking biochemistry scores were not significantly different but scores in all other subjects were significantly higher in the problem-based learning course groups. The results also showed that the overall knowledge recall in the basic sciences by dental students on problem-based learning and conventional didactic courses did not differ between group ($p < .001$). However, the study reflected that students in the PBL course group perceived relevance of different science subjects better than the other groups. The students adopted the problem-based learning course to be challenging course and enjoyable for learning and led to their greater motivation.

Even though the results remained unclear for higher students in some subjects, a comparisons between PBL approach and conventional lecture-based learning approach in pharmacology courses showed that PBL students were more successful in standardized tests and enjoyed their course than lecture-based learning approach students (Shin et al, 1993). Shin also viewed that the PBL student group's scores were higher on knowledge related to information that became useful after their graduation. It was important that students were able to train themselves as an independent learner.

Das, Mpofu, Hasan and Stewart (2002) revealed the study results of student perceptions on tutor skills in problem-based learning tutorials that the tutor's role was to facilitate students' learning process and foster critical thinking skills and attitudes toward their future learning. The students' evaluation indicated that tutorials were crucial for learning process. They needed guidance and support to search for more information about a topic they were researching.

Section 3: Steps of development of problem-based learning course

The National Science Curriculum

The Educational Act of 1999 introduced The National Science Standard for schools in Thailand. The National Science Standard provides core subject for all science curricula for students up to the age of 18. It consists of 8 substands: 1) living things and living processes, 2) Life and the environment, 3) Matters and properties of the matters, 4) Forces and motion, 5) Energy, 6) Processes that shapes the earth, 7) Astronomy and space, and 8) Nature of science and technology.

Following to the Education Reform Act, each local school must develop a school science curriculum for delivery. The subject matters and teaching processes are concerned around different necessary skills and maturity of students. School curriculum has its content on local issues and community interests. The contents are taken from the National Science Standard contents 70% and 30% from local issues. Students are expected to learn things that are important to their lives.

The National Education Act defines the achievement target for science at this level as knowledge, skills and understanding of science including other subjects. The achievement targets will allow teacher to assess students' performance during or at the end of each academic term. The expectations of the National Curriculum for pupils in science learning are the development of ideas and scientific enquiries used in scientific explanations. Students are able to use scientific methods to explain natural phenomena and look for evidence through practical work to examine whether or not.

The achievement target for students Level 3 (The Institute for Promotion of Teaching Science and Technology. 2003) is divided into eight strands of science, which the strand 1 has its detail as follows:

Strand 1 living things and living processes

Strand1.1

Understand basic unit of living things and the relationship between the structure of living things and their functions.

The study of living things: using scientific methods of inquiry, communication and be able to apply knowledge to daily life.

S 1.1 is divided into 7 substrands as follows:

1.1.1 Investigate and explain characteristics and structures of unicellular and multi-cellular organisms, parts of the cell and their functions particular gastrointestinal system, respiratory system, circulatory system, immunity system, reproductive system, and musculo-skeletal system.

1.1.2 Investigate and explain the factors involved in the mechanism of photosynthesis and cell transportation.

1.1.3 Investigate, discuss, and analyze the relevant information to the structure of living things (plants, animals, human), systems and apply knowledge to daily life.

1.1.4 Investigate, observe, analyze and explain the effect of light, temperature, water and touch.

1.1.5 Appreciate the use of Biotechnology for plant propagation and increasing plant and animal yields, and the effects on agriculture, the food, industry, and medicine.

1.1.6 Investigate and test of the quality of food and apply knowledge of nutrition and health.

1.1.7 Investigate, discuss and explain the effects on systemic organ of drug abuse and describe anti-drug strategies and drugs prevention.

The content of the science curriculum in Key Stage 3 starts covers more abstract concepts and more details about scientific processes and more relevant issues to real world thinking. The students are expected to integrate their knowledge and make connections between subjects and to explain natural phenomena.

In this study, the contents were focused on substrand 1.1.1 and 1.1.7. Students iinvestigated and explained the characteristics and structures of human organs and their functions, particularly in gastrointestinal system, respiratory system, circulatory system, immunity system, reproductive system, and musculo-skeletal system. Students also investigate, discuss and explain the effects of drug abuse on systemic organ and describe anti-drug strategies and drugs prevention. One of the important purposes is that the students can see a connection of the two substands when analyzing real-life problems for instance, drugs and drug misuses. The solutions to the problems would include knowledge how humans' body functions and changes due to drug effects, Drugs and nature of drugs, family and social impacts will be looked at as well.

Designing a problem-based learning course

In the problem-Based learning course, the essential components that drive students to learn are the real problems. Duch et al (2001: 41-53) state that one of the keys to success in implementing problem-based learning is the type of the problem teachers use. Typical problems do not foster the development of effective problem-solving and analytical skills (Heller & Hollabaugh.1992) nor do they challenge students to develop critical thinking skills and logical reasoning (Mazur.1996). Delisle (Cited by Kain. 2003: 216) suggested that the problem in problem-based learning should be appropriately developed to the level of the students, and curriculum-based. The experience educators in various fields suggest a number of characteristics for effective problems in problem-based learning.

Duch et al (2001: 41-53) suggested that characteristics of the good problems in problem-based learning course should be based on Bloom's taxonomy as described below:

1. motivate students to learn for deeper understanding,
2. relate the subjects matter to real world problem,
3. require students to make decisions in judgments based on facts, information, logic and rationalization,
4. be complex enough for students to work in groups toward a solution,
5. should be open-ended , based on previously knowledge,
6. incorporate the objectives of the course into the problems, connect previous knowledge to new concepts, and connect new knowledge to concepts in other courses or disciplines.

Kain (2003; 216-217) listed some characteristics for effective problems as followings:

1. are relevant to students and interest them.
2. are interdisciplinary.
3. are significant.
4. are constructed on contextual details, but not enough to solve.
5. are ill structured, in which there are alternative solutions to the problems.

6. are contained achievement targets.

The summary is that characteristics of problem in problem-based learning courses should encourage students' critical thinking, especially in the higher levels. The problems will motivate students beyond Bloom's cognitive levels of knowledge and comprehension, where they analyze, synthesize, and evaluate. These are important skills, which students are expected to develop after learning with this model.

Steps of designing problem-based learning courses

Lane and Remley (2002) suggested the seven steps for designing problem-based learning courses as follows:

1. Analyze the course: Developers determine the course objectives that they will include in the PBL course. They design problems based on objectives set for the course.

2. Select a topic or an issue for the problem: Developers consider the idea and scope which is controlled by content objectives

3. Brainstorm: In this step, the developers ask students to brainstorm the ideas on the selected topic, then use those ideas to come up with the problem.

4. Frame the problem: look at all the gathered information and set up a scope for the problem. This step needs to examine whether the objectives are included in the problem.

5. Write the problem: rough written outline for the problem as the first draft. Review and revise. Check whether the problem meets its intended objectives.

6. Develop a lesson plan: Considering on a use of the problem in class, outside class, and a combination of both. Time for students when they work on the problem. Develop mini lectures.

7. Gather learning resources: Develop a list of learning resources for students. Which they should cover enough information for students to search.

Rangachari (1998) suggested that the problem in problem-based learning should be built around the goals and objectives of the course as well as teacher's interest. This indicated that the problem applies to the students' needs and the National Curriculum objectives. The National curriculum has been the most significant factor for teachers to pay attention to what they should teach their students. This was the most important issue to note in the development of a new curriculum.

Assessment strategies

The National Education Act of 1999, section 26 stated that Educational institutes shall assess learners' performance through observation of their development, personal conduct, learning behaviour, participation in activities and results of the tests accompanied by the teacher-learning process commensurate with the different levels and types of education. Educational institutions shall use a variety of methods for providing opportunities for further education and shall also take into consideration results of the assessment of the learners' performance. The National Education Act of 1999 attempts to produce a quality and quantity assessment of learning to be used as a regular task of classroom practice. The teachers assess student' s progress in learning regularly. The assessment can be ranged from simple observation, conversation to standardized testing.

The significance of assessment is a way for teachers to know how student's progress from learning in the course. These are major criteria as follows: 1) to measure current capacity, 2) to maintain standards, and 3) to reflect on the teaching and learning approach (Rowntree. 1987; Quinn. 1997).

Formative assessment should enable the instructor to measure the students' achievement after they had taken the course. Formative evaluation includes student performance, teacher performance, and the quality of support provided by the school administrators and staffs. Martinez (2001: 167-169) suggested that there are many ways in which the instructor can measure the students' progress by the formative assessment. These include observations, quizzes, and consultations. The instructor can use this method by asking students to have a conversation together. The instructor can evaluate concerns raised by students during the consultation. Sandra Amos and Richard Boohan (2002: 279-288) stated that formative assessment was situated at the heart of effective teaching and learning. It supported learning strategies because it encouraged student to participate actively in learning activity. The formative assessment used in constructivism was very useful in the following ways: 1) reflect on students' learning in a structured and systematic fashion, 2) engage in talking with instructor about students' progress and what students need to do to improve, and 3) develop students competence in the process of learning.

Summative assessment is one of the conventional forms of assessment that focuses on teachers' role. It takes place at the end of a learning course. The important aim of the summative assessment is to measure and report the learning outcomes in order to make a variety of comparison between the students (Bennett. 2003). Students are measured with a variety of tests, such as, standard assessment tasks, National test, or modified essay questions (MEQs) (Crowl et al. 1997). The modified essay questions are an appropriate measurement for assessing students' problem solving skills especially in the clinical problem of medicine course (Janekarn citing Engle. 2530).

Boud (1997) indicated that the instruments used for the PBL assessment should be closely linked to problem-based learning approach and are structured to have a beneficial effect on student learning. Duch et al (2001: 95-106) suggested that assessment method in PBL course is an assessment to examine students' learning progress. Students can be measured through learning objectives such as student's critical thinking skills, communication skills, and research skills. It is recognized as the six characteristics of Barrows's core model of problem-based learning (1996). That is students learn with problem-based learning course will analyze and solve designed problem. The consequence is that students would be assessed their problem solving abilities. Segers et al (2003) expanded that in problem-based learning environment, the assessment should take into account both of the knowledge-based and the students' problem solving skills.

Gijbels et al (2005: 27-61) summarized the assessment congruency with problem-based learning in his report of A Meta -analysis investigation. The descriptions are as the following:

1. Students' problem solving skills are evaluated in an authentic assessment environment.

2. Students' knowledge transferability, skill of acquired knowledge, and demonstrate of understanding on problem analysis as well as problem solving are evaluated with the authentic problem.
3. Students' arguments are evaluated on the basis of relevant perspectives.
4. Stu8dents' integrative knowledge of relevant ideas and concepts are evaluated with test items.
5. Students' application of knowledge in problem solving are evaluated with

The Gijbels et al's summary mainly focused on the test of students' ability to apply their knowledge to problem solving situations. Many research findings cited by Gijbels implied that items assessing knowledge include students strengths and weaknesses and knowledge based. This assessment result enhances future learning of the students in the direction of knowledge base that is necessary for them during problem solving processes.

Sugrue (Cited by Gijbels. 2005) introduced an integrated theory-based model of cognitive components of problem solving. Sugrue explained that successful problem solving comes from the interaction between knowledge structure, metacognitive functions, and motivation. Sugrue categorized each of the three cognitive components into a set of variables that should be targeted by assessments as follows:

Knowledge structure : 1. Concepts, 2. Principles, and 3.Links from concepts and principles to conditions and procedures for application.

Metacognitive functions : 1. Planning, and 2. Monitoring.

Motivation : 1. self-efficacy, 2. demands of the task, and 3. perceived attraction of the task.

According to the findings on his Meta -analysis investigation of the effects of problem-based learning, Gijbels et al (2005; 27-61) presents the various assessment methods related to the main goals of problem-based learning. They are described below.

Progress test: The test is constructed to assess rooted knowledge, not just details. Gijbels et al classified all progress test as assessing the first level of the knowledge structure.

Modified Essay Questions (MEQ): The Modified Essay Questions is standardized series of open questions about a problem. The given sequentially information ordered students must relate theoretical knowledge to the particular answer of the problem. Gijbels et al classified all MEQ as assessing the third level of the knowledge structure.

Short-answer questions: The short-answer questions require students to elaborate short written answer. The questions are used to assess factual knowledge. Gijbels et al stated that this represents the first level of the knowledge structure.

Multiple-choice questions: The multiple-choice questions or MCQ have been not accepted for use in problem-based learning course because it is believed that the MCQ is suitable for assessing only the first level of Bloom's taxonomy (Van Der Vleuten. 1996). Boud & Felletti (1997) however, argued that MCQ can be used in PBL assessment depend on its quality of design and administration of the test. Gijbels et al supported the idea and presented that multiple-choice questions can be used to assess all three components in the knowledge structure but they can assessing only the first level of the knowledge structure.

Furthermore, essay questions and oral examinations were classified as assessing the second level of the knowledge structure, performance-based test and case-based examinations were representing the third level of the knowledge structure.

Based on the information above, the assessments in this study assessed on the three following:

1. Critical thinking skills. All groups of the students were tested with the developed multiple choice questions for assessing students' critical thinking skills at the end of the course.
2. Understanding of science. All student groups were tested on their understanding of science through short answered questions at the end of the course.
3. Science achievement. After completing their different courses, all students were tested with modified essay questions. Its purposes were to assess

students' science knowledge based on reasonable thinking, theoretical science knowledge, and ability to apply knowledge.

Finally, the two experimental groups were evaluated their satisfaction of the science learning model through the developed student satisfaction questionnaires after completing their different courses. The questions in the questionnaires included the course format, classroom management, and students' further suggestions.

Section 4: Definition of thinking, critical thinking, and process of thinking development.

Thinking definition

Smith (1992: 1-2) defines " Thinking " as followings:

1. look back on past events: deduce, explain, and recall etc.
2. project into the future: anticipate, conceive, device, expect, etc.
3. be concern with what is going on at the moment: analyze, argue, assert, comprehend, etc.
4. be anchored to actual events: concentrate, explain, reason, etc.

Smith's thinking definitions is a complex process that consists of a number of thinking skills. The process relates to the past events to the future. It consists of many components that people use to solve problems.

While the thinking is described as a cognitive process that occurs internally or in the mind, it is a mental derivation of a sensory input to formulate thoughts, reasons, or judgements. It is inferred indirectly by cognitive psychologists Andre (1986); Beyer (1987); Halpern (1995) and Anderson (1993) as follows:

1. a process that involves some manipulation or set of operations on knowledge in the cognitive system.
2. a set of direction and result of behaviour that solves a problem.

Presseisen (1985) suggested that thinking is a complex and reflective effort as well as a creative experience. "Thinking" otherwise relates to the basic skills of thinking. Anderson (1993); Andre (1986); Beyer (1987); and Halpern (1989) all advocated that thinking relates to sequential steps in solving problems. Halpern (citedby Andrey B. Champagne. 1992:126-127) expanded "it comprises of essential thinking skills of lower order thinking and higher order thinking skills, reasoning modes and reasoning skills as well as academic and assessment exercises used to teach and test thinking”.

According to the above ideas, Halpern (1995: 39-41) welded the thinking skills into science classroom. Halpern viewed that students in science classroom think scientifically with two different kinds of thinking: 1) thinking with the basics and 2) thinking is basic. In a science classroom with students learning to think with the basics, they enable to use basic science or mathematics knowledge in thinking after they have learnt enough and sufficiently motivated. This implies that thinking is a process which knowledge is considered as raw materials and energy sources. The products of thinking processes are ideas, understandings, and solutions of problems. This kind of learning approach does not encourage students to think before they had acquired new knowledge. The students act as an information receiver. While the classroom with students learning with thinking is basic, they start learning from thinking scientifically and mathematically. The thinking abilities grow through a progression of activities that increase in level of their difficulties. With this concept, the students involve thinking from the beginning rather than the previous kind of thinking. In consequence to the idea, science education should be changed in term of its teaching styles so that thinking is the main focus of activities in learning environment which enable students to develop their capabilities of scientific thinking skills through elaboration, refinement, and modification.

Definition of critical thinking skills

Howe, Robert, Warren and Charles (2003) explained that, thinking critically is based on the essential three components which are: 1) information to acquire, use and believe, 2) plan to make, and 3) action to take. Critical thinking helps people living well in a complex world. Halpern (1995) supported that the components included in critical thinking skills are one of the human potentials to think in many ways. It is the use of cognitive skills to describe the thinking processes. Critical thinking involved in solving problems, formulating inferences, calculating likelihood, and making decisions. The thinker is using these effective skills in a particular context and a thinking task. Shelly (2002) also supported that critical thinking skills are related to students’ thoughts and feelings. It involves knowing how to think, apply, analyze, synthesize, and evaluate data, which are important steps of problem-solving processes.

Swartz and Perkins (1990:19) stated that critical thinking skills are a higher order thinking that people uses as a basic thinking in many ways. The ability to think critically is essential for people to live, work, and solve problem effectively in our current and changing society. Howe and Charles (2003) stated that when people have to make choices, evaluations, and judgments every day, the following components are taken into account in a critical thinking process: 1) information to obtain, use and believe, 2) plan to make, and 3) action to take. This was seen that the critical thinking is an internal process to analyze arguments and generate particular interpretations such as reasoning patterns, understanding situations, and appropriate style of presentation.

Halpern (1996) defined critical thinking is the use of those cognitive skills or strategies that increase the probabilities of a desirable outcome. It is used to describe thinking that is purposeful, rational and goal-directed. It is the kind of thinking involved in solving problems, formulating inferences, calculating likelihood, and making decisions. Critical thinking also involves evaluating the thinking processes of final decisions (Halpern. 2001: 253-256).

Kurfiss (1988:2) defined the critical thinking is a rational response to questions that do not have specific answers, in which case, all the relevant information may not be available. This is a form of problem-solving, but a major difference between the two is that critical thinking involves reasoning about open-ended or ill-structured problems, while problem-solving is usually considered narrow in (scope Kurfiss. 1988:29). Costa (1985) and Keating (1988) expanded that people use four elements of critical thinking skills solving ill-structured problems:1) content knowledge or knowledge of the discipline, 2) procedural knowledge or knowledge of thinking skills, 3) ability to monitor, use and control thinking skills or metacognition, and 4) an attitude to use thinking skills and knowledge. For Costa and Keating, critical thinking also based on people’s background knowledge and ability to manage ways of thinking for finding solutions to problems.

Ennis (1987) and Stephen (1985: 40-45) stated that humans use their critical thinking skills as a tool for decision-making on a daily basis. Ennis (1989) redefined critical thinking is a process of reasonable and reflective thinking. The process includes the following parts: 1) a problem solving process at the beginning, 2) a reasoning process based on prior knowledge, and using of induction and deduction for drawing results, and 3) decision at the end of the task. The results of critical thinking are not tesTable solutions, but rather a justified conclusion on the responsibility to provide supporting arguments. For Ennis’s idea, critical thinking is defined as cognitive skills or strategies that increase the probabilities of desirable outcomes. It is the kind of thinking involved in problem-solving, formulating inferences, calculating likelihoods, and making decisions. Halpern (1995) supported the idea that thinkers will use thinking skills in a particular context and a type of thinking task. This is sometimes called directed thinking because it focuses on a desired outcome and also involves evaluating the thinking processes when people came to a conclusion in making a decision (Halpern. 1989: 5 ; Halpern. 2001: 253-256).

Paul, Binker, Jensen, and Kreklau (1990: 56) identified a list of 35 dimensions of critical thinking, which helps people understand it. The list consists of three groups of strategy that people use them to think and make decisions. There are as follows:

A. Affective strategies: 1) thinking independently, 2) developing insight into egocentricity or sociocentricity, 3) exercising fair-mindedness, 4) exploring thoughts, underlying feelings and feelings underlying thoughts, 5) developing intellectual skepticism and suspending judgment, 6) developing intellectual courage, 7) developing intellectual good faith or integrity, 8) developing intellectual perseverance, 9) developing confidence in reason.

B. Cognitive strategies-macro-abilities: 10) refining generalizations and avoiding over-simplifications, 11) comparing analogous situations: transferring insights to new contexts, 12) developing one's perspective: creating or exploring beliefs, arguments, or theories, 13) clarifying issues, conclusions, or beliefs, 14) clarifying and analyzing the meanings of words or phrases, 15) developing criteria for evaluation: clarifying values and standards, 16) evaluating the credibility of sources of information, 17) questioning deeply: raising and pursuing root or significant questions, 18) analyzing or evaluating arguments, interpretations, beliefs, or theories, 19) generating or assessing solutions, 20) analyzing or evaluating actions or policies, 21) reading critically: clarifying or critiquing texts, 22) listening critically: the art of silent dialogue, 23) making interdisciplinary connections, 24) practicing Socratic discussion: clarifying and questioning beliefs, theories, or perspecting, 25) reasoning dialogically: comparing perspectives, interpretations, or theories, 26) reasoning dialectically: evaluating perspectives, interpretations, ortheories.

C. Cognitive strategies-micro skills: 27) comparing and contrasting ideals with actual practice, 28) thinking precisely about thinking: using critical vocabulary, 29)noting significant similarities and differences, 30) examining or evaluating assumptions, 31) distinguishing relevant from irrelevant fact, 32) making plausible inferences, predictions, or interpretations, 33)evaluating evidence and alleged facts, 34) recognizing contradictions, 35) exploring implications and consequences.

In addition, Paul expanded that critical thinking is disciplined self-directed thinking that exemplifies the perfection of thinking a appropriate to a particular domain of thinking. Paul also suggested that critical thinker is the person who has the following traits of mind: 1) an ability to question deeply in the framework of thought, 2) an ability to reconstruct sympathetically and imaginatively viewpoints and frameworks of thought opposed to one's own, and 3) an ability to reason dialectically to determine one's own point of view in various senses. This explained that critical thinkers are thinkers who think carefully on their own concepts, deliberate determinations of whether to accept, reject, or suspend judgments.

The views of critical thinking above showed that critical thinking is not only a macro-skills but also a micro-skills thinking process as well as strategies that affected people to think critically. For the latter part, Facione (1990) summarized in his findings that one can improve one's own critical thinking in several ways: First, one can critically examine and evaluate one's own reasoning processes. Second, can learn how to think objectively and logically. Third, can expand one's repertories of those more specialized procedures and criteria used in different areas of human thought and inquiry. Last, can increase one's base of information and life experience. The experts agree in his consensus that, critical thinking can not included as a core knowledge in all subjects in school curriculum. Instruction a critical thinking must cover specific disciplines or substances that include events in everyday life in order to develop one's critical thinking. Therefore, skills related to critical thinking and appropriate instructional method containing the real life topic should be considered when teaching students to think critically.

Skills related to critical thinking

Ennis and Paul suggested that critical thinking skills are human unique abilities that include specific skills especially for problems-solvings. Bonnie (ERIC Digests ED 385606) supported that critical thinking skills connect closely to the problem solving skills, which is one of scientific process skills that educators attempt to develop in student own self (AAAS. 1989).

Quinn (1997) advocates that critical thinking requires abilities or skills to identify a problem, select useful information, draw inferences from observed facts, recognize assumptions, formulate hypotheses, deduct information, interpret data, and evaluate arguments. Although there are some quite diverse definitions of critical thinking skills, almost all of them emphasize abilities to gather, evaluate, and use information effectively.

Beyer (1995) defined critical thinking as a predisposition and the skills to scrutinize and assess the thought of oneself and others. The results of critical thinking are to construct reasonable judgements and make decisions. Beyer expanded that critical thinking consist of six elements : 1) disposition, 2) criteria, 3) arguments, 4) reasoning, 5) point of views, and 6) procedures for applying criteria and judging. According to Beyer's definition, critical thinkers have dispositions or skills of being skeptical, questioning for reasoning and providing evidence for their conclusions. The thinkers set the criteria that are appropriate conditions for making judgments. Their judgments are argued based on propositions and evidence, which are facts and principles. In their arguments, reasoning is inferred to make a connection between propositions and evidences. The inference is made under a scrutiny deductively or inductively. The critical thinkers continue to develop their point of views based on their background, prior experiences, and their own knowledge. Critical thinkers use the results from the five former elements to clarify information, identify a point of view, verify assumption, and rectify in reasoning. The actions are included procedures for applying criteria and judging. According to Beyer's critical thinking concept, learners' are considered as a dispositionin that learners are expected to improve on their own.

Watson and Glaser (1980) suggested that students develop their critical thinking skills to bridge the relationships between evidences and explanations through 5 components: 1) inference, 2) recognition of assumptions, 3) deduction, 4) interpretation, and 5) evaluation of argument for coming up with the solutions to the problems.

Sternburge (cited by Halonen and Santrock. 1995) suggested that there are four critical thinking skills that might develop in students. They are as follows: 1) obtaining information, 2) using informal knowledge, 3) thinking in-groups, and 4) developing long-term approaches to long-term problems.

Facione (1990) published the findings for educational assessment and instruction that critical thinking skills can be grouped and sub-classified in many ways. The consensus list of critical thinking skills and sub-skills were:

1. Interpretation: categorization, decoding significance, clarifying meaning.
2. Analysis: examining ideas, identifying arguments, analyzing argument.
3. Evaluation: assessing claims and arguments.
4. Inference: querying evidence, conjecturing alternatives, drawing conclusions.
5. Explanation: stating results, justifying procedures, presenting arguments.
6. Self-regulation: self-examination, self-correction.

With respect to the findings, critical thinking occurred within an individual. The skills are used to detect person's proficiency on a specific task or situation. It is considered as an important thinking process which one uses for solving a problem. Critical thinking is useful when people are facing problems. Accordingly, critical thinking always takes place in response to specific situations. Critical thinking is expressed as the skills of questioning, solving problem, reasoning resolving, evaluating theories or laws, conducting inquiries, interpreting information, and making decision in daily life. All critical thinking instructions should aim at helping critical thinkers improve their critical thinking skills.

During the knowledge-based oriented, critical thinking is used as an important knowledge manager. It is the most important skill for development of beliefs and decision-making. This was supported by Reinmann-Rothmeier and Mandl (1998:33) who revealed their findings in a Delphi-study that experts in education advocated critical thinking as an essential skill in knowledge management. Relevant background knowledge is also an important factor of the quality of thinking. It is valuable as a cognitive resource for logical management and judgment. Critical thinking skills are ways to solve particular problems and they can be transferable through appropriately instructional methods, such as, problem-solving approach, deduct information, and so on.

In Thailand, critical thinking skills are expected to improve Thai students' performance in school. According to the National Education Act of 1999, the provision in section 23 (2) and (3) states that learning process in school must enable students to think critically in fasting change of the world. The expectation of The Act is that when confronting with real life problems, students will use their critical thinking skills as an important thinking process to approach all contents with their much broader, more effective and relevant understanding so that new knowledge and solutions to a problems will be discovered and verified (figure 3).

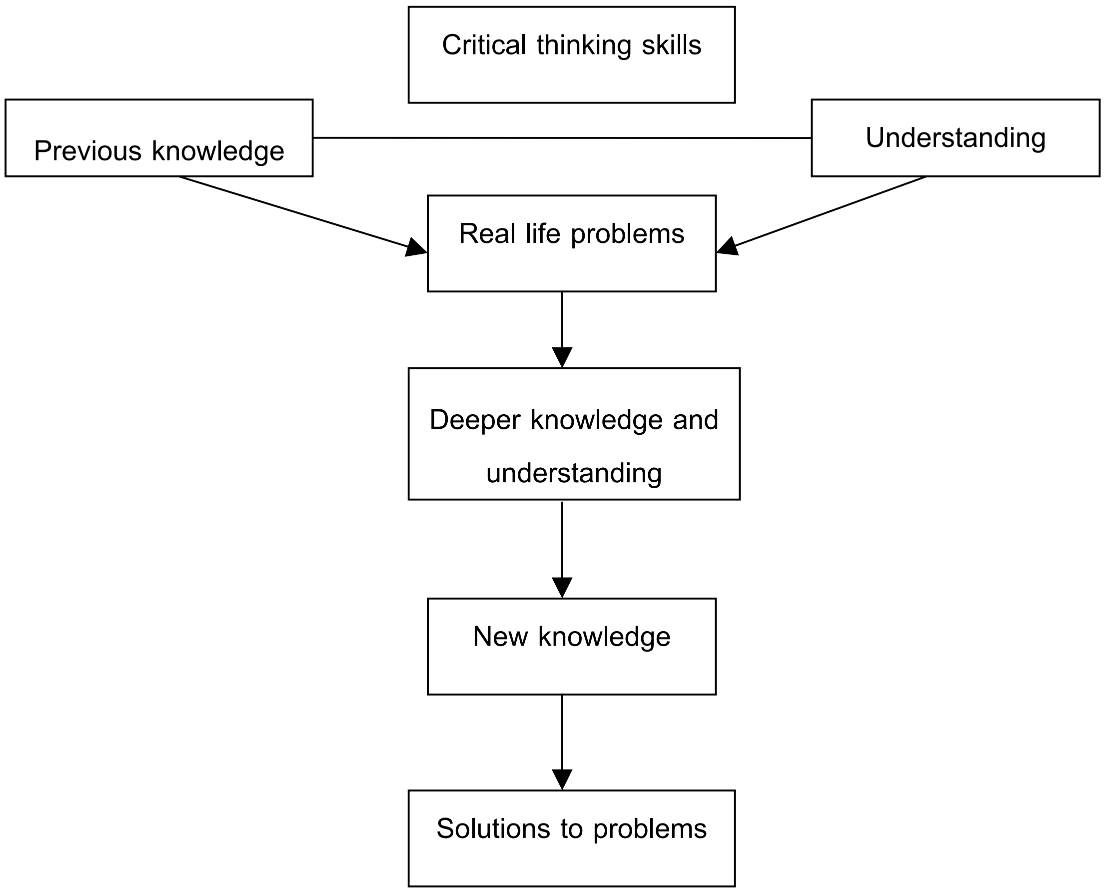

Figure 3. Critical thinking as an important thinking process for solving a problem

Process of critical thinking development

Department for Education and Skills, UK (Department for Education and Skills. 2002: 269-271) described that human thinking ability is related to three factors as follows:

1. Genetic makes up. This is an important spontaneous factor that influences on human intelligence. Although this is controversial, scientists agree that genetics influenced intelligence about 20%.
2. Time. The human brain develops until reaching its peak in the late of teens. This implies the secondary school students' thinking have a tendency to develop rather than the primary school students.
3. Environment. Appropriate stimulating and supportive environments arouse cognitive development.

School can help students develop cognitively by providing challenging learning opportunities. The learning tasks should be based upon students' capabilities in which psychologists believed that better information processing leads to better achievement at school. School should provide students opportunities for their cognitive growths, such as creating disequilibrium for thinking reasonably.

Kraak (2000: 51) suggested that critical thinking is the most important skills in the educational process which students can use in their real life for making decision. This is in line with Facione (1996) who stated that during learning with a critical thinking course, students form judgment of what to believe or do in a particular context. In the process, student will gradually develop more cognitive skills for analysis, interpretation, inference, explanation, evaluation, and self-regulation. Following up from the ideas, Facione identified seven dispositions toward critical thinking. These are: 1) open-mindness, 2) analysis, 3) truth seeking, 4) maturity, 5) systematics, 6) inquisitiveness, and 7) self-confidence. These are essential dispositions that The Thai Educational Act of BE 2544 expects Thai students should have as a critical thinker.

Among the ideas above, they could be summarized that critical thinking skills are transferable skills through an appropriate teaching and learning method. Ennis, Kahane,and Scriven (cited by McPeck. 1990) stated that critical thinking will be transferred in maximum when students learn a set of general skills. On the other hand, transfer will be minimized when students learn with specific information only. This means that appropriate teaching and learning approach for students develop the on their own. The skills should not be taught separately for students' better cognition.

In Thailand, critical thinking has been taught in many schools according to The National Education Act of 1999, Section 23(2) (3). The provision of the Act concerned on learning process must promote students critical thinking skills in order to keep up with the global world. Although many sub-skills of critical thinking have been taught separately, this is considered useful in critical thinking. School curriculum should be developed to motivate students to use critical thinking skills. The interesting point is that critical thinking skills are highly promoted in education system worldwide, among curriculum developers, educational researchers, parents, and employers (Ennis. 1991; Halonen. 1995).

In this study, the science learning model was developed based on educational theories for fostering student's critical thinking development by themselves. The course included three ill-structured problems presented to the students. The developed course was used to enhance the students think critically and achieve science achievement through five components of critical thinking skills. They were the followings:

1) Problem identification: finding the problem, forming problem statements.
2) Selection of useful information: seeking information, gathering relevant information, and determining useful information.
3) Deduction: clarifying and justifying the value of rules, methods, concepts, or principals to form a new knowledge.
4) Interpretation: comprehending and expressing the meaning of situations, data, judgments, rules, and determining the relationships of the data to the whole.
5) Explanation: justifying reasoning in solutions to the problems, producing statements of the evidences based results.

Section 5: Understanding of science

Understanding is a process which human uses for structuring and organizing incoming information. The understanding consists of essential compartments of sense, intelligence and perception. It involves comprehension of communication, being able to translate or describe other terms, interpretation, extrapolation. Comprehension may involve the ability to apply applications into daily life. Crowl (citing Bloom. 1997) concluded that understanding could be categorized into six levels based on cognitive skills. The category called Bloom's Taxonomy classified human cognition into six levels as the followings: level 1) knowledge, level 2) comprehension, level 3) application, level 4) analysis, level 5) synthesis, and level 6) evaluation.

Crowl (1997: 293) expanded that Bloom’s taxonomy focuses on what students should learn and at what levels of comprehension they should achieve in their learning goals. Teachers use the taxonomy to develop questions that require different levels of comprehension. Students reflect their understanding to the questions in different levels upon their constructed meaning from incoming information and existing knowledge. They are reflected as the followings:

Level 1: Knowledge

Student: Remembering information presented to the student. Student is able to exhibit prior knowledge by recalling facts, terms, basic concepts and answers.

Level 2: Comprehension

Student: Understanding the information presented. Student can demonstrate understanding of facts and ideas though various methods of organising, comparing, translating, interpreting, giving descriptions and stating main ideas.

Level 3: Application

Student: Using information in problem solving. Student is able to solving problems by applying acquired knowledge, facts, techniques and rules in a variety way.

Level 4: Analysis

Student: Breaking down information into component parts. Student can examine and break down incoming information into parts by identifying the causes, making relevancy and finding evidence to support decision making

Level 5: Synthesis

Student: Finding connections and relationships among different ideas. Student can compose information together in a different way and create an alternative solution.

Level 6: Evaluation

Student: Examining and judging ideas to determine how well they satisfy criteria. Student is able to criticize and prove the information or idea based on a set of criteria.

The current science curriculum consists of the standards across eight strands of science. It is involved around a unifying theme as follows: 1) Living things and living processes, 2) Life and the environment, 3) Matters and properties of the matters, 4) Forces and motion, 5) Energy, 6) Processes that shapes the earth, 7) Astronomy and space, and 8) Nature of science and technology.

Level 3-science curriculum focuses on making decisions and judgements based on students' scientific knowledge. These learning outcomes are provided in the standard content for science level 3 in Thailand (The Institute for the Promotion of teaching Science and Technology. 2001). The science curriculum for level 3 should be called, therefore, as 'Comprehensive Science'. Similarly, the Nuffield Science Projects in England wildly used the word 'understanding' in their learning outcomes, according to the science curriculum Key Stage 3 (The Nuffield Science Projects. 1994).

Understanding of science is crucial for students to learn science especially for secondary school science. Department for Education and Skills in UK (1998) supported the idea with five reasons as below:

1. Understanding of science helps students make sense of natural phenomena. This means science revolves around us on a daily basis and is worth learning.

2. Understanding of science helps students understand the basis for decisions in an increasingly technological world. In everyday life, people use scientific knowledge as a tool for decision making. They accept that knowledge in science is useful in their lives. When they are facing a social problem, they expect to understand, and make decisions (Steve Alsop and Keith Hicks. 2001:28).

3. When students acquire the skills of how to understand of science, they will develop investigative and practical skills through science, which can help them solve problems. One of the important purposes of science curriculum is to develop student's scientific processing skills. The processes include observing, classifying, inferring, hypothesizing and evaluating. The skills help students see things in new perspectives. Moreover Millar (1989) extends the idea that the scientific process skills are also context dependent. For Millar,

investigating and experimenting is a collaborative activity. Thus, teamwork, respecting for others' ideas and promoting equality of opportunity, developing ideas of co-operation, and exploring the ideas should be encouraged in science classes.

4. Science is interesting and intellectually stimulating. Science stimulates student's intellectual. Millar and Osborne(1998: 5) state that the science curriculum itself is interesting and it can help sustain and increase students' curiosity about the natural world around them, and build up their confidence to inquire things in their habit.

5. Science is an important part of a contemporary culture and has implications for people of all nations and all walks of life. This means, understanding of science helps students to acquires abroad, general understanding of the important ideas and explanatory the framework of science, and the process of scientific enquiry which have impacts on humans environment as a whole (Millar and Osborne. 1998: 8).

Bransford; et al. (cited by Tanaprayothsak. 2005) explained that understanding scientific knowledge involves obtaining knowledge, comprehending meaning of the ideas, and applying the ideas by using scientific thinking to solve a problem. Students construct scientific understanding when discovering conflicts between their observations of the natural world, and express through explanations what they have found. Parkinson (2002) suggested that understanding of science is an active process of organizing and elaborating the information in order to expressing the various ideas in a constructed task. When students are placed in problem-solving situations, they will apply the skills and express their ideas in their own words. Their understanding can be measured through a variety of means: such as group work or class discussion, homework, flip chart, writing or reports. This can be seen that the understanding of science is achieved by students' discoveries though scientific methods, not by reading theories.

In this study, while constructing solutions to problems, the students used their existing scientific knowledge to understand the real world and build up new knowledge for solving the given problem. They expressed their understanding of science through the various assigned works, such as, dairy progress report and final report of each problem. The works required students to identify the problem scenarios where they used their understanding from simple recall to application level. At the end of the course using the developed science learning model, they were tested with short answered questions for measuring their understanding of science

Section 6: Cognitivism and Constructivism

The Process of Learning

Learning is referred to changes in an individual due to experience (Mazur. 1990). Psychologists attempt to explain how learning occurs. There is much research that has been conducted on this issue. Some theories explain particular types of learning, but no single theory adequately explains how all learning takes place (Crowl, et al. 1997: 23). Behaviourists attempt to explain learning in terms of how events in the environment affect behaviour or people's response to some type of stimulus. While the cognitivists explain learning in terms of how people think or focus on the brain's function which the process and stored information are important in the process of learning.

In this research, Cognitivism and Constructivism were the concepts influencing on the active learning science model that motivate students to learn how to learn.

Cognitivism

In cognitive theories, knowledge is viewed as a symbolic mental constructed in the student' s mind. Learning process is a means by which these symbolic representations are committed to memory. Changes in students' behaviour are observed, but only as an indicator to what is going on in the learner's brain.

Following are the well-known psychological theories:

1. Gestalt theory
2. Piaget's theory
3. Vygotsky's theory
4. Gagne's theory

Gestalt theory

Gestalt theory is an interdisciplinary theory, which provides a wide variety of psychology phenomena, processes, and applications. According to Gestalt idea, human being is actively interacting with their environment as an open system. Gestalt assumes that people study to understand the relation of the whole to the parts that make up the whole.

The assumption consists of:

1. Organism responds to specific stimuli.
2. Organisation of the sensory environment influences the human perception.
3. Concept of insight was introduced.

The Gestalt viewpoint is that human perception could not be a product of sensory input, because perception is inherent interpretation, and interpretation is a matter of the subsumption of sensory experience under meaning categories and concepts (David Carr. 2003: 95). Perception is organised into meaningful patterns that include relationships among elements. The Gestalt psychologists believed that a number of innate factors influence how students think, while many psychologists believe that these students thinking is as a result of experience and learning. Although Gestalt psychology emphasises on perception more than learning, many educators draw it on the instruction guidelines later. The edcators believed that learners can learn by being aware of the structure of the contents and relationships among its elements, so that they can organise and retain the body of knowledge. This means that lectures and texts can be constructed in a way that they can recognize what they learned in a classroom (Good and Brophy. 1995: 180-181). Learners use recognition to connect with other disciplines. Köhler (Cited by Good and Brophy to Köhler. 1995: 181) supported that learning condition such as appropriate learning materials can be arranged to encourage student learning by discovery. Following Gestalt' s idea, learner learns through self-guided exploration rather than through teacher's explanation or modelling.

Piaget's Theory

There are three basic components of Piaget's theory:

1. Types of knowledge: Piaget's idea on human cognition is that humans are active and exploratory information processors who build up knowledge rather than take it from the teacher or receive pre-package of knowledge from instructions.

2. Stages of development: This component is divided into 4 stages of:

2.1 Sensorimotor is the first stage of Piaget' s theory. This includes the first two years of human life. At this period, children are discovering their bodies and observing surroundings around them. They learn by their sensory motor ability, which developed after they were born.

1.2 Pre-operational stage. The second stage includes children at the age of 2-7 years. The children can remember, imagine and pretend. They can develop their language and ability to think and solve problems through the use of symbolic thinking.

1.3 Concrete operational stage. The third stage covers the age of 7-12 years. During this stage, children can think about actual objects, but not abstract reasoning.

1.4 Formal operational stage. This stage begins at the age 12 throughout adulthood. The characteristics of this stage are abilities to think in abstract reasoning, formulate hypothesis and test for answering a problem (Good and Brophy. 1995: 31).

3. Processes allow a transfer whether it from one stage to another. The process of cognitive development consists of Schema, assimilation, accommodation, and equilibration. The descriptions are as follows:

3.1 Schema: This is a mental representation. Newborn child knowledge is structured around simple actions on objects, such as sucking, smelling, and shaking, but not in abstract concepts. Piaget explained the schema as cognitive, verbal, and behavioral frameworks, which are developed to organize learning and to guide behavior (Good and Brophy. 1995: 33-35). This stage, knowledge about the environment and how to respond to the external stimuli is stored in a form of scheme. Thus, cognitive schemes are concepts, images and thinking abilities, involves understanding.

3.2 Assimilation; This is an act of integrating new information into the existing schema. It is the process that human perceives information based upon existing schemes or operations and carry out activities or respond to a stimulation.

3.3 Accommodation; Children at this stage adjust their knowledge scheme to accommodate the knowledge items. The cognitive perception requires modification of schemes or operations for facing stimulus and carrying out current purposes.

3.4 Equilibration; This stage is the balance between the assimilation and accommodation. The relationships of both stages push the cognitive growth and the move between different stages of development. This change causes active development towards a new stage. When children are presented with new information, equilibration is unsTable. Accommodation will be adjusted and cognitive perception is changed. (Good and Brophy. 1995: 33-35: Crowl et.al. 1997: 51-53).

Piaget's viewpoint in the scheme development indicated that there are four factors influencing on it. These are 1) maturation, 2) individual experiences, 3) social interaction, and 4) equilibration. The social interaction factor involves formal and informal socialization and education. Equilibration involves internal self-direction and regulation. This is seen that students who self-explore environment and solve problems develop these cognitive operations when constructing knowledge.

Following Piaget's theory, all knowledge is a human construction starting with blank ideas. Learning is an internal process that occurs in the mind of the individual and confliction in thinking is essential to the learning process. Although late research has argued that newborn do not start with blank ideas and many kinds of knowledge develop earlier than Piaget's stage referred, the teacher can stimulate learning in the classroom rather than waiting for natural development.

Gredler (2001) suggested that following up from the arguments, learning environment in Problem-based approach drives and stimulates student's cognitive development rather than have teachers directed. The teachers instead choose problems that can be solved in different ways and all students are engaged in the problem solving process that arouses students to think. The teaching and learning approach helps students reach the higher stage of cognitive development earlier than natural development.

Bruner's theory

The assumptions of Bruner's theory is that learners construct new knowledge or concepts based on learner's current and past knowledge through various steps of:

1. Selecting information
2. Constructing hypothesis
3. Transforming information
4. Constructing hypothesis
5. Making-decision
6. Relying on cognitive structure (Bruner. 1966).

Jerome Bruner is a psychologist who developed a theory of cognitive development to help teachers promote student learning and thinking. He believed that people develop their cognition through the following:

1. Enactive stage; This stage is similar to Piaget’s sensorimotor stage. That is, hands-on activities with a variety of objects are essential for young children to learn effectively.

2. Iconic stage; This focuses on the essential of visual representation, which helps children think and understand the world.

3. Symbolic stage; At this stage, children’s cognition is developed to understand symbols, words, mathematical and scientific notations.

Bruner’s viewpoint is similar to Piaget in that students learn best by doing or active learning which is called Discovery Learning. That is, teacher teaches by using the guiding technique of discovery by creating situations that help students induce ideas for understanding. The technique encourages students to discover the structure of the material by focusing on ideas and seeing a connection between ideas. They learn best when they grasp the structure of material instead of memorizing details (Crowl et al. 1997: 74-75). Teachers encourage students’ curiosity to explore new knowledge through direct experiences.

Following the Bruner's theory, which is adopted as an active instruction, four major aspects should be addressed in learning activities:

1. Predisposition towards learning.
2. The ways in which a body of knowledge could be structured so that most of learners can grasp it.
3. The most effective sequences of learning materials.
4. The nature and pacing of rewards and punishments. Good methods for structuring knowledge should be resulted in simplifying, generating new propositions, and increasing the manipulation of information (Alsop and Hicks. 2001: 50; Amos and Boohan. 2002: 178.; Crowl et al. 1997: 74-76).

Whilst instruction is concerned, the instructor should encourage students to discover principles by themselves. The instructor and student should engage in an active interaction. The tasks of instructors are to translate information into an appropriate form for the learner's existing understanding. Curriculum should be organized in a spiral manner so that students can continually construct knowledge upon the information they have found.

Vygotsky ’s theory

The assumptions of Vygotsky’s theory are:

1. Making sense of meaning.

2. Tools for cognitive development. Learning tools include parents, important persons to the students, culture, and language. The type and quality of these tools affect the rate of development (Vygotsky. 1978).

3. Zone of Proximal Development. This assumption was developed because Vygotsky felt that the Piaget’ s theory had underestimated the social nature of human being in learning and development ability. In the zone of Proximal Development, human has the difference between individuals’ levels of performance when working alone and when they work by being guided with experienced person (Reynolds and Gutkin. 1999: 178-180). Following Vygotsky’s theory, Faculty of Education, University of Malta (2003) categorized students’ level of problem solving skills into: 1) Student could perform independently, 2) Student could not perform even with help, and 3) Student could only perform with help from others.

Vygotsky believed that humans create culture and life in a society. He emphasized the importance of socio-cultural contexts in student’s learning and supports Bruner’ discovery model of learning. That is the teacher is placed in an active role while the students develop their cognition naturally through discovery from various methods. For Vygotsky, learning and cognitive development depend on students constructing self-understanding through social and collaborative activities. The teacher’s role is as a facilitator in the learning activity.

Many researchers supported Vygotsky’s theory, such as, Slavin (1987) who researched the effects of enhancing cooperative learning on student cognitive development. Brown and Palincsar (1989) studied the effects of reciprocal teaching on foster cognitive processing and individual knowledge acquisition. Johnson and Johnson (1986) studied the effects of the motivational processing, competitive and individual learning situation in the science classroom. The researchers reported that social and collaborative activities positively affected students on achieving learning goals.

Constructivism

Gredler (1992) stated that “ Piaget has been admired as a radical constructivist”. His cognitive development theory is a radical of constructivism. Synonymously defined as learner centered or problem-based learning (Faculty of Education, University of Malta. 2003). Yaker (1991), on the other hand, stated that it is a model of how learning takes place rather than a theory of how rationality develops. The viewpoint behind constructivism focuses on thoughts or understanding rather than formal operations of logic that thought can be involved. Constructivism is a concept that learners actively construct their own knowledge. The heart of constructivism is the view that the proactive mental construction processes develop cognition (Gunstone and White, 1994). Students’ conceptualization arises through the interaction between previously stored knowledge and current data. Simson (1990) and Mahoney (1988) advocated that this point is sTable at work, testing and hold the meaning to new information in terms of the previous conceptions of phenomena. This is in line with Dewey’s idea that students learn best when they need the knowledge or skills to explain natural or real life phenomena (cited by Gunstone and White. 1994).

Constructivism not only emphasises on how learners learn, but itself also is a powerful tool of learning processes. The approach has been applied to the cognitivists’ theories of Piaget, Vygotski, and Bruner. Although the three theories are different based on roles of individuals and social contexts, they are similar in that the learners actively construct their knowledge of the world by their own self. This implies that constructivism approach emphasizes on student-centered learning rather than teacher-centered. The teachers role are as facilitators or coaches who facilitate and help students construct their knowledge and come up with solutions to problems. Piaget supported the ideas that the most important role of the teacher is to arrange an environment supporting the students to learn by self-experiencing. Their understanding will be formed through many routes, such as; reading, listening, exploring, and experiencing their environment. The students should be challenged with real life problems, which are arranged in the classroom. He also stressed that students should have a freedom to understand and construct learning through individual developmental processes (Gunstone and White. 1994). This is seen that Piaget’s philosophy focused on students’ attention and their needs. Students will provide opportunities to explore and construct their own knowledge rather than receiving knowledge directly from the teachers (DeVries and Kohlberg. 1987).

Lev Vygotsky (1978) developed the social constructivist theory. That places a teacher as a facilitator. The students' cognitive abilities, however develop spontaneously through the steps of discovery. He emphasized that development and learning are influenced each other. In the classroom, students build up their own understanding through social activities and collaborative tasks. Vygotsky believed that self-learning through those cannot be taught. When students face situations, they will apply their existing knowledge. As a result, learning should take place in meaningful contexts. The students' previous knowledge will mean more when provided with guidance and assistance from teachers, parents, or experienced peers. Moreover, Piaget and Vygotsky were interested in cognitive development, but piaget believed that cognitive development is vital before learning, whereas Vysgotky believed that experienced persons and social interaction play important role in determining learners' cognitive development.

Following Vygotsky's idea, Faculty of Education, University of Malta (2003) suggested that school experiences should be related to real-life situations. Pictures, news clips, and personal stories are integrated into classroom activities, which gives students chances to interact with their real situations in communities. So when students are trying to solve problems, they are required to know more than that of their existing knowledge by:

1. Thinking hard about their ideas that may form a solution later on,
2. Collaborating and discussing with others,
3. Simply learning by chance.

Johnson and Johnson (1986) supported that in-group work situation, students will interact with the members of the group, in which they can learn from their peers. This is in accordance with the Vygotskian's theory that children can achieve through proximal development provided by the helps and supports of an adult but not on their own (Vygotsky, 1978). The idea was supported by the concept of scaffolding, which was introduced by Bruner (1986). Bruner places teacher as supporter to help the pupils learning by themselves through activities, questioning, explanations and discussions. During scaffolding, teachers do not adjust the task but offers support and guidance for the learners. By doing so, it helps students develop their intellect. Alsop and Hicks (2001) extended the idea that 'Scaffolding' can come in a variety of forms and depend on the nature of task. Teachers might set up situations that are familiar to the students, then split a task into series of manageable stages in order to reduce a level of complexity. The task should be psychologically and socially appealing to reduce stress and create a classroom environment that is supportive of learning.

Learner's ability to learn depends on their abilities to process new information (Amos and Boohan citing Adey. 2002). The effectiveness of the information processing depends on the previous understanding that the receiver already has and the abilities how well the information is being processed. Human's ability to process information grows along with ages and experiences. This is in line with the basis of the stages of cognitive development described by Jean Piaget (Gunstone and White citing Piaget. 1994). Children' abilities to think abstractly will be developed in the stage of formal operation (from the age of 12 up). At the end of the stage, students are able to design an experiment themselves and formulate qualitative relationships between variables (Alsop and Hicks. 2001). The Piagetian framework is used for students' cognitive development projects in UK as well as the CASE project. Adey and Shayer (1994) developed the project as an intervention programme based on Piagetian Stages. The CASE project is a series of teaching activities and it becomes popular in British seconadry schools.

Learning process in constructive science classroom consists of the activities that students will inquire, search, and construct knowledge by themselves. That is, students learn science through individuals' creativity and acquire knowledge based on their previous knowledge. Students will understand what they are learning and gain more knowledge to get the concepts on their own. This is in line with Szesze (cited by Tanaprayothsak. 2005: 25) who describes the constructive science classroom. They are as follows:

1. Encourage and accept students autonomy and initiation.
2. Use raw data and primary sources, along with manipulative, interactive and physical materials.
3. Use cognitive terminology, when designing tasks.
4. Allow students to think, and be flexible based on students' responses.
5. Inquire students whether they understand the concepts.
6. Encourage students to engage in dialogue with others.
7. Encourage students to ask open-ended questions.
8. Help students come up with their hypotheses which come from the discussion.
9. Encourage students preliminary discuss their preliminary hypotheses.

10. Allow wait time after posing questions.
11. Provide time for students to create metaphors.
12. Nurture students' curiosity using the 5Es learning cycle.

According to Szesze, constructive science classroom emphasizes on students-centred learning and teaching style through various instructional strategies, such as, collaborative approach, problem solving approach, problem-based learning approach. All strategies are considered as important tools that can help students enhance their critical thinking skills.

Considering The Thai National Science Curriculum of B.E. 2544 particularly on level 3 science, students encourage to learn and develop their cognition at a formal level of thinking through learning activities. The objectives of the science curriculum are to help students improve their abilities to think with scientific thinking skills. Activities can be carried out over a period of time and content free. This indicates that The Thai National Science Curriculum of B.E. 2544 emphasized that science learning process is an intervention approach rather than instructions given in teaching. In this study, the problem-based learning approach is used as an instructional strategy to train students to be scientific thinkers. The approach is viewed as an effective teaching approach, which was discussed in the section 1.

Chapter 3

Research Methodology

This study was the Research and Development of a science learning model on life and living for level 3 using problem-based learning and tutorials. In this research, there were two major steps concerning development of a science learning model as follows:

1. Steps of Development
2. Steps of Implementation

Steps of development

The steps of development consisted of six essential tasks as follows.

1. Investigating the current teaching and learning style, problems and ways for finding the problem.

1.1 Studying background information from governmental documents, published articles in newspaper, handouts presented in educational conferences, as well as teachers interviewing and science educators' suggestions.

1.2 Exploring on educational system from journals, e-journals and handouts presented in educational conferences.

1.3 Synthesising the information to choose the situation that students encountered on their daily basis and on how was their understanding of science.

1.4 Setting up the criteria when developing new materials.

2. Exploring the principles of science curriculum development including processes of thinking, critical thinking development, understanding of science and nature of science. It was important to set up the expected achievement in the science learning model. This stage was done by exploring the methods used for curriculum development in secondary schools, comparing between new teaching and learning approach, and methods for assessment. The tasks consist of:

2.1 Identifying the main curriculum ingredients before deciding the appropriate methods. The emphasis was on the acquisition of critical thinking skills as the basic scaffolding to understanding of science.

2.2 Reviewing principles of curriculum development from texts and governmental publications.

2.3 Reviewing educational research.

2.4 Reviewing results of studying from theses and dissertations.

2.5 Synthesizing the principles and theme of science curriculum to develop a set of criteria for new materials.

3. Exploring theories of developmental psychology particularly in the cognitivism and constructivism.

3.1 Reviewing educational research.

3.2 Reviewing theses and dissertations.

3.3 Reviewing theories of developmental psychology and educational psychology emphasised on Theory of cognitive development and constructionism from texts, e-texts, and handouts presented in educational conferences.

3.4 Synthesising the processes of cognition development that were appropriate for the target groups.

4. Exploring the concepts of problem-based learning, evolution of problem-based learning, models for problem-based instruction, strategies for using problem-based learning, as well as related development psychology to problem-based learning.

4.1 Reviewing the evolution of Problem-Based learning, concepts, model of problem based instruction and strategies.

4.2 Reviewing educational research about Problem-Based learning approach.

4.3 Synthesising the ideas for development of new teaching and learning approach for secondary school students.

5. Developing the science learning model on life and living for level 3 using problem-based learning and tutorials. The main aims for development of the science learning model were to encourage the development of students' critical thinking skills, understanding of science, and increase students' science achievement. The model was carefully designed and modified through seven consecutive stages of Lane and Remley (2002). The essential elements of designing model were focused on the National Science Curriculum objectives and science content for level 3 focusing on human body, drugs and drug addiction, students' alternative ideas, integration of educational tools, and social issues.

In this stage, there were eight steps for developing the problem-based learning course for lower secondary schools as described in the below.

5.1 Setting up the goal for providing the content areas, which were covered in the content of the course. This step was based on The National Science Curriculum of B.E.2544 and strand titles.

5.2 Setting up the course objectives and learning outcomes, which were substantial for organizing the courses.

5.3 Developing a set of criteria when selecting a topic for the problems in the problem-based learning and tutorial course. The problem should be intriguing and appropriate for students to learn in a school context, whereas teachers should have knowledge on the issues.

In this study, a set of criteria for selecting problems in the problem-based learning and tutorial approach was developed around the factors influencing on students' interest and school contexts. The developed criteria was as follows:

1. Students' interests: This was a starting step for students to participate in their learning. They discussed what they were interested in and wanted to investigate more. This learning activity was arranged in line with the students' interests and appitudes following to the Section 24(1) of The National Educational Act of 1999.

2. Interestedness: In a social context, every issue relates to science subjects and may become a problem in the problem-based learning. Students started to learn how they should set a priority of the interested problems. Simultaneously, they learned how to make decisions and sorted out the ideas.

3. Learning objectives: The selected problem should cover the intended objectives and achievement target provided by The National Science Curriculum.

4. Feasibility of school management: The limited factors in the school context should be considered, such as, availability of school facilities, level of difficulty for the students to learn, etc. In this step, local school teachers' meetings were held to share the ideas, consider on instruction tools, and plan for the actual implementation.

5.4 Constructing the problem and give a scenario situation, which described sequences of events. The scenarios helped drive students' learning processes.

Following the criteria for selecting problems in the problem-based learning and tutorial approach, three real life issues were developed to be problems in the science learning model using problem-based learning and tutorials. Those were;

1. Alcohol and health effects
2. Paracetamol and health effects
3. Amphetamine and health effects

5.5 Developing a set of learning plans by selecting suiTable activities and giving students enough time for each provided problem. Learning plans in this study consisted of three important parts: science concepts, learning processes, and expected outcomes. The developed learning plans were approved by the three experts. These included a science educator, an experienced scientist and an educator in instructional design. All of them had more than 5-year experiences in instructional design, or science teaching. A set of developed learning plans was shown in Table 2.

TABLE 2 Learning plans in the science learning model using problem-based learning and tutorials

Section	Concepts	Learning process	Expected outcomes
Problem1: Alcohol and Health effects	1. Alcohol is a depressant drug. Excessive quantity of drinking alcohol can cause many problems, at worst alcoholism, can kill. 2. The role of the digestive system is to break down the eaten large size food into small pieces enough to be absorbed through the gut wall and dissolved in the blood. 3. The nervous system co-ordinate muscles and regulates body's internal environment, such as, breathing and heart rate.	1. Teacher presented a problem scenario to drive the students to learn. 2. Students learned in-groups for identifying the given problems, exploring and selecting the related information, deducting the information, interpreting data, and explaining the solutions. 3. The teachers acted as a tutor or monitor who supported the students' learning by motivating them to learn and guiding them with the developed tutorial guides contained science core concepts, learning objectives, information sheets, as well as giving teachers' feed back immediately for correcting the students'	Students are able to: 1. Describe how alcohol affected human body, and how over drinking can lead to liver cirrhosis. 2. Explain the role of digestive system, nervous system, and homeostasis. 3. Describe the structures and functions of the digestive system, nervous system, nervous system, and homeostasis. 4. Interpret the given sequential information to come up with a solution to the problem.

TABLE 2 (continued)

Section	Concepts	Learning process	Expected outcomes
		mis-conceptions. 4. The students used their critical thinking skills as scientific skills to solve the problems.	
Problem 2: Paracetamol and health effects	1. Paracetamol is a fever and painkiller. The overuse of paracetamol can cause harm and even death through accidental overdose or suicide. 2. Kidneys are excretory organs, which remove wastes and harmful substances with a lot of water called urine out of body. 3. Liver also excretes some breakdown products pass-out of body within feces. 1. Homeostasis is the process of managing the internal environment of human body.	1. A problem was presented scenario to drive the students' learning. 2. Students learned in-groups in order to identify the given problem, selecting the useful information, deducting the information, interpreting, and explaining the solutions. 3. The monitor motivated students to learn and guided them with the developed tutorial guides. 4. The students used their critical thinking as scientific skills skills to work on the given problems.	Students are able to: 1. Describe how paracetamol affected human body, and how overdose can lead to liver and kidneys damages. 2. Explain the role of kidneys to produce urine, and how a kidney is involved in homeostatsis. 3. Explain the functions of liver and the roles in regulating the blood substances. 4. Interpret the given sequential information to a solution of the given problem.

TABLE 2 (continued)

Section	Concepts	Learning process	Expected outcomes
Problem 3: Amphetamine and health effects	1. Amphetamine is stimulant and cause physical dependence. It produces serious depression, and affect human health in many ways. 2.The nervous system has two parts of: central nervous system (CNS), and peripheral nervous system (PNS). Brain contains the centers that control various functions and emotions. The spinal cord connects messages from the sensory receptor and the motor nerves and then to the effector organs. 3. The respiration is the act of breathing. Gas exchange is necessary to maintain life. The gases breathed out containing the body waste products are exhaled from the lungs.	1. Present a problem scenario to drive the students' learning. 2. Students learned in-groups for identifying the given problem, selecting the useful information, deducting the information, interpreting, and explaining the solutions. 3. The facilitator motivated students to learn and guided them with the developed tutorial guide. 4. The students used their critical thinking skills as scientific skills to work on the given problems.	Students are able to: 1. Describe how amphetamine affects human health, and how it leads to death. 2. Describe the tructure and functions of CNS. 3. Explain the structure and functions of PNS. 4. Describe how the nervous system maintains homeostasis. 5. Describe the structure and functions of the respiratory system. 6. Describe the breathing mechanism. 7. Summarize the functions of various hormones. 8. Describe the male and female reproductive organs, and their functions. 9. Describe how the composition of blood changes when it passes

TABLE 2 (continued)

Section	Concepts	Learning process	Expected outcomes
	And the gases breathed in oxygen for the tissues of the body 4. Hormones are chemicals substances which are produced from various glands of the body. Its effects on the organs are a long lasting and functions to adjust the target organs function. 2. The reproductive system is different between male and female. The sexual reproduction involves the production of sex cells. It contains chromosomes filled with the hereditary information that are transferred to offspring. 3. The blood is circulated throughout the body by the heart and the blood vessels. It transport food and oxygen to every cell in the body.		into the lungs and the intestine.

TABLE 2 (continued)

Section	Concepts	Learning process	Expected outcomes
Lectures and discussions	The lectures and practicals focus on: 1. The respiratory system 2. The nervous system 3. The reproduction system 4. The skeleton and muscle system 5. Homeostasis 6. The blood circulation system 7. Drugs and drug addictions	Lectures and laboratory practices are based on the National Science Curriculum by the teacher.	1. Discuss and explain the structures of human body systems and their functions. 2. Discuss and explain the experimental results related to human body and its functions.

5.6 Determining appropriate learning resources and provide a list of resources available when needed, as well as had information sheets provided as fundamental information for stimulating students' curiosity as well.

Some examples of textbook and websites which were learning resources in this study were shown as follows:

1. GCSC (2003). *Double Science Biology: The Revision Guide for Highe Level CGP books*. London.
2. Thaiwatanapanit (1999). *Human body.* Bangkok.
3. http://www.ipst.ac.th
4. http://www.geocities.com
5. http://www.thaiquit.com
6. www.vichakarn.com
7. www.thailabonline.com

5.7 Providing tutorial guides. Which included the contents and a series of questions. The tutorial guide was on for teachers' use.

For this study, tutorial guides were considered as an important part for the science learning model. The tutorials were structured based on the subject contents and achievement goal. It included a list of defined concepts of the given problems and related information, learning objectives that lead to apply the concepts to the solutions of the problems, and the stimulus materials (such as information sheets and tutorial guides).

The steps for developing the tutorials were:

1. Reviewing literature on theoretical frameworks of tutorials in problem-based learning approach.

2. Designing a set of tutorials guide for each section in the science learning model using problem-based learning and tutorials.

3. Examining the tutorials by the three experts. These included a science educator, an experienced scientist and an educator in instructional design. All of them had more than 5-year experiences in instructional design, or science teaching. The results were shown in terms of the Item-Objective Congruence (IOC) value as shown in Table 3.

4. Trying out in small group of students. The objective of tutorials guide was to motivate students to learn on their own and to encourage them to dig deeper in

what they were interested in. Students' further suggestions were valuable to this type of learning.

TABLE 3 The Item-Objective Congruence (IOC) evaluating results of the science learning model using problem-based learning and tutorials.

The evaluation list	IOC (N = 3)	Interpretation
1. The purposes of the science model corresponding to the Problem-based learning philosophy	1.0	Appropriate
2. The learning outcomes of the section 1	1.0	Appropriate
3. The learning outcomes of the section 2	1.0	Appropriate
4. The learning outcomes of the section 3	1.0	Appropriate
5. The learning outcomes of the section 4	1.0	Appropriate
6. The learning plan of the section 1	0.67	Appropriate
7. The learning plan of the section 2	0.67	Appropriate
8. The learning plan of the section 3	0.67	Appropriate
9. The learning plan of the section 4	0.67	Appropriate
10. Tutorials	1.0	Appropriate
Section 1	1.0	Appropriate
Section 2	1.0	Appropriate
Section 3	1.0	Appropriate
Section 4	1.0	Appropriate

5.8 Identifying and developing a set of assessment instruments and assessment procedure. Assessment was necessary because it helped reflect students' progress during their learning.

The assessment instruments included three important tests: critical thinking test, understanding of science test, and science achievement test. The steps of development of each test were described below.

1. Critical thinking test

Critical thinking test in this study consisted of 15 multiple choices questions. They covered 5 components of critical thinking skills, which included identify the problem, select the useful information, deduce the relevant information, interpret the given data, and explain the finding results. The tasks for developing the critical thinking test were as follows;

1.1 Reviewing literature on theoretical frameworks of critical thinking tests, for instance, the Watson-Glaser Critical Thinking Appraisal (WGCTA) by Watson and Glaser(1964), critical thinking skills model by Sternburge’s (cited by Halonen and Santrock, 1995), and Facione’ s crititical thinking test model (1990). All models presented a variety of the cognitive components of problem-solving skills.

1.2 Setting the learning objectives and the learning outcomes.

1.3 Designing a critical thinking test. The test consisted of 15 multiple choice questions covering 5 components of critical thinking skills: 1) problem identification, 2) selection of useful information, 3) deduction, 4) interpretation, and 5) explanation. The time given for this critical thinking test was 30 minutes.

1.4 Examining and verify the validity of the test. Three Experts examined on the contents and structure of the test. The results were shown in terms of the Item-Objective Congruence (IOC) value as shown in Appendix C.

1.5 Evaluating level of difficulty (p-value), item discrimination (r-value), and reliability coefficient (Kuder-Richardson 20) of the test. The subjects were 100 students of MS 3/3, 3/4, and 3/5 in Mathayom Sangkit Wittaya Bangkok School who learned the related contents last academic year. The findings were that p value and r value of the test were 0,46-0.63 and 0.24-0.61 respectively, and the reliability coefficient (Kuder-Richardson 20) was 0.52.

2. Understanding of science test

Understanding of science test was structured based on science core contents. It emphasized on substrand 1.1.1 and 1.1.7. Students used their science knowledge to answer the test that consisted of

2.1 Reviewing the documents on the target achievement of The National Science Standard focusing on human body, drugs and drug misuses for level 3.

2.2 Designing the test, which consisted of 6 short-answer questions. The answers were related to the digestive system, respiratory system, nervous system, reproductive system, circulatory system, immunity system, drugs and health effects.

2.3 Examining and verify the validity of the test. Three Experts examined on the contents and structure of the test. The results were shown in terms of the Item-Objective Congruence (IOC) value as shown in Appendix C.

2.4 Evaluating the reliability of the test. 30 students of MS 3/3 and 3/5 in Mathayom Sangkit Wittaya Bangkok School were tested to measure the reliability of the test. The finding was that Cronbach's alpha coefficient of the test was 0.925.

2.5 Evaluating the construct validity in small group experimenting by using Carver method (Saiyot.1996). The finding was that the construct validity was 0.70.

3. Science achievement test

3.1 Reviewing the documents on the target achievement of The National Science Standard focusing on human body, drugs and drug misuses for level 3.

3.2 Designing the test consisting of 5 questions of Modified Short Essay Questions. The test emphasized on assessing the third level of knowledge structure.

3.3 Examining and verify the validity of the test. Three Experts examined on the contents and structure of the test. The results were shown in terms of the Item-Objective Congruence (IOC) value as shown in Appendix C.

3.4 Evaluating the reliability of the test. 30 students of MS 3/3 and 3/5 in Mathayom Sangkit Wittaya Bangkok School were tested to measure the reliability of the test. The finding was that Cronbach's alpha coefficient of the test was 0.996.

3.5 Evaluating the construct validity in small group experimenting by using Carver method (Saiyot. 1996). The finding was that the construct validity of the test was 0.70.

4. Student satisfaction questionnaires

4.1 Reviewing the documents relating to the student satisfaction questionnaires.

4.2 Designing the questionnaires, which consisted of 18 questions. Those were:

Part 1 question 1-4; regarding student' satisfaction with the course format.

Part 2 question 5-15; regarding classroom management information.

Part 3 question 16-18; regarding the student's reflection of the science learning model using problem-based learning and tutorials.

4.3 Examining the test by the three experts. The finding was shown in Appendix C.

4.4 Trying out in a small group. The consideration was that the the objectives and language used in the questionnaires were appropriately.

The evaluation framework of the research instruments and outcomes of this study was shown in Table 4.

TABLE 4 Evaluation framework of instruments and outcomes

Research instruments	Methods for evaluation and outcomes
1.Science learning model	1. Experts considered on the essential elements of learning goals and objectives. The results were shown in term of the "Item -Objective Congruence". The science learning model was improved following the experts' comments.
2.Learning plans	2. Experts criticized the learning plans on learning objectives, context of learning, learning activities, educational materials, and learning assessments. Following their comments, lesson plans were drastically improved and they were be try out in small group before implementing in science classroom.
3. Assessment instruments	
3.1 Critical thinking test	3.1 Approved by the educational experts and tested in a small group students. All questions of the test were selected regarding to the accepted p-value and r-value. These were 0,46-0.63 and 0.24-0.61 respectively, and r_{tt} (KR-20) was 0.52.
3.2 Understanding of science test	3.2 Approved by the educational experts and tested in a small group students. The Cronbach's alpha coefficient of the test was 0.925 and the construct validity was 0.70.
3,3 Science achievement test	3.3 Approved by the educational experts and tested in a small group students. The Cronbach's alpha coefficient of the test was 0.996 and the construct validity was 0.70.
4. Satisfaction questionnaires	4. Experts commented the test in term of the IOC value.

6. Trying-out in a small group. The purpose of this step was to determine the quality of the science model before implementing in a science classroom. Teaching and learning processes, steps of delivery, language for communication would be considered. The tasks in this step were that the science learning model using problem-based learning and tutorials was used to teach in a group of 10 Mathayom 2/5 students who have never learnt the contents of human body and its functions, drugs and drug misuse before. The group was not then target population and had heterogeneously mixed learning abilities. Also the 10 Mathayom 3/5 students who took some science course before were selected to try-out. Observation and Interviewing on students' learning process were considered in this step. The students' alternative ideas, the observation results, and students' suggestions were used to improve the model before implementation.

Revising the science learning model using problem-based learning and tutorials followed to the findings from the try-out

The experts' opinions were that the words used in the science learning model should be improved for students' better understanding. The timeTable should be adjusted in order for students to learn effectively. They stated that the instructional strategy used in the science learning model was new for Thai students. Although it might be difficult at the beginning, students were later familiarised with it, enjoyed learning and got better achievement at it.

The findings from the experts' suggestions, the trying-out and the teachers' opinions were used in order to revise the science learning model. Particular the language used in the model was revised to easier language for students understanding what they were learning about. The time length for each scenario problem was revised from 8 hours to be 6 hours. All the experts and the teachers advocated that the problem-based approach is a new way for students learning in science. The contents related to problems were appropriately for level 3 students although they were not familiar to the approach. The teachers agreed that this was an effective approach that should be engaged in multidisciplinary subjects.

According to the findings, those indicated that the science learning model using problem based learning and tutorials focused on human body, drugs and drug misuses was appropriately used for level 3 science students and learning objectives, the time length of 24 hours in total, and the assessing tools. This was ready for moving to the step of implementing in the science classroom.

Steps of implementation: There were two steps as follows:

1. Research methodology

A randomized control-group pretest-posttest design (Campbell and Stanley cited by Saiyot and Saiyot. 1995) was used to compare the learning outcomes between students who took a science class using a problem-based learning and tutorial approach, students who did so with a problem-based learning approach, and students who did so with a conventional approach in the same science contents programme. The subjects were arranged into groups of six for solving the provided problems. The positive learning outcomes were reflected through the students' higher critical thinking skills, higher understanding of science, higher science achievement, and higher satisfaction of the science learning model.

Population and sample:

Population was the lower secondary science students in a local school in Prathumthanee Province. Subjects were three classrooms in Mathayom 1 from Mathayom Sangkit Wittaya Bangkok School. They were in their 13 at average. These students were taking the science course in the second semester of academic year 2004. The course timeTable was two periods of two-hour class and 1-hour class per week for eight weeks. Students from three different classrooms came from the same socio-economics background and had mixed of students' abilities. The 41 students of Mathayom 1/5 were the experimental group learned with the science learning model using problem-based learning and tutorials approach. The 43 students of Mathayom 1/4 learned with the problem-based learning approach. The other group of 35 students of Mathayom 1/1 was the control group learned with the conventional learning approach. This research design is shown in Table 5.

TABLE 5 Research design.

	Experimental group 1	Experimental group 2	Control group
Instructional approach	Problem-based learning learning and tutorial approach	Problem-based learning approach	Conventional approach

Course duration:

The course duration of the science learning models on life and living for level 3 using problem-based learning and tutorials was 8 weeks (16 class periods) with a total of 24 hours. There were four sections in the science learning model. These are 1) Alcohol and health effects, 2) Paracetamol and health effects, 3) Amphetamine and health effects, and 4) Lectures and discussions, which were in response to the students' needs through evaluation of the previous sessions. The overview of the course duration was shown in Table 6.

TABLE 6 The overview of the course duration.

Activities and duration	Topic	Assessment
Pre-test, during December 26-28, 2004		Critical thinking test, understanding of science test, and science achievement test
Section 1 (6 hrs), during January 3 – 17,2005	Alcohol and health effects	Daily progress report and written report of the problem
Section 2 (6 hrs), during January 18- 31, 2005	Paracetamol and health effects	Daily progress report and written report of the problem
Section 3 (6 hrs) during Febuary 1-14, 2005	Amphetamine and health effects	Daily progress report and written report of the problem
Section 4 (6 hrs), during Febuary 15-28, 2005	Lectures and discussions	Daily progress report
Post-test, during March 1-3, 2005		Critical thinking test, understanding of science test, science achievement test, and students satisfaction questionnaires

The science learning model was implemented in science classrooms from December, 2004 to Febuary, 2005 (24 hrs). Data collection was done before, during and after the implementation as shown in Table 7.

TABLE 7 Trying-out and implementation activities in this study.

Stage of study	Procedure implementation	Date of implementation
Trying-out in small group	10 students who had heterogeneously mixed learning ability and were not target group.	December, 2004
Implementation in science classroom	Presented the science learning model to the Mathayom 1 science classrooms.	December, 2004 - February, 2005 (24 hrs totally)
Data collection and analysis	Before, during and after the implementation.	December,2004 - March, 2005

2. Data collection and analysis

Students were evaluated on their critical thinking skills, understanding of science, science achievement, and satisfaction of the science learning model. The data was collected before, and after the implementing in science classrooms.

Data from several sources was collected during the course. Quantitative data was primarily from students' evaluations based on scores that they received from a critical thinking test, an understanding of science test, a science achievement test, and a satisfaction questionnaires. Qualitative data was gathered from student's interview, class observation and opinions.

2.1 Quantitative data. Quantitative analysis was useed to compare how the science learning model has an effect on the experimental groups and the control group. Comparisons of the experimental groups and the control group were conducted using the various assessments. Descriptive and statistical analysis were carried out using SPSS. Standardized effects sizes with 95% confidence intervals were calculated to compare the difference between the mean scores in the experimental and control groups. The study evaluation was as follows;

1. Critical thinking test: Before and after learning, students were asked to do the pretest and posttest followed by a critical thinking test. The results were analyzed with the descriptive statistics and compared between groups with ANCOVA technique.

2. Understanding of science: The comparison between the pre-test and post-test results among the three groups would be done using ANCOVA technique.

3. Science achievement: Students were tested with the developed modified essay questions as is the final examination. The results were compared with ANOVA technique.

4. Satisfaction of the science learning model: The student satisfaction questionnaires were presented to the two experimental groups. They were asked to reflect their experiences on the science learning model. Descriptive statistics was used for analysing the results.

5. Levene statistics and Welch statistics were used instead of ANCOVA and ANOVA when the variances between groups were unequal (Vanichbancha, 2006: 244-250).

The evaluation framework and statistical analysis in this study was shown in Table 8.

TABLE 8 Evaluation framework and statistical analysis.

Assessment	Student group	Statistical methods
Critical thinking test	Between groups	Percentage, standard deviation, ANCOVA
Understanding of science test	Between groups	Percentage, standard deviation, Welch statistics
Science achievement test	Between groups	Percentage, standard deviation, ANOVA
Satisfaction	The two experimental groups	Descriptive statistics

2.2 Qualitative data. The plenary discussions among students in classroom were documented. During the process, teachers' interview, solutions, conclusions and summary, students feedback were collected. identifying the students' learning processes. Teacher's and researcher's opinions should be taken into consideration in any analysis. This interpretative commentary is intended to integrate the classroom context while this research was being conducted.

Chapter 4

Results of the study

This chapter presents the results of the study of the development of science learning model using problem-based learning and tutorial approach. The hypotheses of this study were as follows.

The research hypotheses of this study were:

1. The students who took the course with the problem-based learning and tutorial approach received critical thinking test scores higher than those who did so with the problem-based learning approach and the conventional approach.

2. The students who took the course with the problem-based learning and tutorial approach received science understanding scores higher than those who did so with the problem-based learning approach and the conventional approach.

3. The students who took the course with the problem-based learning and tutorial approach received science achievement scores higher than those who did so with the problem-based learning approach and the conventional approach.

4. The students were satisfied with the science learning model using problem-based learning and tutorial approach.

The results of the effects of the science learning model using problem-based learning and tutorial approach were shown below.

1. The first hypothesis: The students who took the course with the problem-based learning and tutorial approach received critical thinking test scores higher than those who did so with the problem-based learning approach and the conventional approach.

Regarding the hypothesis, it was expected that the science learning model using problem-based learning and tutorial approach was an effective approach in developing students' critical thinking skills more than the other approaches. Comparison of students' score from the three sample groups on the critical thinking test was shown in Table 9.

TABLE 9 Students' score from the three sample groups on the critical thinking test.

Student group-course		N	Minimum	Maximum	Mean	S.D.
PBL and tutorial	Pre-test	41	0.00	2.00	1.0976	0.58330
	Post-test	41	6.00	13.00	8.3171	1.67987
PBL	Pre-test	43	0.00	3.00	1.0465	0.65296
	Post-test	43	5.00	11.00	7.5581	1.53223
Conventional	Pre-test	35	0.00	2.00	1.1429	0.60112
	Post-test	35	5.00	12.00	7.6571	1.69676

According to the result shown in Table 9, the pretest minimum score was 0 in all groups, while the students who took the course using problem-based learning and tutorial approach received the highest maximum posttest scores at 13, as well as the highest posttest means scores at 8.3171. The group who only took the course with the PBL and who did so with conventional approach received 7.5581 and 7.6571 respectively. The group that only took the course with PBL approach received the lowest score.

TABLE 10 Test of Homogeneity of Variances of critical thinking posttest scores

Levene Statistic	df 1	df2	Sig.
.125	2	116	.883

p < .05

Levene's test of homogeneity of variance of the posttest scores was computed by SPSS to test the ANCOVA assumption. It was found that the posttest variance (dependent variable) was equal across groups at the .883 level of significance as shown in Table 10. Then ANCOVA technique was used to determine the main effect of teaching approach and pretest score (covariate) on posttest score. The ANCOVA result was shown in Table 11.

TABLE 11 Test of Between-Subjects Effects for individual approach score by teaching approach

Source	Type III SS	df	MS	F	Sig.
Corrected Model	29.736(a)	3	9.912	3.883	.011*
Intercept	1439.243	1	1439.243	563.849	.000*
Pretest	15.827	1	15.827	6.200	.014*
Teaching approach	13.571	2	6.786	2.658	.074
Error	293.542	115	2.553		
Total	7654.000	119			
Corrected Total	323.277	118			

a R Squared = .092 (Adjusted R Squared = .068)

*p< .05

The findings in Table 11 indicate that at least one pair of the posttest scores are unequal significantly at F = 3.883, p< .05. According to the result, pairwise comparisons were used to determine the differences of group means as shown in Table 12.

TABLE 12 Results of pairwise comparisons of critical thinking test

(I)Approach	(J)Approach	MD(I-J)	Std.Error	Sig.[a]	95% Confidence Interval for Difference	
					Lower Bound	Upper Bound
PBL+tutorial	PBL	.728	.349	.039*	3.703E-02	1.419
	Conventional	.687	.368	.064	-4.146E-02	1.416
PBL	PBL-tutorial	-.728	.349	.039*	-1.419	-3.703E-02
	Conventional	-4.109E-02	.364	.910	-.763	.681
Conventional	PBL-tutorial	-.687	.368	.064	-1.416	4.146E-02
	PBL	4.109E-02	.364	.910	-.681	.763

a. Adjustment for multiple comparisons: Least Significance Difference

*$p < .05$

The findings shown in Table 12 indicated that there were means significant differences between the group who took the course with problem-based learning and tutorial approach and the group who did so with problem-based learning approach at $p < .05$ level. Therefore the students who took the course with the problem-based learning and tutorial approach received critical thinking test scores higher than those who did so with the problem-based learning approach.

Therefore the first hypothesis is supported.

2. The second hypothesis: The students who took the course with the problem-based learning and tutorial approach received science understanding scores higher than those who did so with the problem-based learning approach and the conventional approach.

TABLE 13 Shows the score data of understanding of science test by the three sample groups.

Student group-course		N	Minimum	Maximum	Mean	S.D.
PBL and tutorials	pre-test	41	3.00	9.00	6.195	11.30804
	post-test	41	16.00	35.00	23.4390	5.18193
PBL	pre-test	43	4.00	9.00	6.1395	1.42397
	post-test	43	17.00	33.00	22.8605	4.62695
Conventional approach	pre-test	35	3.00	8.00	5.8000	1.34602
	post-test	35	18.00	33.00	23.2857	4.30165

The results in Table 13 showed that the group that followed the problem- based learning and tutorial approach received the highest posttest means score of understanding of science test which is 23.4390. Whereas the groups that took the courses with problem-based learning approach and conventional approach received 22.8605 and 23.2857. The group who took the course with problem-based learning approach received the lowest scores.

TABLE 14 Levene's Test of Equality of Error Variances(a) of posttest score, pretest score and independent variable.

F	df1	df 2	Sig.
7.059	2	116	.001

a Design: Intercept+pretest scores +dependant variable

Following the Table 14, Levene’s test of homogeneity of varience was computed to test the dependent and covariate variances. It was found that there was unequal variances across groups at .001 level of significance. Then Robust tests of Equality of means was used to test the posttest means among the three teaching approaches (Vanichbancha, 2006: 244-250). The result was shown in Table 15.

TABLE 15 The results of Robust tests of equality of understanding of science posttest means

	Statistic [a]	df1	df 2	Sig.
Welch	.163	1	76.539	.850

a. Asymptotically F distributed.

The finding in Table 15 indicated that there was no significant difference of posttest means score across groups at p > .05 level. It means the students who took the course with the problem based learning and tutorial approach received understanding of science scores equal to the students who did so with the problem-based learning approach, and the group who did so with the conventional approach.

Therefore the second hypothesis is not supported.

3. The third hypothesis: The students who took the course with the problem-based learning and tutorial approach received science achievement scores higher than those who did so with the problem-based learning approach and the conventional approach.

Table 16 Shows the score data of science achievement test by the three sample groups.

Student group-course	N	Minimum	Maximum	Mean	S.D.
PBL and tutorials	41	18.00	40.00	28.2195	4.31574
PBL	43	18.00	38.00	26.6047	4.00083
Conventional	35	18.00	39.00	25.3714	4.96509

The means score in Table 16 shows that the students who took the course with problem-based learning and tutorial approach received the highest science achievement means score (28.2195). Whereas the means score of the group that did so with the problem-based learning approach and with the conventional approach received 26.6047 and 25.3714 respectively. The group who took the course with the problem-based learning approach received the lowest means score.

TABLE 17 Test of Homogeneity of Variances of science achievement score across the three sample groups

Levene Statistic	df1	df2	Sig.
1.392	2	116	.253

Levene statistics was used to determine variances across groups. The result shown in Table 17 indicated that there was equal variances across groups at $p > .05$ level of statistical significance. Following the result, ANOVA technique was used to determine the posttest differences among the three groups because all groups received 0 pretest score. The result was shown in Table 18.

TABLE 18 ANOVA analysis of science achievement scores by the three sample groups

	SS	df	MS	F	Sig.
Between Groups	155.685	2	7.842	4.003	.021*
Within Groups	2255.475	116	19.444		
Total	2411.160	118			

*p <.05

The ANOVA result shown in Table 18 indicated that with F = 4.003, the posttest means score was significant difference at p< .05 level across the three groups. Therefore a multiple comparisons (least significant difference test (LSD)) of science achievement scores among the three groups was used to compare all pairs of posttest means. The result of multiple comparisons of science achievement scores among the three groups was shown in Table 19.

TABLE 19 Multiple comparisons of science achievement scores among the three groups

(I)Approach	(J)Approach	MD (I-J)	Std. Error	Sig.a	95% Confidence Interval for Difference Lower Bound	Upper bound
LSD						
PBL-tutorials	PBL	1.6149	.96251	.096	-.2915	3.5212
	Conventional	2.8481*	1.01478	.006*	.8382	4.8580
PBL	PBL-tutorial	-1.6149	.96251	.096	-3.5212	.2915
	Conventional	1.2332	1.00385	.222	-.7550	3.2215
Conventional	PBL-tutorials	-2.8481*	1.01478	.006*	-4.8580	-.8382
	PBL	-1.2332	1.00385	.222	-3.2215	.7550

*p< .05 level

The findings in Table 19 indicated that there was different means score between the students who took the course with problem-based learning approach and the students who did so with the conventional approach at $p < .05$ level of statistical significance. It means the students who took the course with the problem-based learning and tutorial approach received science achievement scores higher than those who did so with the conventional approach.

Therefore the third hypothesis is supported.

According to the scores of all tests, bar charts were used to express the characteristics of student individual scores as the follows:

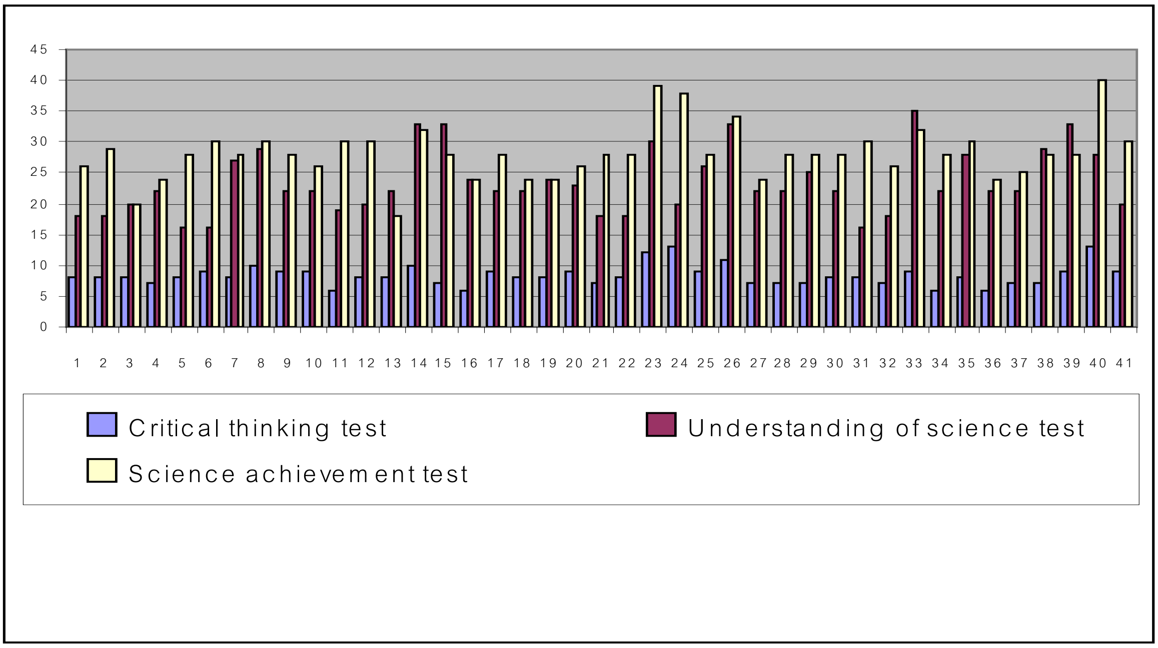

Figure 4 Shows the critical thinking test score, understanding of science test score, and science achievement score of the students who took the course with the science learning model using problem-based learning and tutorial approach

The figure 4 showed each student's score of all tests who took the course with the science learning model using problem-based learning and tutorial approach. The fact that most students received pretty much the same scores suggested that students were likely to high critical thinking scores, high understanding of science scores, and high science achievement scores (e.g.student ID 40 received 13, 28, and 40 score from the critical thinking test, understanding of science test, and science achievement test respectively). On the other hand, the student who received low score from critical thinking test, low score of understanding of science and science achievement (e.g. student ID. 3 received 8, 20, 20 respectively).

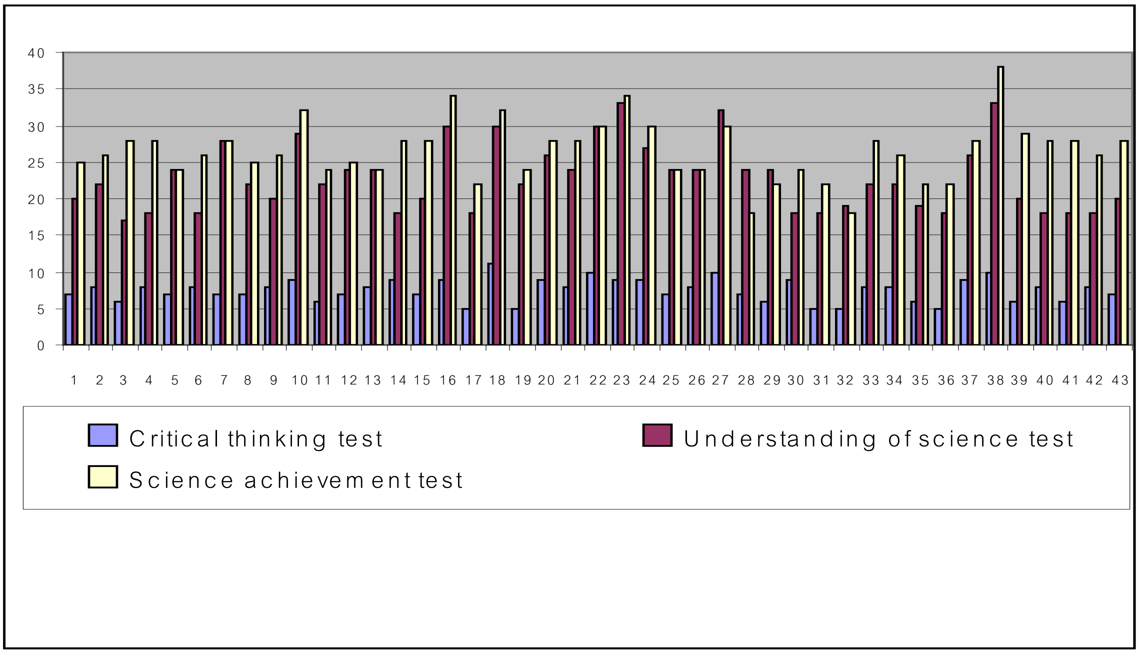

Figure 5 Shows the critical thinking test score, understanding of science test score, and science achievement score of the students who took the course with the problem-based learning approach.

The figure 5 showed each student's scores of all tests who studied from the science learning model using problem-based learning approach. The findings could be explained in the way as shown in figure 4. That is student who received the high critical thinking scores, high understanding of science scores and high science achievement scores. Student who received low score of critical thinking scores, on the other hand, were likely to receive low scores of understanding of science and science achievement.

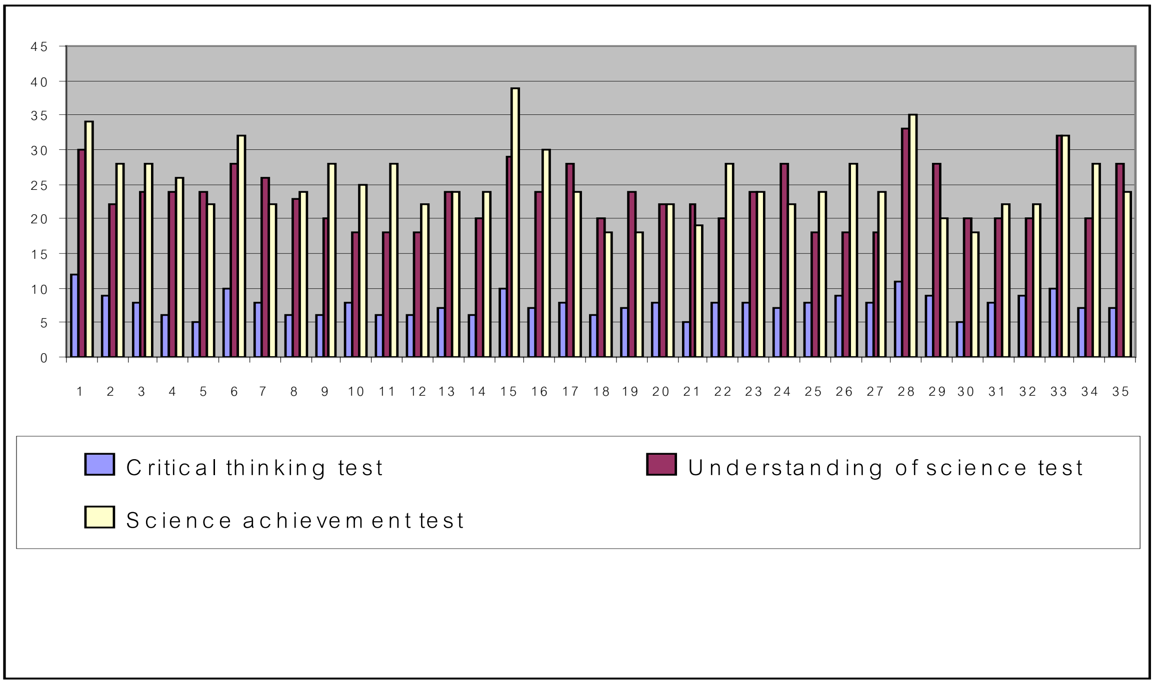

Figure 6 Shows the critical thinking test score, understanding of science test score, and science achievement score of the students who took the course with the conventional course

The figure 6 showed each student's scores of all tests who studied from the science learning model using conventional approach. The findings could be explained in the way as shown in figure 4. That is, student who received high critical thinking scores, high understanding of science scores and high science achievement scores. Student who received low score of critical thinking scores, on the other hand, were likely to received low scores of understanding of science and science achievement.

4. The fourth hypothesis: Students were satisfied of the science learning model using problem-based learning and tutorial approach.

4.1 The experimental group with the science learning model using problem-based learning and tutorial approach

The satisfaction of the science learning model questionnaires showed that students in the class were 12.4 -year average. The male and female sex ratio was 1: 3.56.

There were 2 of 41 (0.98%) students who experienced on problem-based learning course before participating in this class. In the school, the 38 of 41 (92.68 %) students worked together on the given problems once or twice a week for 30 minutes up to one hour, while 7.32 % (3/41) never did.

The 58.54% (24/41) of students reported that the science learning model using problem-based learning and tutorial approach was very difficult to learn, 34.15% (14/41) difficult, and 7.32 % (3/41) easy.

The mean scores of students' opinion on the science learning model using problem-based learning and tutorial approach were shown in Table 20.

TABLE 20 The students' opinion on the pattern of science learning model using problem-based learning and tutorials

Items	Mean	SD	Interpretation
Classroom preparation and management	3.02	.27	strongly appropriate
Learning materials	3.88	.29	strongly appropriate
Acquired knowledge	3.88	.29	strongly appropriate
Load of Work assignment	2.88	.32	appropriate
Useful of the assignments	3.88	.29	strongly appropriate
Student and Teacher interaction	3.88	.29	strongly appropriate
Student cooperation	2.34	.35	fair
Student group effectiveness	2.88	.32	appropriate
Science contents	3.88	.29	strongly appropriate
Assessment methods	3.88	.29	strongly appropriate
Appropriateness for learning in science	3.88	.29	strongly appropriate
Mean of total	3.41		strongly appropriate

Student group structure:

The students organized their group work when solving the problem in different ways:

1. 1 out of 7 groups (14.28%) closely worked together. A leader elected by the group members was primarily responsible for taking the group on the learning tasks. In the group, there was a recorder, and four information seekers. The classroom observation showed that the roles of the group members were rotated every class.

2. The 2 out of 7 groups (28.56%) assigned their group members to search for the information on the same topic. After that they discussed before making a conclusion on. Most of the learning process, each group member worked individually. The problem was that they spent a lot of time on the given problem. They did not change the roles through out the learning process.

3. The 4 out of 7 groups failed to address group members' roles in their group structure. Each of them learned individually without discussing and working together. They spent a lot of time for searching for information. The classroom observation showed that the students also learned in a traditional way. They mainly used school textbooks and information sheets. After class, they never got together for discussion. Their assessment scores from the three tests were ranged in the middle to low level.

The development of the problem solving method:

The 3 out of 7 groups developed their problem solving method by using 5 components of critical thinking skills at the beginning of learning process. This included problem identification, selection of the useful information, deduction, interpretation, and explanation. The teacher guided them to solve the given problem following 5 components. They all agreed that the method helped them to reach solutions using less time. The classroom observation showed that the 2 out of 3 groups could learn without the teacher's assistance from the early period of week 3. The students in these two groups had all test scores higher than the others.

The 23 out of 41 students were trained to use the 5 components of critical thinking skills to solving the given problems starting at the 5^{th} week. They recored the solution every time they could find the relevant information. They revised their solution when they found that the information was not directly irrelevant to the point. The classroom observation showed that the students expressed their feelings at the fourth week. They mainly used the information from the textbooks or the provided information sheets. The classroom observation showed that most of them were the students who were from the non-structured group member. From the interviews and record, the students felt so worries and frustrated at the early period of learning process. They needed more time and help from the teacher. It seemed that the students worked as a group more at the fifth week. The interviewed students described that their collaborative learning ability was developed gradually after the 4^{th} week. They improved their analyzing skills and they were able to express their opinions to the group members. The 5 components of critical thinking skills were used as a tool for solving problems. By doing so, it helped them achieve the learning objectives better than the conventional method.

According to the observation, 41 out of 41 students sought out the information mainly form the school textbooks or the information sheets. Only 4 (9.76%) students searched more information from the Internet particularly www.google.com and www.vichakarn.com. It was found from the interview that all of the 4 had their own personal computer at home and usually use it for their homework assignments. And yet their solution to the given problems came mainly from the school texts and the information sheets.

The 4 out of 41 students came from the families whose parents are nurses, university instructor, and engineer who helped them with their studies after class. They all advocated that the science learning approach motivated them to read more when solving the given problems. The students felt responsibilities with their learning.

The 6 out of 41 (14.63%) students who had alcoholic parents or relatives had unique personalities in learning process. They wrote in their answer that they wanted to see their parents stop their drinking habit. Although the students did not have high effects on their learning.

Extending the learning experiences to other disciplines:

There were 7 out of 41 (17.07%) students who suggested that problem-based learning and tutorial approach should be used in other subjects as well. They felt that this approach motivated them to learn rather than the conventional teaching approach. They suggested that school should design a similar learning project covered all subject contents for their learning rather than giving them 17-19 assignment projects at the same time.

4.2 The experimental group with the science learning model using problem-based learning

According to the science learning model questionnaires, students in the class with a problem-based learning approach were 12.3-year average. The male and female sex ratio was 1:0.86 (23:20). There was no (100%) student who experienced on problem-based learning course. When staying in school, the 35 out of 43 (81.40 %) students worked together on the given problems once or twice a week for 30 minutes up to 1 hour, and 8 out of 43 (18.61 %) students never did.

The 30 out of 43 (69.77 %) students reported that the science learning model using problem-based learning approach was very difficult to learn, and 13 out of 43 (30.23%) difficult. No single students thought that the problem-based learning approach was easy to learn.

The students' satisfaction of the science learning model using problem-based learning approach was shown in Table 21.

TABLE 21 The students' satisfaction of the science learning model using problem-based learning

Items	Mean	SD	Interpretation
Classroom preparation and management	2.30	.45	fair
Learning materials	2.44	.47	fair
Acquired knowledge	2.84	.38	appropriate
Load of Work assignment	2.16	.32	fair
Useful of the assignments	2.84	.38	appropriate
Student and Teacher interaction	2.16	.32	fair
Student cooperation	1.98	.49	fair
Student group effectiveness	2.44	.47	fair
Science contents	3.84	.24	strongly appropriate
Assessment methods	2.84	.38	appropriate
Appropriateness for learning in science	2.84	.38	appropriate
Mean	2.61		appropriate

Student group structure:

The students organized their study group in different ways as the follows:

1. There was 2 out of 7 groups (27.91%) organized their group structure similar to other experimental group. . The group structure looked like the structure of the other experimental classroom. The group had a leader focusing on the learning task. There were a recorder, and four information seekers. The classroom observation showed that the group members' roles were assigned different all the times.

2. The 3 out of 7 groups (48.84%) assigned their group members to find out the information independently. After that, they brought up the received information for group discussion. They worked individually, rather than group dependence. The students spent a lot of time on the first two given problems. The students said that they faced some difficulties in learning while working on the two given problems. They did not know what they were doing, and how they could achieve to science subject achievement. According to the classroom observation, the students in this group always tried to ask for solutions from the former group, although they did not answers from them. During the week 5^{th} –6^{th}, most of the students had their attitude changed toward the group work and group discussions. The leader's role was to help the group members to achieve the learning objectives.

3. The last 2 out of 7 groups failed to assign the roles to group members. Most of them learned individually without discussing and working together. The classroom observation showed that they felt bored during class. After class, they had never met together for working. The study found that all of their assessment scores were in the low level of all tests.

The development of the problem solving method:

The 21 out of 43 students (3 out of 7 groups) started their learning process by using 5 components of critical thinking skills from the beginning of learning process. They included problem identification, selection of the useful information, deduction, interpretation, and explanation. The interviewed students stated that they learned by following the teacher's guide from the introduction phase. They realized that this was the best way to solve the given problem and they could. According to the interview, a few students in these groups came from families whose parents are highly educated people. They felt that their parents had a positive influence on their learning process.

The 22 out of 43 students tried to use the 5 components of critical thinking skills to solving the given problems, but failed to do it on their own. They preferred to learn by themselves. The classroom observation found that the students sought out information mainly from the existing texts or the provided information sheets. The interviewed students expressed that they felt so worries and frustrated with this learning method. The students wrote the solutions to problems in short essay writing. There were 6 students who could not pass their dairy progress report all the given problems. They, however, managed to pass and tests.

The observation showed that 43 of 43 (100%) students mainly used information mainly form the school texts and the information sheets. Only 2 (4.65%) students searched more information from the Internet, particularly www.google.com and www.sanook.com. And yet their solution to the given problems came mainly from the same resources as others.

The 6 out of 43(13.95%) students came from the families whose parents are scientist, nurses, middle school science teacher, and engineer who helped them with their studies after school. They all advocated that the science learning model using problem-based learning approach motivated them to learn more when solving the given problems.

The 9 out of 43(20.93%) students who had alcoholic parents had unique personalities in learning process similar to the other experimental group. They wanted to see their parents stop their drinking habit. The students in this group stated that the given problems motivated them to learn because they were similar to their real life problems. This was the positive effect of the science learning model using a problem-based learning approach.

Extending the learning experiences to other subjects:

There were 2 out of 43 (4.65%) students suggested that problem-based learning approach should be used with the other subjects as well. They felt that the approach fostered them to be an effective investigator. The students said that they have learnt although they could not receive the highest scores. All the students (100%) advocated that the problem-based learning approach was too difficult for their learning because of their insufficient background knowledge.

According to the findings, it indicated that the students who took the course with problem-based learning and tutorial approach were satisfied with the science learning model rather than the students who did so with the problem-based learning approach.

Therefore the fourth hypothesis is supported.

Chapter 5

Conclusions, Discussions, and Recommendations

This study was a semi-experimental research for development of a science learning model on life and living for level 3 using problem-based learning and tutorials. In this chapter, it includes conclusion, discussion, and recommendation as follows

Conclusions

The primary purposes of this research were to determine the effects of the science learning model using problem-based learning and tutorial approach on students' critical thinking skills, understanding of science, and science achievement. In order to achieve the purposes, research and development (R & D) was applied as the research design for this present study. A science learning model using problem-based learning and tutorial approach was developed based on four educational theories. These were Piaget 's theory, Vygotsky's theory, Dewey's theory, and Bruner' s theory. Tutorials were an important factor for motivating students to learn more new knowledge and find out solutions to the problems. The tutorials were developed based on the core content and achievement goal provided in The National Science Curriculum. The teacher or monitor used these tutorials to help students in difficult tasks.

The research instruments of this study consisted of:

1. Critical thinking test. The test emphasized on assessing the first and third level of knowledge structure.

2. Understanding of science test. The test emphasized on assessing the first and second level of knowledge structure.

3. Science achievement test. The test emphasized on assessing the third level of knowledge structure.

4. Student satisfaction questionnaires. The questionnaires reflected students' feedback on the science learning model using problem-based learning and tutorial approach

The research based on the hypotheses that a problem-based learning and tutorial course had the positive effects more than the others did. A randomized control group pretest-posttest design was used to compare the three lower secondary science classrooms of

Mathayom Sanggit Wittaya Bangkok School, Pathumthani province, which were the sample groups who took the courses with the problem-based learning and tutorial approach, problem-based learning approach, and the conventional approach respectively.

The research findings:

The implementation results were concluded following the hypotheses. They were as follows:

The first hypothesis: The students who took the course with the problem-based learning and tutorial approach received critical thinking test scores higher than those who did so with the problem-based learning approach and the conventional approach.

The ANCOVA results showed that the posttest scores were unequal across the teaching approaches with the significance of the corrected model at $p< .05$. Pairwise comparisons were used to determine the differences among groups' means. The results presented that there was significant difference of the posttest means score between the students who took the course with problem-based learning and tutorial approach and the students who did so with the problem-based learning approach at $p< .05$ level. Therefore, the pairwise comparison indicated that tutorials influenced the students' critical thinking skills scores, particularly when comparing between the group with problem-based learning and tutorial approach and the group with problem-based learning approach. This is concluded that tutorials had its positive effect on students' critical thinking skills.

The second hypothesis: The students who took the course with the problem-based learning and tutorial approach received science understanding scores higher than those who did so with the problem-based learning approach and the conventional approach.

The results of Levene's test of homogeneity of variance presented that the experimental groups and the control group had unequal variances at $p< .05$ level of statistical significance. Therefore the Robust tests of equality was used to determine the differences among the groups. The findings indicated that there is no significant difference of posttest scores of understanding of science test across the groups at $p > .05$ level. Therefore the problem-based learning and tutorial approach did not influence on the students' understanding of science higher than the other approaches.

The third hypothesis: The students who took the course with the problem-based learning and tutorial approach received science achievement scores higher than those who did so with the problem-based learning approach and the conventional approach.

The ANOVA result indicated that there was significant difference of science achievement posttest scores by the three samples group at $p < .05$. The results of least significant difference test indicated that there is significant difference of means scores between the group who took the course with problem-based learning and tutorial approach and the conventional approach. The finding indicated that the problem-based learning and tutorial approach had positive effect on students' science achievement.

The fourth hypothesis: Students were satisfied with the science learning model using problem-based learning and tutorial approach

The findings showed that most of the students in both groups were fond of the science learning model. The students thought that it was an effective teaching approach that could increase students curiosity and develop critical thinking skills on their own. However, there were some students who did not satisfy with the science learning model throughout the course particularly within the group with problem-based learning approach.

Discussions

Students' critical thinking skills:

The implementing results indicated that the tutorials in the course with the science learning model using problem-based learning and tutorial approach fostered students to be the critical thinkers rather than the problem-based learning approaches. The result supports Das, Mpofu, Hasan and Stewart (2002) who studied student perceptions on tutor skills in problem-based learning tutorials. The result showed that the tutor's role influenced students' learning process and fostered critical thinking skills and attitudes toward students' future learning. The students' comment was that the tutorials were crucial for their learning process. Students needed guidances and supports on the information about a topic they were researching. This research findings also supported the educators' ideas (Bolhuis, 1996; Temple & Rodero, 1995., Guthric, Solomon and Rinchart; 1997) that tutorials help students efficiently see a connection between school knowledge and real-world problems.

In lower secondary science classroom, students were average 11-14 year-old. Although a survey study by Shayer (cited by Amos, 2002:156-157) revealed that less than 30 percent of secondary students between the ages of 11-16 were in Piaget's formal operational stage, tutorials in this study helped students achieved the learning objectives particularly on critical thinking skills well. The finding supported the Piaget's theory and the Vygotsky's theory that students during these ages are able to develop their critical thinking by learning with the knowledgeable peers and from appropriate tutorials. The finding supported the Ennis, Kahane,and Scriven (cited by McPeck, 1990) who stated that critical thinking skills can be developed when learning with an appropriate teaching and learning approach. This suggests that the tutorials in the problem-based learning and tutorial approach is an important factor for lower secondary students to learn science.

Students' understanding of science

The finding from this research indicated that there were no significant differences among the posttest scores across the three classrooms. The results were similar to the recent study on the effects of problem-based learning and conventional course on basic science knowledge of dental students at Liverpool by Last et al (2001) that the results showed no significant difference in the total scores of students' performance test comparing to the students who took the course with the conventional approach.

In this study, students of the three different classes came from the same economic background and had mixed learning abilities. All students' background knowledge were reflected on their previous GPA which had the same variances across groups. They viewed that science was useful in their lives and were willing to understand science contents in order to tackle the questions. This was in line with Steve Alsop and Keith Hicks (2001:28) who stated that students learn science as their knowledge based during problem-solving process. Parkinson (2002) suggested that students' understanding of science are based on their background knowledge and scientific processing skills, which they had trained previously. This could be a reason why the students of the three classes received exactly the same scores on science.

However, this study reflected that students in the problem-based learning and tutorial approach perceived relevant knowledge better than the other groups. The students also received slightly higher scores than the others on understanding of science.

Students' science achievement

The students' science achievement results shown in Table 18 and 19 indicated that there was a significant difference among the science achievement scores of the three classrooms, particularly between the group with the problem-based learning and tutorial approach and the group with conventional approach at $p < .05$ level of statistical significance. This finding supported the recent studies by Chang (2001) who found the positive effects of a problem-based Computer-assisted instruction (PBCAI) on students' earth science achievement in Year 10 students in Taiwan, Chin and Li-Gek (2000) who found that an integrated problem-based learning approach in biology curriculum had a positive influence on students' science achievement, Chang and Weng (2002: 441-451) who found the interrelationship between secondary school students' problem solving ability and their science-process skills in the area of earth science that enhanced students' progress on learning achievement, and Rangson Thongsooknok (2003) found the positive effects of Problem-based learning approach in Theory of number for secondary school students. All of the studies used open-ended problems for motivating students in learning process and revealed the positive effects of the problem-based learning approach on development of students' critical thinking skills and increasing students' achievement in science.

The purpose of using modified short essay questions as a test of science achievement was to assess students' third level of the knowledge structure. The students might relate theoretical knowledge to the particular answer of the problem. Students used their critical thinking skills as an important knowledge management skill, which were on the basis of relevant background knowledge as a factor of the quality of thinking (Reinmann-Rothmeier and Mandl, 1998). It was valuable as a cognitive resource for reasoned management and judgement. That means, students who were good critical thinkers, they could use their background knowledge as a thinking resource before making decisions. In addition, the students who used their critical thinking skills when confronting with problems could come up with better solutions.

Although the understanding of science scores were equal across the groups in this study, critical thinking skills helped students who took the course with problem-based learning and tutorial approach achieved better than the others did on science achievement. Problem-based learning and tutorial approach, therefore, was an effective instructional approach to promote students' critical thinking skills for seeing a connection between theoretical knowledge and real-world problems.

In figure 4, 5, and 6, the graphs showed each student' s score. Figures 4, 5 and 6 were similar to one another. All the graphs were resemble to each other. The students who received high score in critical thinking test were likely to receive the understanding of science test and science achievement test. The finding supported McPeck' s idea (1981) on development of cognitive skills to help raise critical thinking skills. The background knowledge played an important role how students could think critically. The consequence of such skill was that new knowledge arises when the given problem was being tackled. At the same time, the acquired knowledge helped students learn more effectively (Bruner, 1966).

It was found that the differences between the critical thinker students and non-critical thinker students were that the former could reach the learning objectives and passed the criteria of student dairy progress report within the 2^{nd} class period. The students used their critical thinking skills to tackle the problems more sophisticatedly and more effectively, while the latter could not do so. This is in line with Woods (cited by Kain. 2003: 19-20) who stated that unsuccessful problem solvers tend to spend most of their time doing irrelevant things, whereas, successful problem solvers spend most of their time deciding what to do. Kain also suggested that problem solvers should start by identifying the problem. Students then dig into the problem details and find more about the facts before they decide what the real problem is (Kain. 2003: 19-20).

It was found in this study that most students in all classrooms could not see a connection between concepts or facts and the given problems. This is the important skill at a deductive stage that people use for making decisions. Students could not interpret the given data and explain the problems. Lack of the abilities to see a connection occurred particularly in the first 2-3 week of their learning processes. But the positive changes occurred after that point. This confirmed that the critical thinking skills are transferable skills through the appropriate instructional technique. The finding supports the Ennis, Kahane, and Scriven (cited by McPeck. 1990) who stated that critical thinking skills can be developed when learning with an appropriate teaching and learning approach.

As mentioned in Chapter 2, Department for Education and Skills, UK (Department for Education and Skills. 2002: 269-271) described that human thinking ability is related to three factors: 1) Genetic makes up about 20%, 2) Time that the human brain develops until reaching its peak in the late of teens. and 3) Appropriate environment that motivate students cognitive development. The three factors were used to describe the differences of critical thinking and science achievement among the participants in this study. The critical thinking skills are transferred from students' parents about 20%. And the 80% was gained from the students' experiences and appropriate learning strategies. This was supported by students who had their attitude change toward the science learning model.

The students' learning process:

The findings showed that problem based learning and tutorial approach is an instructional approach that integrates a variety of teaching methods, such as, problem solving approach, investigating approach, discussing approach, group learning approach, role play approach, learning by using situation approach, learning by using reading skills and tutorial. This was supported by Evenson and Hmelo (cited by Gijbel, Dochy, Bossche, and Segers. 2000) who stated that problem-based learning is a mixture of contexualized approaches integrated instructions, and learning is a result from the process of working toward the understanding or solution to a problem. Each instructional approach has different advantage and disadvantages, which can be found in this study. The classroom observation revealed that when students were challenged by open-ended problems, they sought for new knowledge to explain the provided problem. The learning atmosphere roused the students' interesting to research with various learning resources. The students used the scientific methods to solve a problem, which are the 5 components of critical thinking skills. The idea was corresponded to the educational psychology that critical thinking skills facilitate learning with problem-based learning (Sutep and Ausa. 2526:69). By doing so, it motivated students learning in-group. Also they managed to use democracy in their group. This approach led the teacher who acted as a facilitator to approach his or her students easier. The teacher could observe the students' development and help students who have faced a problem in their learning process immediately.

When the students worked in-group, they expected to discuss with the group. Discussion plays a major role in this research. During discussion, students gradually built up their knowledge. They expressed their opinions and were not afraid when their ideas were challenged by the other member in the group. They learnt how to respect other people' s opinions. The learning atmosphere was suiTable for learning in-groups (Sutep. 2526:76). On the other hands, the observation showed that there was some disadvantage. For instance, students were easily distracted from the topic being discussed. Students ended up discussing about something else not related to topic provided. They failed the group discussion and therefore did not meet the objective learning set. This approach is more time consuming than the other instructional methods. The observation also showed that they were silent at the beginning of the class period. This suggested that students learnt more on their own and they took their time in learning. This supported the research of the effects of instructional method using group discussion approach (Tanutkha. 2517:157-158; Laohapibool. 2537:150; Chatveerakhom. 2003: 21-22).

In the science learning model using problem-based learning and tutorials, the learning activity was provided into 3 situations related to human body and drug addictions as well as in section 4. The situations were designed to enhance the students' curiosity to learn by themselves. The students were given a role, in this case, a doctor who used medical biology to solve the problem. The students gradually accumulate knowledge about human body and its functions including drug and drug effects. The class observation at the first three-class period viewed that the participants in the two experimental groups were curious to learn all the time and developed their critical thinking skills when they were searching information from various resources. This was in accordance with the investigating approach (Laohapibool. 2537:126). The students who took the course with problem based learning and a tutorial course had no problems in searching for data comparing to the other groups. They discussed and shared ideas within their group as well as consulted with their tutor. The tutor helped them learn and understand the relevant science contents. Most of the students could pass the criteria set for dairy learning progress quicker than the other groups.

The study found that the students' asking and seeking of their teacher's assistance decreased continually from the 3^{rd} –4^{th} class period. At the same time, the class observation met that the science learning model using problem-based learning and tutorial approach is similar to that of the investigating approach. The students felt bored when they did not know whether the correct or not. The students who needed the teacher's assistance or the students whose learning ability lower than the others criticized that the science content in this model was too hard to understand. They preferred the traditional way of teaching that the teacher taugh and directly told them what would be included in the final examination.

The students in class who took the course with the problem-based learning, were enthusiasm at the beginning to learn with the provided problems. They enjoyed the first stage, but their enthusiasm toward the group work decreased. The class observation showed that the students were not sure what they might learn and what to do on the provided problem. As the whole class, the students needed teacher's assistance from the beginning of the course until the late of the problem 3. Although the teacher gave them only the questions to motivate them to learn, students asked for the teacher's help all the time. They all seemed passive in learning until they studied the problem 3. The study found that the students' calling and seeking teacher's assistance decreased continually from the late of the problem 3 or the 5^{th} – 6^{th} class period. Moreover at least 2 groups of the class expressed their ability to learn followed the problem 3 without any teacher's assistance. They reached their solution toward the provided problem by doing the following: identify the problem, select the information, deduction, interpretation, and explain the problem. The conclusion was that the 2 groups' student achieved science achievement better than the other students.

The students expressed that they were distant from their teacher. They preferred to have closer relationship with their teacher like the conventional approach rather than the science learning model using problem-based learning course.

The students in class who used the science learning model using problem-based learning course started to solve the given problem by using their existing science knowledge and scientific skills. The class observation showed that discussion activity within the student group had filled with investigated scientific data. They developed their critical thinking skills by communicating with each other. The study also received that there were a few students whose parents were nurses, officers in the hospital or an engineer. These students were given a role of a doctor or a nurse who takes care of drug addict patients. Then, they asked the questions such that, "what are the causes of vomiting?" "Is the gastritis a cause of vomiting?", or "Does the gastritis affect vomiting?". After that, they investigated the function of stomach and the causes of vomiting to identify the given problem. The interviewed students showed that after the school time, they often consulted with their parents about their learning and got some ideas to solve the given problem. These are the dispositions of the good problem solvers (Woods cited by Kain. 2003: 19-20) and are seen that the parents also are an important out of school time learning resources for students. Weiss and Brigham (2003) stressed that the parents' role as the learning resources increase students' positive development of systemic thinking and academic performance.

There were a few students in both of experimental groups who came from addict families. The students would seek the information and solution for use to persuade their father to stop addict behaviour. The student had a curiosity to investigate information about addict substances problem. Although this student's scores in all tests were not high, at least her showing curiosity to learn reflected from the questions they asked, such as, "how is the addict's brain damaged? How do the normal brain functions? How does the brain control the whole body?. The interviewed students expressed that they acquired the knowledge related to substances and its harmful effects on health and used it to their family to be away from its danger. The findings supported the study by Dochy, Segers, and Buehl (1999) that the students' familiarity with the learning topics had an influence on students' performances. They reviewed that the effects varied depending on questioning abilities related to family backgrounds, and problem solving competencies. This finding also supports Chin and LI-Gek (2000) that in problem finding process, the participated students engaged their friends and family members in their research. The activity made learning more fun and meaningful. This finding was summarized that students' curiosity to learn came from family concerns or experiences.

In problem-based learning, students who came from the high-educated families preferred to learn using role-play in their learning process. The classroom observation showed that the students acted as a nurse or a doctor. Parkinson, Windale and Shelton (1999:7) commented that the instruction by using role-play provide students to uses their background knowledge and scientific method more meaningful. The students used their real life experiences to discuss and communicate with other persons. They could control their emotion well and give reasons when arguing with other students. Although at the beginning of the course, most of the students still felt shy and intimidating to express their ideas in-group discussion, the positive changes occurred during the 3^{rd} –4^{th} week. At this point, the student learning style was changing from to group dependent. There was a disadvantage in that, student's role as a nurse or a doctor specified the related science contents was not clear. Sometimes, it looked amused because there was no contents in the role. As a result, students spent time in learning more than the other group. The students who took the course with problem-based learning and tutorials, used teacher guidance or tutorials to help them learn with their own pace.

Following the students' feedback on satisfaction questionnaire with the science learning model using problem-based learning and tutorials, students in the two experimental groups organised their learning to learn in-group with 6 members. A few groups in both experimental classrooms had group structure comprised of a group leader, information seekers, and a recorder. They shared their acquired knowledge within their group. These learning activities are similar to that of cooperative learning method. Parkinson, Windale and Shelton (1999: 13-18) and Bennett (2003: 169) presented that the cooperative learning help students develop analysing and communicating skills. But the limitation of this learning method is that most of the group members did not analyze their acquired information together. They were not responsible for their roles. This resulted is that most of the learning tasks fell on one or two students.

The findings showed that the students spent their time reading more than those who took the course with the conventional approach. The students gradually developed their abilities to question logically. Only a few students in each experimental group found information from the websites, such as, www.google.com, www.sanook.com, or also from the other websites. The students expressed that they read science articles more and this made them as an omniscient who knows and understand more than in school textbooks. The students in this group understand scientific terms more than the other groups.

From the questionnaires, the students felt negative toward group work. They expressed that their group members were not responsible for their own task. Most of them preferred to learn by themselves. Although the science learning model provided suiTable science contents, its related to many other disciplines made students feel bored. They faced the difficulties in learning particular in the group using the problem-based learning approach. The teacher gave them questions in order to get students involved in their group discussion, while the group with tutorials from the teacher, the students were provided guiding sheet and teacher's assistance. They felt that the method promoted their thinking skills during the problem solving process. The teacher helped them correct their misconceptions and motivated them to learn more. The students in both experimental groups accepted that the given problems in PBL course helped them learn more effectively. The real life scientific issues were appropriately challenging for them. They started their learning with 5 components of critical thinking skills, which is the important tool for a problem solver. The students in both groups expressed that the science learning model is appropriate for learning as a whole. Although the students in the group who in the problem-based learning course reflected that the learning resources for this program was not enough, the preparation and learning administration were all good. All students agreed that the quantity of the provided tasks that they received from the course was suiTable. But they complaint that they also had assignments from other subjects, which overwhelmed them. The finding showed that each student might have to do 17 homeworks during the same period as his or her science courses. The students suggested that the school should combine all the projects to be one project like the science learning model, which covered many subjects areas.

Recommendations

These suggestions were provided for further research that focuses on the use of problem-based learning and tutorial approach in science classroom. It was also the basic information for improving science education in the context of problem-based learning approach.

From the research results, it was clear that the science learning model using problem-based learning and tutorial approach could help students learning well, particularly on student critical thinking, understanding of science, and science achievement. Although the students who used the science learning model using problem-based learning reached learning goal in equally or lower effective than the students who received the other instructions, they could develop critical thinking skills and construct knowledge themselves on human body and addicts.

On all of the measures used, students in the problem-based learning course received lower scores than the other groups. They also expressed their lower level of satisfaction than the students in problem-based learning and tutorial approach. Although all of their raw scores were slightly different, these indicated that problem-based learning approach without tutorial may not be appropriate for level 3 science students. When the students were given the open-ended problem without teacher guidance, they felt that they had no direction to learn and could not reach to learning objectives particular at the beginning of the course. Whilst the tutorial could help the students to understand what they were learning and what they should investigate more for solving the problem. The students in the group with teacher’s tutorials learnt with their confidences. Their learning achievements were better than the students in problem-based learning course and the students in conventional course. This indicated that a tutorial was important factor influenced on students' cognition development. Tutorials induced students to learn and investigate new knowledge without confusion. The appropriate tutorials should be constructed based on course objectives and outcomes for students to know what they must learn and understand in their learning plans.

Recommendation for school administrators

1. Using of the problem-based learning and tutorial approach in school context should be considered on the feasibility of school management. That the school limited factors should be considered, such as, availability of school facilities, level of difficulty for the students to learn. Therefore, teachers meeting should be held before using the course in science classroom for sharing ideas, considering on the appropriate instructional tools, and planning for the actual implementation.

2.In problem-based learning context, library and ICT are effective information resources for students to studies on. Students should be trained to use the school library and ICT for self-studying before taking the course with problem-based learning and tutorial approach.

Recommendations for teachers

1. The teachers in the problem-based learning and tutorial approach should place themselves as monitor who encourage students learning by supporting active learning climate and participating in students group discussion. At the same time, the teacher may help students in psychological support, which always do at the beginning of the course. The teachers must clear of when the tutorials guide should be given the students in their learning processes. Also the teacher should constantly check the students' progresses for helping them to reach learning target.

2. Since the science learning model using problem-based learning and tutorial approach includes a various teaching method. All skills and relevant concepts should be organized into the tutorial guide for motivating students in learning process.

Recommendations for further study

However the scope of this study was to investigate the effects of the science model using problem-based learning and tutorial approach on the students' critical thinking skills, science achievement, and satisfaction with the science model as the main independent variable for level 3 only. It would be interesting for the further research to investigate into the effects of problem-based learning and tutorials on the other levels and subjects, and probably be considered in all education research.

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APPENDIX A

NAME OF THE EXPERTS IN THIS STUDY

รายชื่อผู้เชี่ยวชาญตรวจสอบคุณภาพเครื่องมือการวิจัย

แบบการเรียนรู้วิทยาศาสตร์เรื่อง ชีวิตกับการดำรงชีวิต สำหรับช่วงชั้นที่ 3 โดยใช้ปัญหาเป็นฐานร่วมกับการสอนทบทวน ได้รับการตรวจสอบคุณภาพโดยพิจารณาความสอดคล้องด้านวัตถุประสงค์ เนื้อหา วิธีการเรียนรู้ และแนวคิดทฤษฎีที่เกี่ยวข้องโดยผู้เชี่ยวชาญจำนวน 3 คน ดังต่อไปนี้

1. ผศ.ดร.ปรินทร์ ชัยวิสุทธางกูล
   ภาควิชาชีววิทยา คณะวิทยาศาสตร์ มหาวิทยาลัยศรีนครินทรวิโรฒ
2. ดร.เกียรติศักดิ์ ส่องแสง
   ภาควิชาวัดผลประเมินผล คณะศึกษาศาสตร์ มหาวิทยาลัยเทคโนโลยีราชมงคลธัญบุรี
3. ดร.ศิริพร มโนพิเชฐวัฒนา
   อาจารย์ 2 ระดับ 7 โรงเรียนสตรีสมุทรปราการ

แบบการเรียนรู้วิทยาศาสตร์เรื่อง ชีวิตกับการดำรงชีวิต สำหรับช่วงชั้นที่ 3 โดยใช้ปัญหาเป็นฐานร่วมกับการสอนทบทวน ได้ปรับปรุงแก้ไขตามคำแนะนำของผู้เชี่ยวชาญและอาจารย์ประจำวิชาวิทยาศาสตร์โรงเรียนมัธยมสังคีตผู้ร่วมสอนในการวิจัยได้แก่

1. อาจารย์อนงค์นาถ จินดาประพันธ์
   อาจารย์ 3 ระดับ 8 กลุ่มสาระวิทยาศาสตร์ โรงเรียนมัธยมสังคีตวิทยา กรุงเทพมหานคร
2. อาจารย์เนาวรัตน์ ถวายทรัพย์
   อาจารย์ 2 ระดับ 7 กลุ่มสาระวิทยาศาสตร์ โรงเรียนมัธยมสังคีตวิทยา กรุงเทพมหานคร

APPENDIX B

THE STUDENTS' RAW SCORES FROM EACH TEST

TABLE 22 Pretest and posttest scores from the critical thinking test for the experimental group who followed a science learning model using problem-based learning and tutorial course (N=41), a problem-based learning course (N=43), and control group who followed a conventional group (N=35). (Total scores 15)

No.	PBL and tutorial course		PBL course		Conventional course	
	pretest	posttest	pretest	posttest	pretest	posttest
1	0	8	0	7	2	12
2	2	8	0	8	2	9
3	1	8	1	6	1	8
4	2	7	1	8	0	6
5	1	8	1	7	0	5
6	1	9	1	8	1	10
7	1	8	1	7	1	8
8	1	10	1	7	1	6
9	1	9	1	8	1	6
10	2	9	2	9	1	8
11	2	6	1	6	0	6
12	1	8	0	7	2	6
13	2	8	1	8	1	7
14	1	10	1	9	1	6
15	1	7	1	7	2	10
16	0	6	2	9	1	7
17	1	9	2	5	1	8
18	1	8	3	11	1	6
19	1	8	1	5	1	7
20	0	9	1	9	1	8
21	1	7	1	8	1	5
22	2	8	2	10	1	8
23	1	12	1	9	1	8
24	1	13	1	9	1	7
25	1	9	1	7	2	8

TABLE 22 (Continued)

No.	PBL and tutorial course		PBL course		Conventional course	
	pretest	posttest	pretest	posttest	pretest	posttest
26	1	11	1	8	2	9
27	2	7	1	10	2	8
28	1	7	0	7	1	11
29	0	7	0	6	1	9
30	1	8	1	9	1	9
31	1	8	1	9	0	5
32	2	8	1	5	2	8
33	1	7	0	5	2	9
34	0	9	1	8	1	10
35	1	8	2	6	1	7
36	2	6	2	5		
37	1	7	1	9		
38	1	7	1	10		
39	1	9	0	6		
40	1	13	1	8		
41	1	9	1	6		
42			2	8		
43			1	7		

TABLE 23 Pretest and posttest scores from the understanding of science test for the experimental groups who followed a science learning model using problem-based learning and tutorial course (N=41), a problem-based learning course (N=43), and control group who followed a conventional group (N=35). (Total score 39)

No.	PBL and tutorial course		PBL course		Conventional course	
	pretest	posttest	pretest	posttest	pretest	posttest
1	7	18	6	20	8	30
2	6	18	7	22	6	22
3	5	20	7	17	6	24
4	6	22	5	18	5	24
5	6	16	5	24	6	24
6	7	16	4	18	8	28
7	8	27	7	28	7	26
8	7	29	5	22	5	23
9	5	22	4	20	4	20
10	6	22	8	29	5	18
11	7	19	5	22	6	18
12	6	20	5	24	6	18
13	6	22	6	24	7	24
14	7	33	7	18	4	20
15	8	33	6	20	6	29
16	6	24	8	30	7	24
17	4	22	5	18	8	28
18	5	22	8	30	4	20
19	4	24	4	22	6	24
20	5	23	5	26	6	22
21	6	18	5	24	5	22
22	5	18	8	30	5	20
23	7	30	9	33	6	24
24	6	20	7	27	8	28
25	6	26	8	24	3	18

TABLE 23 (Continued)

No.	PBL and tutorial course		PBL course		Conventional course	
	pretest	posttest	pretest	posttest	pretest	posttest
26	5	33	6	24	4	18
27	7	22	9	32	5	18
28	8	22	6	24	8	33
29	6	25	7	24	7	28
30	5	22	4	18	5	20
31	3	16	5	18	5	20
32	4	18	6	19	4	20
33	8	35	6	22	7	32
34	7	22	5	22	5	20
35	6	28	7	19	6	28
36	7	22	5	18		
37	6	22	6	26		
38	8	29	9	33		
39	9	33	4	20		
40	6	28	7	18		
41	8	20	6	18		
42			6	18		
43			6	20		

TABLE 24 Posttest scores from the science achievement test for the experimental groups who followed a science learning model using problem-based learning and tutorial course (N=41), a problem-based learning course (N=43), and control group who followed a conventional group (N=35). (Total score 54)

No.	PBL and tutorial course	PBL course	Conventional course
1	26	25	34
2	29	26	28
3	20	28	28
4	24	28	26
5	28	24	22
6	30	26	32
7	28	28	22
8	30	25	24
9	28	26	28
10	26	32	25
11	30	24	28
12	30	24	28
13	18	24	24
14	32	28	24
15	28	28	39
16	24	34	30
17	28	22	24
18	24	32	18
19	24	24	18
20	26	28	22
21	28	28	19
22	28	30	28
23	39	34	24
24	38	30	22
25	28	24	24

TABLE 24 (Continued)

No.	PBL and tutorial course	PBL course	Conventional course
26	34	24	28
27	24	30	24
28	28	18	35
29	28	22	20
30	28	24	18
31	30	22	22
32	26	18	22
33	32	28	32
34	28	26	28
35	30	22	24
36	24	22	
37	25	28	
38	28	38	
39	28	29	
40	40	28	
41	30	28	
42		26	
43		28	

APPENDIX C

QUALITY TEST OF ASSESSMENT INSTRUMENTS

TABLE 25 Index of Item-objective congruence (IOC) of the critical thinking test

No	Experts' Evaluation score			IOC
	1	2	3	
1	1	1	1	1
2	1	1	1	1
3	1	1	1	1
4	1	1	1	1
5	1	1	1	1
6	1	1	1	1
7	1	1	1	1
8	1	1	1	1
9	1	1	1	1
10	1	1	1	1
11	1	1	1	1
12	1	1	1	1
13	1	1	1	1
14	1	1	1	1
15	1	1	1	1

TABLE 26 Index of Item-objective congruence (IOC) of the understanding of science test

No	Experts' Evaluation score			IOC
	1	2	3	
1	1	1	1	1.0
2	1	1	1	1.0
3	1	0	1	0.66
4	1	1	1	1.0
5	1	1	1	1.0
6	1	1	1	1.0

TABLE 27 Index of Item-objective congruence (IOC) of the science achievement test

No	Experts' Evaluation score			IOC
	1	2	3	
1	1	1	1	1.0
2	1	1	1	1.0
3	1	1	1	1.0
4	1	1	1	1.0
5	1	1	1	1.0

TABLE 28 Index of Item-objective congruence (IOC) of the satisfaction questionnaires

No	Experts' Evaluation score			IOC
	1	2	3	
1	1	1	1	1.0
2	1	1	1	1.0
3	1	1	1	1.0
4	1	1	1	1.0
5	1	1	1	1.0
6	1	1	1	1.0
7	1	1	0	0.66
8	1	1	1	1.0
9	1	1	1	1.0
10	1	0	1	0.66
11	1	1	1	1.0
12	1	1	0	0.66
13	1	1	1	1.0
14	0	1	1	0.66
15	1	1	1	1.0
16	1	1	1	1.0
17	1	1	1	1.0
18	1	1	1	1.0

TABLE 29 The Item Difficulty (P), Item discrimination (r) and $r_{KR\text{-}20}$ of a critical thinking test.

Question	P	r	$r_{tt\ (KR\text{-}20)}$
1	.58	.21	.52
2	.63	.24	
3.	.57	.24	
4.	.5	.46	
5.	.53	.46	
6.	.47	.52	
7.	.55	.61	
8.	.50	.52	
9.	.49	.60	
10.	.55	.46	
11.	.56	.40	
12.	.56	.52	
13.	.55	.42	
14.	.46	.30	
15.	.58	.48	

TABLE 30 Mean scores, S.D. and r_{α} of an understanding of science test.

Question	Mean	S.D.	r_{α}
1.	3.2	1,276	.996
2.	4.23	1,803	
3.	2.53	1.702	
4.	5.27	1.382	
5.	2.23	1.382	
6.	1.8	0.748	

TABLE 31 Mean scores, S.D. and r_α of a science achievement test.

Question	Mean	S.D.	r_α
1.	5.63	2.249	0.925
2.	4.40	2.010	
3.	4.066	1.652	
4.	4.533	2.419	
5.	4.667	2.173	

APPENDIX D

AN EXAMPLE OF LESSON PLAN

แผนการเรียนรู้โดยใช้ปัญหาเป็นฐานร่วมกับการสอนทบทวน ตอนที่ 1
วิชาวิทยาศาสตร์
เรื่อง ระบบร่างกายกับผลกระทบของแอลกอฮอล์
ช่วงชั้นที่ 3 เวลา 6 คาบ

ความคิดรวบยอด

1. อาหารที่เข้าสู่ร่างกายจะถูกย่อยโดยระบบย่อยอาหารให้เป็นโมเลกุลเล็กก่อนเปลี่ยนเป็นพลังงาน เพื่อใช้ในการเจริญเติบโตและซ่อมแซมส่วนที่สึกหรอ

2. สารอาหารที่ย่อยแล้วจะถูกดูดซึมทางลำไส้เล็กด้วยกระบวนการแพร่และออสโมซิส แล้วถูกลำเลียงไปยังเซลล์ต่าง ๆ โดยระบบไหลเวียนเลือด

3. การรับรู้สึกและตอบสนองต่อสิ่งกระตุ้นเป็นการทำงานของระบบประสาท โดยมีสมองและไขสันหลังเป็นศูนย์กลาง และมีหน่วยรับรู้สึกกระจายอยู่ตามอวัยวะรับสัมผัสต่างๆ ทั่วร่างกาย

4. แอลกอฮอล์เป็นสารเสพติดจำพวกสารกดประสาท เมื่อเสพติดนานๆจะทำให้การทำงานของระบบร่างกายที่เกี่ยวข้องผิดปกติมากมาย เช่น สมองเสื่อม การทรงตัวไม่ดี เสี่ยงต่อการเป็นมะเร็งหลอดอาหาร ตับอักเสบมีไขมันแทรกและตับแข็ง กระเพาะอาหารและตับอ่อนอักเสบมีเลือดออก ความดันโลหิตสูง หัวใจโต ท้องมาน และเสียชีวิตในที่สุด

จุดประสงค์การเรียนรู้ นักเรียนสามารถ

1. อธิบายผลของการเสพติดแอลกอฮอล์ที่มีต่อร่างกาย การป้องกันและต่อต้านสารเสพติดแอลกอฮอล์ได้
2. อธิบายโครงสร้างหน้าที่และการทำงานของระบบย่อยอาหารของมนุษย์ได้
3. อธิบายโครงสร้าง หน้าที่และการทำงานของระบบประสาทของมนุษย์ได้
4. อธิบายโครงสร้างหน้าที่และการทำงานระบบไหลเวียนเลือดของของมนุษย์ได้

เนื้อหา

1. แอลกอฮอล์กับระบบร่างกาย

แอลกอฮอล์ถูกดูดซึมโดยมีองค์ประกอบที่เกี่ยวข้อง ได้แก่ 1) ความเข้มข้นของแอลกอฮอล์ 2) ปริมาณที่ดื่ม 3) ความเร็วในการดื่ม 4) การกินอาหารร่วมกับการดื่ม 5) ระดับสารเคมีในร่างกาย และ 6) เพศ

แอลกอฮอล์มีฤทธิ์กดระบบประสาทส่วนกลาง คนนิยมดื่มเพื่อการหย่อนคลายและรู้สึกเป็นสุข แต่เป็นอาการที่เกิดในระยะแรกเท่านั้น เมื่อดื่มมากขึ้นจะมีอารมณ์เปลี่ยนแปลง ก้าวร้าว ควบคุมตัวเองไม่ได้ ง่วงซึม เป็นอันตรายต่อสุขภาพของตนเองและก่ออุบัติเหตุแก่บุคคลอื่นๆ ได้ ผลกระทบที่พบได้บ่อย นอกจากโรคตับแข็งและตับอักเสบแล้ว ได้แก่

เสียชีวิต เนื่องจากระบบหายใจเป็นอัมพาต สำลักสิ่งอาเจียน เกิดอุบัติเหตุ

สับสน จิตใจสับสน สูญเสียการตัดสินใจที่ดี หงุดหงิด และไม่รับรู้สึกสัมผัสใดๆ

โคม่า โคม่าและหมดสติ อุณหภูมิร่างกายต่ำกว่าปกติ ระบบไหลเวียนโลหิตและหายใจผิดปกติ และตับถูกทำลาย

อาการเคลิ้มสุข (Euphoria) มีความเชื่อมั่นในตัวเองมากเกินไปและขาดความยับยั้งคิด การควบคุมและการตัดสินใจไม่ดี

อาการเพ้อเจ้อ พูดมาก เพ้อเจ้อ

กฏหมายที่เกี่ยวข้อง

ความผิดทางกฏหมายที่เกี่ยวกับแอลกอฮอล์ ได้แก่ 1) จำหน่าย จ่าย แจก แอลกอฮอล์ให้แก่เด็กอายุต่ำกว่า 18 ปี 2) ขับขี่ยวดยานพาหนะขณะมึนเมา และพบแอลกอฮอล์ในเลือดมากกว่า 80 มก./ เลือด 100 มล.

2. ระบบร่างกายที่เกี่ยวข้อง

ระบบย่อยอาหาร

เมื่ออาหารเข้าสู่ร่างกายจะถูกย่อยด้วยเอ็นไซม์ทำให้มีขนาดโมเลกุลเล็กลงก่อนจะเปลี่ยนเป็นพลังงานและใช้ในการสร้างเนื้อเยื่อเพื่อการเจริญเติบโตและซ่อมแซมส่วนที่สึกหรอ

การย่อยอาหาร หมายถึง การเปลี่ยนสารอาหารโมเลกุลใหญ่ให้มีขนาดเล็กลงด้วยเอ็นไซม์และสามารถดูดซึมได้

1. ระบบย่อยอาหารของมนุษย์ ประกอบด้วย

ก. ปาก อาหารถูกเคี้ยวเป็นชิ้นเล็กๆ และคลุกเคล้ากับน้ำลายซึ่งมีเอ็นไซม์ย่อยแป้งก่อนผ่านไปตามหลอดอาหาร

ข. หลอดอาหาร ประกอบด้วยกล้ามเนื้อเรียบทำหน้าที่หดรัดตัว ทำให้อาหารเคลื่อนผ่านไปยังกระเพาะอาหารได้

ค. กระเพาะอาหาร มีหน้าที่สร้างกรดเกลือและเอ็นไซม์ย่อยโปรตีน และมีการบีบตัวเพื่อให้อาหารคลุกเคล้ากับน้ำย่อยก่อนจะผ่านไปยังลำไส้

ง. ลำไส้เล็ก เป็นอวัยวะส่วนที่มีการย่อยอาหารทุกประเภทเป็นสารอาหารโมเลกุลเล็กและดูดซึมเข้ากระแสเลือดเพื่อส่งไปยังอวัยวะและเซลล์ทั่วร่างกาย

จ. ลำไส้ใหญ่ กากอาหารที่ผ่านการย่อยแล้วจะพักอยู่บริเวณนี้ โดยส่วนที่เป็นน้ำจะถูกดูดกลับเข้ากระแสเลือดและกากจะถูกขับออกเป็นอุจจาระทางไส้ตรงและทวาร

2. อวัยวะที่ช่วยย่อยอาหาร

ตับ ตับสร้างน้ำดีเพื่อทำให้น้ำมันที่กินเข้าสู่ร่างกายแตกตัว เพื่อให้เอ็นไซม์ย่อยได้ง่ายขึ้น น้ำดีที่สร้างขึ้นจะกักเก็บรวมกันในถุงน้ำดีและมีท่อน้ำดีเปิดต่อไปในลำไส้เล็ก

ตับอ่อน ตับอ่อนสร้างเอ็นไซม์ย่อยสารอาหารหลายชนิด เอ็นไซม์ที่สร้างขึ้นนี้จะผ่านจากตับอ่อนไปยังลำไส้เล็กโดยตรง

2. การย่อยอาหาร

เอ็นไซม์เป็นสารโปรตีน มีหน้าที่ย่อยสารอาหารต่างๆ สารอาหารที่ย่อยแล้วจะมีโมเลกุลขนาดเล็ก สามารถซึมผ่านเข้าสู่กระแสเลือดไปยังเซลล์ทั่วร่างกายเพื่อใช้ประโยชน์ต่อไป

การทำงานของเอ็นไซม์แต่ละชนิดจะมีความจำเพาะต่อสารอาหารชนิดใดชนิดหนึ่งเท่านั้น

$$\text{คาร์โบไฮเดรต} \xrightarrow{\text{เอ็นไซม์อะไมเลส}} \text{กลูโคส}$$

$$\text{โปรตีน} \xrightarrow{\text{เอ็นไซม์โพรทีเอส}} \text{กรดอะมิโน}$$

$$\text{ไขมัน} \xrightarrow{\text{เอ็นไซม์ไลเปส}} \text{กรดไขมัน + กลีเซอรอล}$$

3. การดูดซึมอาหาร

การย่อยและการดูดซึมอาหารจะเกิดในส่วนลำไส้เล็กมากกว่าที่กระเพาะอาหาร และจะย่อยอย่างสมบูรณ์ก่อนถูกดูดซึมเข้าสู่กระแสเลือด ภายในลำไส้เล็กมีส่วนที่ยื่นเข้าไปด้านในลักษณะคล้ายนิ้วมือจำนวนมาก เรียกว่า วิลลัส (villus) ช่วยเพิ่มพื้นที่การดูดซึมอาหารและมีเส้นเลือดฝอยทำหน้าที่ดูดซึมสารอาหารมากมาย เอ็นไซม์ในลำไส้เล็กถูกสร้างและส่งมาจากตับอ่อน ตับและลำไส้เล็กโดยตรง

ระบบไหลเวียนของเลือด

ประกอบด้วย เลือด หลอดเลือด และหัวใจ

1. เลือด มีส่วนประกอบที่สำคัญคือ

1.1 น้ำเลือด ประกอบด้วย น้ำ โปรตีน วิตามิน แร่ธาตุ เอนไซม์ และแก๊ส

1.2 ส่วนที่เป็นเซลล์และเกล็ดเลือด ได้แก่ เม็ดเลือดแดง มีเฮโมโกลบินเป็นส่วนประกอบที่สำคัญต่อการลำเลียงออกซิเจน เม็ดเลือดขาว ทำหน้าที่ต่อสู้เชื้อโรคโดยการจับกินหรือสร้างภูมิคุ้มกันโรค และเกล็ดเลือดช่วยให้เลือดแข็งตัว

2. หลอดเลือดหรือเส้นเลือด แบ่งเป็น 2 ประเภท ได้แก่

2.1 เส้นเลือดที่นำเลือดออกจากหัวใจเรียกว่า อาร์เตอรี (artery) เพื่อนำเลือดไปยังอวัยวะต่างๆ แล้วแตกแขนงเป็นเส้นเลือดขนาดเล็ก เรียกว่า อาร์เตอริโอล (arteriole) และหลอดเลือดฝอย

2.2 เส้นเลือดที่นำเลือดเข้าสู่หัวใจ เรียกว่า เวน (vein) ประกอบด้วย เวน เวนูล (venues) และหลอดเลือดฝอย

3. หัวใจ หัวใจมีรูปร่างคล้ายดอกบัว เป็นอวัยวะที่ประกอบด้วยกล้ามเนื้อที่แข็งแรงมาก เรียกว่า cardiac muscle อยู่ในช่องอกที่ล้อมรอบด้วยกระดูกซี่โครง ภายในหัวใจแบ่งเป็น 4 ห้อง ห้องบน 2 ห้อง และห้องล่าง 2 ห้อง เลือดดำจากส่วนต่าง ๆ ของร่างกายไหลเข้าสู่หัวใจทางห้องบนขวา แล้วผ่านลงในห้องล่างขวา ระหว่างห้องบนและห้องล่างแบ่งกั้นด้วยลิ้นหัวใจ เลือดจากหัวใจห้องล่างขวาจะถูกส่งไปสู่ปอดเพื่อการแลกเปลี่ยนก๊าซออกซิเจนและคาร์บอนไดออกไซด์ เลือดที่ผ่านการฟอกแล้วจะอ้อกซิเจนมากจะเคลื่อนออกจากปอดเข้าสู่หัวใจห้องบนซ้าย ห้องล่างซ้ายแล้วไปยังอวัยวะส่วนต่าง ๆ ต่อไปทางเส้นเลือดแดงใหญ่เรียกว่า เอออต้า (aorta) หัวใจเป็นอวัยวะที่สำคัญ อยู่ในทรวงอกใต้ราวนมด้านซ้าย ทำหน้าที่เสมือนเครื่องสูบฉีด ทำให้มีแรงดันให้แก๊สและอาหารไหลไปกับเลือดเลี้ยงส่วนต่างๆทั่วร่างกาย และเกิดการแลกเปลี่ยนแก็สที่ปอดก่อนไหลกลับสู่หัวใจ

การไหลเวียนโลหิต

หัวใจเป็นอวัยวะหลักในระบบไหลเวียนโลหิต การบีบตัวของหัวใจทำให้เลือดสูบฉีดไปได้ เรียกว่า การเต้นของหัวใจ เลือดไหลผ่านไปตามหลอดเลือดแดง โดยมีหลอดเลือดแดงขนาดเล็ก แทรกกระจายตามเนื้อเยื่อทั่วไป และส่วนที่เล็กที่สุดเรียกว่า หลอดเลือดฝอย (capillaries) ซึ่งเป็นตำแหน่งที่สารอาหารต่าง ๆ และออกซิเจนแพร่ผ่านออกจากเลือดไปยังเซลล์ของอวัยวะในร่างกาย ขณะเดียวกันของเสียจากการเผาผลาญสารอาหารในเซลล์ก็จะเคลื่อนผ่านเข้าสู่กระแสเลือดเทางหลอดเลือดดำฝอย สู่หลอดเลือดดำใหญ่หรือ veins แล้วกลับเข้าสู่หัวใจ เพื่อนำเลือดไปยังปอด การหมุนเวียนของเลือดนี้เรียกว่า ระบบไหลเวียนโลหิต ซึ่งประกอบด้วยวงจรการไหลเวียน 2 วงจร ได้แก่

การไหลเวียนในปอด เลือดดำไหลผ่านมายังหัวใจห้องบนขวา แล้วเข้าห้องล่างขวาไปยังปอดโดยผ่านไปทางเส้นเลือดแดงปอด คาร์บอนไดออกไซด์ และก๊าซบางชนิดที่ร่างกายไม่ต้องการจะถูกขับออกที่ถุงลมปอด และออกซิเจนจะแพร่เข้าแทนที่ในกระแสเลือด เลือดที่ฟอกแล้วจะไหลกลับเข้าหัวใจห้องบนซ้ายทางเส้นเลือดดำปอด เลือดจะไหลหมุนเวียนเช่นนี้ตลอดเวลา

การไหลเวียนในตับ ภายหลังจากเลือดไหลเวียนผ่านอวัยวะต่าง ๆ เช่น ม้าม ตับอ่อน กระเพาะอาหาร ลำไส้เล็กและลำไส้ใหญ่แล้ว เลือดจะไหลเข้าสู่ตับก่อนเข้าหัวใจ สารพิษและยาหลายชนิดจะถูกกำจัดทิ้งที่ตับนี้

ความดันเลือด

ขณะที่หัวใจบีบตัว เลือดจะถูกดันออกไปตามหลอดเลือดด้วยความดันสูง ทำให้เลือดไหลไปยังส่วนต่างๆ ได้ ในขณะที่รับเลือดกลับเข้าหัวใจจะมีแรงดันเลือดน้อยที่สุด การวัดความดันเลือดจึงวัดออกมาได้เป็น 2 ค่า มีหน่วยเป็นมิลลิเมตรปรอท เช่น 120/80 มิลลิเมตรปรอท

ความดันเลือดในคนปกติขึ้นกับปัจจัยหลายอย่าง เช่น อายุ เพศ การออกกำลังกายและสภาวะอารมณ์ เป็นต้น

ชีพจร

ชีพจรคือ การหดและคลายตัวของเส้นเลือด ในจังหวะเดียวกับการเต้นของหัวใจ การวัดชีพจรสามารถวัดได้จากหลอดเลือดแดงที่อยู่ใต้ผิวหนังตื้นๆ เช่นที่ข้อมือ ซอกคอ หรือขาหนีบ ในเพศชายมีอัตราชีพจรประมาณ 70 ครั้งต่อนาที ส่วนเพศหญิงประมาณ 75 ครั้งต่อนาที

เรื่อง ระบบประสาท

ระบบประสาทแบ่งออกเป็นระบบประสาทส่วนกลาง ประกอบด้วยสมองและไขสันหลังและระบบประสาทส่วนนอก ได้แก่ เส้นประสาทต่าง ๆ ที่ไม่อยู่ในระบบประสาทส่วนกลาง

สมองและไขสันหลัง (Brain and Spinal cord)

สมองเป็นอวัยวะที่สำคัญของมนุษย์ในการควบคุมการทำงานของร่างกาย โดยมีกะโหลกศีรษะทำหน้าที่ป้องกันสมองจากอันตรายที่อาจเกิดขึ้น สมองจะทำงานตลอดเวลา ดังนั้นจึงต้องการพลังงาน สารอาหารและออกซิเจนมากตลอดเวลา สมองผู้ใหญ่มีน้ำหนักประมาณ 1,300-1,400 กรัม มีเซลล์ประสาทประมาณ 1,000 ล้านเซลล์ แต่ละเซลล์มีขนาดราว 10 ไมครอนเท่านั้น

ไขสันหลังมีความยาวโดยประมาณ 45 เซนติเมตรในเพศชาย และ 43 เซนติเมตรในเพศหญิง ไขสันหลังเป็นส่วนหนึ่งของประสาทส่วนกลางมีหน้าที่เป็นทางผ่านของข้อมูลจากร่างกายส่วนต่าง ๆ ไปยังสมอง

เซลล์ประสาทหรือเซลล์สมอง

เซลล์ประสาทหรือเซลล์สมองแบ่งออกเป็น 3 ชนิด ได้แก่ 1) เซลล์ประสาทรับความรู้สึก 2) เซลล์ประสาทสั่งการ และ 3) เซลล์ประสาทประสานงาน การทำงานประสานกันของเซลล์สมองเกิดเป็นศูนย์ควบคุมกิจกรรทต่างๆ เช่น

1. ศูนย์ควบคุมความคิด ความจำและอารมณ์
2. การรับฟังเสียง การมองเห็น การเคลื่อนไหว
3. การประสานงานของอวัยวะต่างๆ เช่น การนั่ง การเดิน การนอน เป็นต้น
4. การหายใจ การย่อยอาหาร การเต้นของหัวใจ เป็นต้น

เซลล์ประสาทประกอบด้วยหน่วยรับรู้สึกทำหน้าที่รับความรู้สึก และหน่วยส่งความรู้สึกทำหน้าที่ส่งความรู้สึก โดยแต่ละเซลล์จะเชื่อมต่อกันที่ตำแหน่งเชื่อมต่อระหว่างปลายประสาทเรียกว่า ซินแนพซ์(synapse) กระแสรับรู้สึกจะเคลื่อนที่ผ่านซินแนพซ์นี้โดยมีสารเคมีเรียกว่าสารสื่อประสาทนำพาไป ได้แก่ โดพามีน ซีโรโตนีน ทำให้การรับรู้สึกเกิดได้โดยทั่วถึง

ระบบประสาทของมนุษย์

การทำงานเพื่อตอบสนองต่อสิ่งเร้า เรียกว่าระบบประสาท มนุษย์มีหน่วยรับรู้สึกอยู่ 5 อย่างคือ

ตา

ตามีหน่วยรับสัมผัสแสงสว่างแล้วส่งกระแสประสาทไปยังสมองเพื่อรับรู้ ตามีส่วนประกอบดังนี้

เปลือกตา เป็นส่วนหุ้มลูกตานอกสุด ด้านหน้าเรียกว่า กระจกตา มีสีขาวและแข็งแรง

เลนส์ตา อยู่ถัดกระจกตาเข้าไปด้านใน มี ม่านตา อยู่ด้านหน้าเลนส์เพื่อควบคุม รูม่านตา ให้แสงเข้าออกได้มากน้อยเพื่อป้องกันอันตรายแก่จอตา

จอตา ทำหน้าที่รับภาพจากภายนอก โดยมีหน่วยประสาทรับแสงอยู่มากมายทำหน้าที่ส่งข้อมูลไปที่สมอง

ลิ้น

ลิ้นทำหน้าที่รับรู้สึกรสชาดอาหาร หวาน ขม เค็มและเปรี้ยว โดยมีตุ่มรับรสกระจายทั่วลิ้น และมีประสาทรับรสส่งกระแสประสาทไปยังสมอง

จมูก

เป็นอวัยวะรับรู้เกี่ยวกับกลิ่น มีหน่วยรับรู้ด้านกลิ่นอยู่ที่โพรงจมูก

หู

ทำหน้าที่รับเสียงโดยหน่วยประสาทรับเสียงในช่องหูด้านใน ก่อนส่งกระแสประสาทไปยังสมองต่อไป

ผิวหนัง

นอกจากทำหน้าที่ป้องกันอันตรายอวัยวะภายในต่าง ๆ และการเคลื่อนไหวแล้ว ผิวหนังยังมีหน่วยประสาทรับรู้สึกเกี่ยวกับแรงกดดัน ความร้อน และความเย็นด้วย

การตอบสนอง

การตอบสนองเป็นปฏิกิริยาตอบสนองต่อสิ่งเร้าภายนอก เช่น เมื่อปลายนิ้วสัมผัสน้ำร้อน จะมีขั้นตอนการทำงานของระบบประสาทดังนี้

1. ความร้อนกระตุ้นหน่วยรับรู้สึกร้อนใต้ผิวหนังปลายนิ้ว
2. กระแสความรู้สึกผ่านไปตามเซลล์ประสาทรับรู้สึกสู่ศูนย์ประสาทรับรู้สึกร้อนไปยังสมอง

3. สมองรับรู้สึกแล้วสั่งการมาตามเซลล์ประสาทสั่งการไปยังกล้ามเนื้อแขน
4. กล้ามเนื้อรับคำสั่งแล้วหดตัวงอแขน ทำให้นิ้วหนีน้ำร้อนได้

ดังนั้น การทำงานของประสาทก็คือ การตอบสนองต่อสิ่งเร้า ในที่นี้คือน้ำร้อนและการหดมือหนีก็คือการตอบสนองนั่นเอง

กิจกรรมการเรียนรู้ รวม 6 คาบ

ขั้นกิจกรรมการเรียนรู้	กิจกรรมการเรียนรู้
นำเข้าสู่บทเรียน (15 นาที)	ผู้อำนวยการการเรียนรู้นำเสนอปัญหาธรณีพิบัติภัยทางภาคใต้ของประเทศไทย แล้วให้นักเรียนร่วมกันนิยามปัญหาสุขภาพและความเสียหายที่เกิดขึ้น ผู้อำนวยการการเรียนรู้เขียนปัญหาที่นักเรียนระบุได้บนกระดาน นักเรียนอภิปรายเลือกข้อมูลที่เกี่ยวข้องกับปัญหา แล้วนำข้อมูลและกฏหรือทฤษฏีมาใช้ในการสรุปผลกระทบที่เกิดขึ้น การแปลผลจากข้อมูลปัญหา และการอธิบายสรุปข้อแก้ปัญหา เพื่อให้นักเรียนเข้าใจวิธีการเรียนรู้โดยการใช้ปัญหาเป็นฐาน
สถานการณ์ที่ 1	กิจกรรมการเรียนรู้โดยใช้ปัญหาเป็นฐานด้วยสถานการณ์ที่ 1 **ขั้นตอนที่ 1** ขั้นการนิยามปัญหา นักเรียนแต่ละกลุ่มรับใบสถานการณ์ที่ 1 อ่านและทำความเข้าใจภายในกลุ่มเกี่ยวกับสถานการณ์ที่ได้รับเพื่อระบุปัญหาย่อยที่ประกอบในสถานการณ์ แล้วร่วมกันนิยามปัญหาย่อย การนิยามปัญหา นักเรียนภายในกลุ่มอภิปรายเพื่อนิยามปัญหาจากการเสพแอลกอฮอล์กับผลกระทบต่อระบบร่างกายตามข้อมูลที่ปรากฏในสถานการณ์ นักเรียนรวบรวมรายละเอียดที่เกี่ยวข้องโดยการระบุปัญหาต้องระบุเป็นข้อๆที่สามารถสืบค้นรายละเอียดเพิ่มเติมได้ ผู้อำนวยการเรียนรู้ให้ความช่วยเหลือนักเรียนด้วยการใช้คำถามชี้แนะและสอนทบทวนเพื่อกระตุ้นการเรียนรู้ของนักเรียนอย่างต่อเนื่องและแก้ไขข้อผิดพลาดของนักเรียนขณะเดินเยี่ยมกลุ่มต่างๆตลอดเวลา **ขั้นตอนที่ 2** การเลือกข้อมูลที่จะนำมาประกอบการพิจารณา นักเรียนร่วมกันวางแผนพิจารณาเลือกแหล่งการเรียนรู้จากมุมความรู้และแหล่งเรียนรู้ที่นักเรียนมีอยู่ โดยคัดเลือกเนื้อหาสาระที่เกี่ยวข้องกับปัญหาที่ได้นิยามไว้ นักเรียนบันทึกรายละเอียดที่สืบค้นได้เพื่อนำ

	มาอธิบายและสร้างข้อแก้ปัญหาที่ได้นิยามไว้ สมาชิกในกลุ่มจะร่วมรับผิดชอบในการแสวงหาข้อมูลเพิ่มเติมจากแหล่งอื่น แล้วทำความเข้าใจพร้อมกันภายในกลุ่มโดยละเอียด ผู้อำนวยการการเรียนรู้ให้ความช่วยเหลือนักเรียนด้วยการร่วมอภิปรายในกลุ่มนักเรียนแต่ละกลุ่มเพื่อให้ข้อมูลที่สืบค้นมาได้มีความสัมพันธ์กับปัญหาที่สุด และตั้งคำถามกระตุ้นให้สืบค้นข้อมูลเพิ่มเติมเพื่อสร้างความเข้าใจให้ถูกต้อง **ขั้นตอนที่ 3** การนิรนัยข้อมูลที่เลือกมาแล้วเพื่อหาข้อสรุปในการสร้างข้อแก้ปัญหา นักเรียนร่วมกันพิจารณาข้อมูลที่ได้เลือกแล้วนำข้อมูลมาสังเคราะห์เพื่ออธิบายสภาพปัญหาที่ได้รับมา ถ้าข้อมูลยังไม่เพียงพอ นักเรียนภายในกลุ่มจะร่วมกันกำหนดข้อมูลที่ต้องสืบค้นเพิ่มเติม แหล่งการเรียนรู้และการนิรนัยข้อมูลในการอธิบายปัญหา ผู้อำนวยการการเรียนรู้ร่วมอภิปรายในกลุ่มนักเรียนแต่ละกลุ่มเพื่อให้การนิรนัยข้อมูลที่สืบค้นมาได้มีความชัดเจนต่อปัญหาและถูกต้อง **ขั้นตอนที่ 4** การแปลผลโดยใช้ข้อมูลในปัญหามาคิดคำนวณ นักเรียนคิดคำนวณข้อมูลสุขภาพจากสถานการณ์แล้วสรุปผล ผู้อำนวยการการเรียนรู้วิเคราะห์แปลผลข้อมูลจากปัญหาร่วมกับกลุ่มนักเรียนแต่ละกลุ่มเพื่อให้การวิเคราะห์มีความถูกต้อง **ขั้นตอนที่ 5** การอธิบายสรุปสิ่งที่ค้นหาสืบเสาะได้ เมื่อได้ข้อมูลครบตามต้องการแล้ว นักเรียนร่วมกันสร้างข้อสรุปเพื่ออธิบายผลกระทบต่อร่างกายจากการดื่มแอลกอฮอล์ แล้วทำรายงานเพื่อการสื่อสารทางวิทยาศาสตร์ พร้อมกับจัดทำแผ่นพับเผยแพร่ความรู้เกี่ยวกับพิษภัยของแอลกอออล์ต่อระบบร่างกาย ในขั้นตอนนี้ผู้อำนวยการการเรียนรู้ร่วมอภิปรายในการสร้างข้อสรุปเพื่ออธิบายสถานการณ์ที่ได้รับมอบหมาย ให้นักเรียนจัดทำรายงานสถานการณ์ที่เกี่ยวกับพิษภัยของแอลกอฮอล์ แล้วส่งก่อนคาบการเรียนรู้ที่ 7

วัสดุการเรียนรู้

1. ใบสถานการณ์ที่ 1
2. ใบความรู้เรื่อง แอลกอฮอล์และผลกระทบต่อสุขภาพ ระบบย่อยอาหาร ระบบไหลเวียนเลือด และระบบประสาท

การประเมินผล

1. ผลการตรวจรายงานความก้าวหน้าประจำคาบ
2. ผลการตรวจรายงานสถานการณ์ที่ 1
3. แบบสังเกตพฤติกรรมการเรียนรู้ภายในห้องเรียน

ใบสถานการณ์ปัญหาที่ 1

คำแนะนำการเรียนรู้ด้วยสถานการณ์ที่ 1

ให้นักเรียนปฏิบัติงานตามคำแนะนำอย่างรอบคอบ

ก. นักเรียนจัดแบ่งกลุ่มออกเป็นกลุ่มละ 6 คน แต่ละกลุ่มจัดแบ่งงานออกเป็นขั้นตอนได้แก่ การนิยามปัญหา การเลือกข้อมูลเพื่อประกอบการอธิบายปัญหา การนิรนัยจากกฏหรือข้อเท็จจริง การแปลผลจากสถานการณ์ และการอธิบายสรุปสถานการณ์ นักเรียนในกลุ่มงานควรแบ่งหัวข้อเพื่อค้นหาและรวบรวมข้อมูลที่จำเป็น แลกเปลี่ยนความคิดกันภายในกลุ่ม การอภิปรายกลุ่มเกี่ยวกับคำถามที่ใช้ตอบปัญหาช่วยให้การตอบปัญหาสมบูรณ์ยิ่งขึ้น ความคิดและข้อมูลที่ค้นหาได้ควรจดบันทึกเพื่อใช้ประกอบการเรียนรู้ต่อไป

ข. นักเรียนควรมีการบันทึกแหล่งที่มาของข้อมูล คำอธิบาย และข้อสรุปอย่างย่อไว้ทุกครั้งที่ใช้ข้อมูลนั้น

ค. ใบความรู้เกี่ยวกับสารเสพติดต่าง ๆจัดวางไว้ที่มุมข้อมูลความรู้เพื่อใช้สืบค้นและอ้างอิง

ง. นักเรียนต้องส่งบันทึกความก้าวหน้าทุก ๆคาบการเรียนรู้

จ. นักเรียนจะได้รับการประเมินความคิดวิจารณญาณที่เกี่ยวกับระบบร่างกายและยาพาราเซตามอลเมื่อสิ้นสุดคาบการเรียนรู้ที่ 6 แล้ว

สถานการณ์ที่ 1

นายน้อง อายุ 20 ปี น้ำหนักตัว 55 กิโลกรัม ถูกนำตัวส่งโรงพยาบาลภายหลังจากการดื่มเบียร์กระป๋องยี่ห้อหนึ่งขนาดบรรจุ 375 ลบ.มล. ปริมาณแอลกอฮอล์ร้อยละ 5 ปริมาตรต่อปริมาตร จำนวน 12 กระป๋องในเวลาเดียวกันเมื่อเวลา 19.00 น. โดยเพื่อนของเขามาพบขณะที่นายน้องมีอาการอาเจียนรุนแรง หายใจแรงและเร็ว สูญเสียการทรงตัว โคม่า และหมดสติ ก่อนนำส่งโรงพยาบาลในคืนวันเดียวกันนั้น

ให้นักเรียนตอบคำถามดังต่อไปนี้

1. ระบบร่างกายใดบ้างที่ได้รับผลกระทบจากอาการพิษของแอลกอฮอล์และมีอาการอย่างไร
2. ระบบร่างกายในข้อ 1 มีส่วนประกอบและหน้าที่ที่สำคัญอย่างไรบ้าง และได้รับผลจากพิษของแอลกอฮอล์อย่างไร
3. ในกรณีนี้การเสียชีวิตเนื่องจากการดื่มแอลกอฮอล์อาจเกิดขึ้นได้อย่างไร
4. นายน้องจะเป็นอันตรายถึงชีวิตหรือไม่เพราะเหตุใด
5. นักเรียนจะอธิบายเกี่ยวกับการดื่มแอลกอฮอล์มีผลต่อสุขภาพร่างกายอย่างไร

แผนการเรียนรู้โดยใช้ปัญหาเป็นฐานตอนที่ 1
วิชาวิทยาศาสตร์
เรื่อง ระบบร่างกายกับผลกระทบของแอลกอฮอล์
ช่วงชั้นที่ 3 เวลา 6 คาบ

ความคิดรวบยอด

1. อาหารที่เข้าสู่ร่างกายจะถูกย่อยโดยระบบย่อยอาหารให้เป็นโมเลกุลเล็กก่อนเปลี่ยนเป็นพลังงาน เพื่อใช้ในการเจริญเติบโตและซ่อมแซมส่วนที่สึกหรอ
2. สารอาหารที่ย่อยแล้วจะถูกดูดซึมทางลำไส้เล็กด้วยกระบวนการแพร่และออสโมซิส แล้วถูกลำเลียงไปยังเซลล์ต่าง ๆ โดยระบบไหลเวียนเลือด
3. การรับรู้สึกและตอบสนองต่อสิ่งกระตุ้นเป็นการทำงานของระบบประสาท โดยมีสมองและไขสันหลังเป็นศูนย์กลาง และมีหน่วยรับรู้สึกกระจายอยู่ตามอวัยวะรับสัมผัสต่างๆ ทั่วร่างกาย
4. แอลกอฮอล์เป็นสารเสพติดจำพวกสารกดประสาท เมื่อเสพติดนานๆจะทำให้การทำงานของระบบร่างกายที่เกี่ยวข้องผิดปกติมากมาย เช่น สมองเสื่อม การทรงตัวไม่ดี เสี่ยงต่อการเป็นมะเร็งหลอดอาหาร ตับอักเสบมีไขมันแทรกและตับแข็ง กระเพาะอาหารและตับอ่อนอักเสบมีเลือดออก ความดันโลหิตสูง หัวใจโต ท้องมาน และเสียชีวิตในที่สุด

กิจกรรมการเรียนรู้ รวม 6 คาบ

ขั้นกิจกรรมการเรียนรู้	กิจกรรมการเรียนรู้
นำเข้าสู่บทเรียน (15 นาที)	ผู้อำนวยการการเรียนรู้นำเสนอปัญหาธรณีพิบัติภัยทางภาคใต้ของประเทศไทย แล้วให้นักเรียนร่วมกันนิยามปัญหาสุขภาพและความเสียหายที่เกิดขึ้น ผู้อำนวยการการเรียนรู้เขียนปัญหาที่นักเรียนระบุได้บนกระดาน นักเรียนอภิปรายเลือกข้อมูลที่เกี่ยวข้องกับปัญหา แล้วนำข้อมูลและกฏหรือทฤษฎีมาใช้ในการสรุปผลกระทบที่เกิดขึ้น การแปลผลจากข้อมูลปัญหา และการอธิบายสรุปข้อแก้ปัญหา เพื่อให้นักเรียนเข้าใจวิธีการเรียนรู้โดยการใช้ปัญหาเป็นฐาน
สถานการณ์ที่ 1	**ขั้นตอนที่ 1** ขั้นการนิยามปัญหา นักเรียนแต่ละกลุ่มรับใบสถานการณ์ที่ 1 อ่านและทำความเข้าใจภายในกลุ่มเกี่ยวกับสถานการณ์ที่ได้รับเพื่อระบุปัญหาย่อยที่ประกอบในสถานการณ์ แล้วร่วมกันนิยามปัญหาย่อย การนิยามปัญหา นักเรียนภายในกลุ่มอภิปรายเพื่อนิยาม

	ปัญหาจากการเสพแอลกอฮอล์กับผลกระทบต่อระบบร่างกายตามข้อมูลที่ปรากฏในสถานการณ์ นักเรียนรวบรวมรายละเอียดที่เกี่ยวข้อง โดยการระบุปัญหาต้องระบุเป็นข้อ ๆที่สามารถสืบค้นรายละเอียดเพิ่มเติมได้ ผู้อำนวยการเรียนรู้ให้ความช่วยเหลือนักเรียนด้วยการใช้คำถามกระตุ้นการเรียนรู้ของนักเรียน **ขั้นตอนที่ 2** การเลือกข้อมูลที่จะนำมาประกอบการพิจารณา นักเรียนร่วมกันวางแผนพิจารณาเลือกแหล่งการเรียนรู้จากมุมความรู้และแหล่งเรียนรู้ที่นักเรียนมีอยู่ โดยคัดเลือกเนื้อหาสาระที่เกี่ยวข้องกับปัญหาที่ได้นิยามไว้ นักเรียนบันทึกรายละเอียดที่สืบค้นได้เพื่อนำมาอธิบายและสร้างข้อแก้ปัญหาที่ได้นิยามไว้ สมาชิกในกลุ่มจะร่วมรับผิดชอบในการแสวงหาข้อมูลเพิ่มเติมจากแหล่งอื่น แล้วทำความเข้าใจพร้อมกันภายในกลุ่มโดยละเอียด ผู้อำนวยการการเรียนถามคำถามกระตุ้นให้สืบค้นข้อมูลเพิ่มเติมเพื่อสร้างความเข้าใจให้ถูกต้อง **ขั้นตอนที่ 3** การนิรนัยข้อมูลที่เลือกมาแล้วเพื่อหาข้อสรุปในการสร้างข้อแก้ปัญหา นักเรียนร่วมกันพิจารณาข้อมูลที่ได้เลือกแล้ว นำข้อมูลมาสังเคราะห์เพื่ออธิบายสภาพปัญหาที่ได้รับมา ถ้าข้อมูลยังไม่เพียงพอ นักเรียนภายในกลุ่มจะร่วมกันกำหนดข้อมูลที่ต้องสืบค้นเพิ่มเติม แหล่งการเรียนรู้และการนิรนัยข้อมูลในการอธิบายปัญหา ผู้อำนวยการการเรียนรู้กระตุ้นนักเรียนให้ตรวจสอบความถูกต้องของข้อสรุปที่ได้ **ขั้นตอนที่ 4** การแปลผลโดยใช้ข้อมูลในปัญหามาคิดคำนวณ นักเรียนคิดคำนวณข้อมูลสุขภาพจากสถานการณ์แล้วสรุปผล **ขั้นตอนที่ 5** การอธิบายสรุปสิ่งที่ค้นหาสืบเสาะได้ เมื่อได้ข้อมูลครบตามต้องการแล้ว นักเรียนร่วมกันสร้างข้อสรุปเพื่ออธิบายผลกระทบต่อร่างกายจากการดื่มแอลกอฮอล์ แล้วทำรายงานเพื่อการสื่อสารทางวิทยาศาสตร์ เกี่ยวกับพิษภัยของแอลกอออล์ต่อระบบร่างกาย ให้นักเรียนจัดทำรายงานสถานการณ์ที่ 1 ส่งก่อนคาบการเรียนรู้ที่ 7

วัสดุการเรียนรู้

1. ใบสถานการณ์ที่ 1

2. ใบความรู้เรื่อง แอลกอฮอล์และผลกระทบต่อสุขภาพ ระบบย่อยอาหาร ระบบไหลเวียนเลือด และระบบประสาท

การประเมินผล

1. ผลการตรวจรายงานความก้าวหน้าประจำคาบ
2. ผลการตรวจรายงานสถานการณ์ที่ 1
3. แบบสังเกตพฤติกรรมการเรียนรู้ภายในห้องเรียน

รายงานความก้าวหน้าของนักเรียนประจำคาบ

ชื่อ...เลขที่.................ห้อง...........................

สถานการณ์ที่ ....แผนการเรียนรู้ที่..............วันที่...................................

1.เรื่องหรือเนื้อหาที่สืบค้นในวันนี้..
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2.เหตุผลที่สนับสนุนการสืบค้นเรื่องหรือเนื้อหานั้น...
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3.เนื้อหาที่สืบค้นได้...
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4.แหล่งข้อมูลที่ใช้สืบค้น..
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5.สรุป..
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รายงานการศึกษาสถานการณ์ที่ 1

ชื่อ..เลขที่.................ห้อง...........................

แผนการเรียนรู้ที่..............วันที่...................................

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1. ระบบร่างกายที่ได้รับผลกระทบจากอาการพิษของแอลกอฮอล์

   ระบบ...อวัยวะที่เกี่ยวข้อง...................................

   ระบบ...อวัยวะที่เกี่ยวข้อง...................................

   ระบบ...อวัยวะที่เกี่ยวข้อง...................................

   ระบบ...อวัยวะที่เกี่ยวข้อง...................................

   ระบบ...อวัยวะที่เกี่ยวข้อง...................................

   ระบบ...อวัยวะที่เกี่ยวข้อง...................................

   ระบบ...อวัยวะที่เกี่ยวข้อง...................................

2. ระบบร่างกายในข้อ 1 มีส่วนประกอบและหน้าที่ที่สำคัญอย่างไรบ้างและได้รับผลจากพิษแอลกอฮอล์อย่างไร

ระบบ...

ส่วนประกอบและหน้าที่ที่สำคัญคือ...

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อาการพิษคือ...

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ระบบ...

ส่วนประกอบและหน้าที่ที่สำคัญคือ...

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อาการพิษคือ..
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ระบบ..
ส่วนประกอบและหน้าที่ที่สำคัญคือ...
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อาการพิษคือ...
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ระบบ..
ส่วนประกอบและหน้าที่ที่สำคัญคือ...
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อาการพิษคือ...
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ระบบ..
ส่วนประกอบและหน้าที่ที่สำคัญคือ...
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อาการพิษคือ...
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ระบบ...

ส่วนประกอบและหน้าที่ที่สำคัญคือ..

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อาการพิษคือ..

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ระบบ...

ส่วนประกอบและหน้าที่ที่สำคัญคือ..

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อาการพิษคือ..

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3. ในกรณีการเสียชีวิตเนื่องจากแอลกอฮอล์อาจเกิดขึ้นได้อย่างไร

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4. นายน้องอาจเป็นอันตรายถึงชีวิตหรือไม่เพราะเหตุใด

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5. อธิบายการดื่มแอลกอฮอล์ที่มีผลกระทบต่อสุขภาพร่างกาย

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ให้นักเรียนส่งรายงานนี้ก่อนคาบการเรียนรู้สถานการณ์ที่ 2

แบบทดสอบความคิดวิจารณญาณก่อนและหลังเรียน
ช่วงชั้นที่ 3

คำชี้แจง

1. แบบทดสอบนี้มีจำนวน 15 ข้อ ให้เวลาทำ 30 นาที
2. ในแต่ละสถานการณ์ใช้ในการตอบคำถามตามข้อที่กำหนดให้
3. ให้นักเรียนเลือกคำตอบที่ถูกต้องที่สุดเพียงคำตอบเดียวแล้วทำเครื่องหมาย X ลงในช่อง ก ข ค ง ในกระดาษคำตอบ
4. ห้ามเปิดหนังสือหรือปรึกษากันระหว่างการทดสอบโดยเด็ดขาด

คำชี้แจง สถานการณ์ที่ 1 ใช้ตอบคำถามข้อที่ 1 - 5

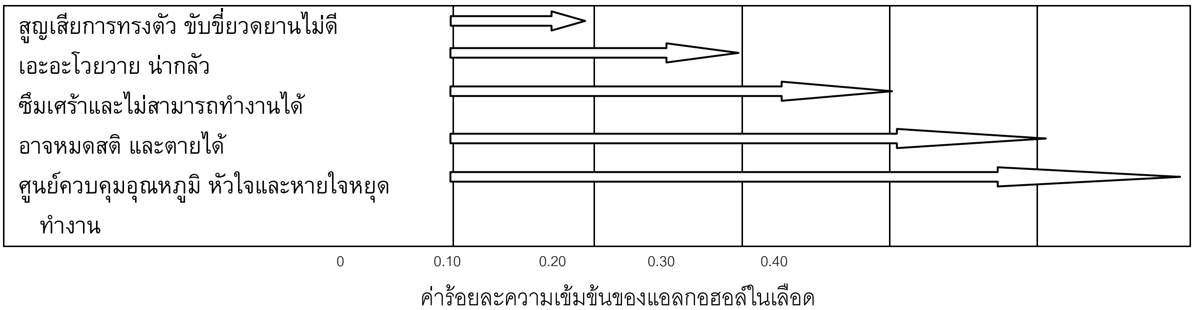
นาย ก มีน้ำหนักตัว 55 กิโลกรัม มีน้ำหนักตัว 60 กิโลกรัม เขาชอบดื่มเบียร์เป็นประจำและขาดไม่ได้ กระทั่งมีอาการตับโตผิดปกติ ตับอ่อนอักเสบ และมือสั่น วันหนึ่งเมื่อรู้ว่าเขาต้องออกจากงาน เขากลุ้มใจมาก จึงดื่มเบียร์ 10 กระป๋องอย่างรวดเร็วและมีอาการเมาอย่างรุนแรง ภายหลังการดื่มแล้ว 10 นาที เพื่อน ๆ จึงช่วยกันนำตัวส่งโรงพยาบาล

	ปริมาณที่ดื่ม (เบียร์กระป๋อง)											
นำหนักตัว (ปอนด์)	1	2	3	4	5	6	7	8	9	10	11	12
100 lb.	.038	.075	.113	.150	.188	.225	.263	.300	.338	.375	.413	.450
110 lb.	.034	.066	.103	.137	.172	.207	.241	.275	.309	.344	.379	.412
120 lb.	.031	.063	.094	.125	.156	.188	.219	.250	.281	.313	.344	.375
130 lb.	.029	.058	.087	.116	.145	.174	.203	.232	.261	.290	.320	.348
140 lb.	.027	.054	.080	.107	.134	.161	.188	.214	.241	.268	.295	.321

ตารางที่1 แสดงระดับร้อยละของแอลกอฮอล์ในเลือดตามปริมาณที่ดื่มและน้ำหนักตัวในเพศชาย

ที่มา:NHTSA สหรัฐอเมริกา

ตารางที่ 2 แสดงผลของแอลกอฮอล์ต่อพฤติกรรมการแสดงออกและอาการพิษของผู้ดื่ม



ที่มา : Focus on health by Dale B.Hahn and Wayne A. Payne,1994:185

1. ข้อใดน่าจะเป็นปัญหาสุขภาพของนาย ก ก่อนเกิดเหตุการณ์ในครั้งนี้
   ก. พิษสุราเรื้อรัง
   ข. อาการกังวล นอนไม่หลับ
   ค. ตับอักเสบจากการติดเชื้อไวรัส บี
   ง. การว่างงานกับการดื่มสุรายาเมา
2. รายละเอียดหรือเรื่องที่ควรสืบค้นเพิ่มเติมเพื่อทำความเข้าใจในสถาณการณ์นี้คืออะไร
   ก. การติดเชื้อไวรัสตับอักเสบ บี
   ข. สถานภาพแต่งงานหรือหย่าร้าง
   ค. การว่างงานกับการดื่มสุรายาเมา
   ง. การเกิดตับอักเสบจากพิษสุราเรื้อรัง
3. จากตารางที่ 1 และ 2 ข้อใดกล่าวมีเหตุผลมากที่สุด
   ก. พิษของแอลกอฮอล์ขึ้นกับเพศ น้ำหนักตัว และปริมาณที่ดื่ม
   ข. พิษของแอลกอฮอล์ขึ้นกับยี่ห้อของเบียร์ น้ำหนักตัว และปริมาณที่ดื่ม
   ค. พิษของแอลกอฮอล์ขึ้นกับยี่ห้อของเบียร์ น้ำหนักตัว เพศ และปริมาณที่ดื่ม
   ง. พิษของแอลกอฮอล์ขึ้นกับความแข็งแรงของผู้ดื่มและความทนทานต่อปริมาณที่ดื่ม
4. นางสาว ก น่าจะมีอาการพิษจากแอลกอฮอล์ในระดับใด
   ก. เอะอะโวยวาย น่ากลัว
   ข. ซึมเศร้า ทำงานไม่ได้
   ค. อาจหมดสติ และตายได้
   ง. ศูนย์ควบคุมอุณหภูมิ หัวใจและระบบหายใจหยุดทำงาน
5. ข้อใดอธิบายสรุปสถานการณ์นี้ได้ดีที่สุด
   ก. นาย ก ป่วยด้วยอาการกังวล
   ข. แอลกอฮอล์ทำให้นาย ก ตกงานและเป็นกังวล
   ค. นาย ก มีอาการโรคประสาท มือเท้าสั่น และดื่มเบียร์มากเกินไป
   ง. แอลกอฮอล์ทำให้นาย ก ขาดสติปัญญา และเป็นปัญหาทำให้ตกงาน

สถานการณ์ที่ 2 ใช้ตอบคำถามข้อที่ 6-10

แสนสุข อายุ 17 ปี ผิดหวังกับชีวิตครอบครัว เขามักบ่นว่าปวดศีรษะตลอดเวลา และกินพาราเซตามอลขนาด 2 เม็ดต่อมื้อวันละ 4 ครั้งมานานมาก เขาไปพบแพทย์ด้วยอาการตัวบวม อ่อนเพลียรุนแรง ตัวซีดเหลือง และต้องพักรักษาตัวในโรงพยาบาลจนกว่าจะเป็นปกติ

จากข้อมูลที่เผยแพร่โดย Dr.R McConnell(http:/www.studenthealth.co.uk/leaflets/ParacetamolPoisoning.htm) กล่าวว่า พาราเซตามอลเป็นยาบรรเทาอาการปวดดลละลดไข้ ไม่ควรกินเกิน 8 เม็ด ๆ ละ 500 มิลลิกรัมต่อวัน การกินติดต่อกันนาน ๆ ควรปรึกษาแพทย์ อาการพิษจากการกินยาพาราเซตามอลเป็นเวลานาน ๆ และดื่มน้ำน้อย คือตับและไตวาย ผู้ป่วยมักเสียชีวิตหากไม่ได้รับการรักษาที่ถูกต้อง ส่วนอาการพิษที่รุนแรงจะเกิดกับผู้ป่วยที่กินยามากกว่า 25 เม็ดพร้อมกันทันทีและมีอาการตับวายเฉียบพลันเป็นสำคัญ

6. จากสถานการณ์ ข้อใดกล่าวถึงปัญหาได้ถูกต้องที่สุด
   ก. แสนสุขกินพาราเซตามอลมานานกว่า 8 ปีและป่วยด้วยอาการพิษจากยา
   ข. แสนสุขพบแพทย์เพราะโรคความดันโลหิตสูงทำให้มีอาการตัวบวม และดีซ่าน
   ค. แสนสุขมีอาการตัวบวม ตัวซีดเหลือง น่าจะเกี่ยวกับพิษยาพาราเซตามอลที่กินมานาน
   ง. แสนสุขควรพบจิตแพทย์โดยเร็วมากกว่าที่จะพบแพทย์ผู้เชี่ยวชาญโรคไตและตับอักเสบ
7. เรื่องที่ควรสืบค้นเพิ่มเติมเพื่อความเข้าใจเกี่ยวกับสถานการณ์นี้คืออะไร
   ก. ความผิดปกติทางประสาทที่ทำให้ตัวซีดเหลือง
   ข. การเป็นพิษของยาพาราเซตามอลขนาดมากกว่า 10 กรัม
   ค. ผลการกินพาราเซตามอลขนาด 8 เม็ดๆละ 500 มิลลิกรัมต่อวันในการรักษาอาการไข้
   ง. การเกิดพิษจากการกินพาราเซตามอลกับอาการตัวบวม ซีดและระบบร่างกายที่เกี่ยวข้อง
8. จากสถานการณ์และข้อมูลที่มีอยู่นี้ ข้อใดกล่าวได้เหมาะสมที่สุด
   ก. ปัญหาครอบครัวเกี่ยวข้องกับอาการไตและตับวายเรื้อรัง
   ข. ไต ตับและระบบขับถ่ายเกี่ยวข้องกับอาการพิษจากการใช้พาราเซตามอลนาน ๆ
   ค. การกินพาราเซตามอลเกินกว่า 25 เม็ดพร้อมกันทันทีเป็นสาเหตุการตายแบบฉับพลัน
   ง. ภายหลังการรักษาตัวที่โรงพยาบาลผู้ป่วยด้วยอาการตัวบวมและซีดเหลืองหายเป็นปกติทุกราย
9. จากสถานการณ์ ข้อใดกล่าวได้ถูกต้องที่สุด
   ก. แสนสุขป่วยเพราะการกินพาราเซตามอลมากกว่า 4,000 มิลลิกรัมต่อวันทุกวัน
   ข. แสนสุขป่วยเพราะการกินพาราเซตามอลขนาด 4,000 มิลลิกรัมต่อวันติดต่อกันนานมาก
   ค. แสนสุขป่วยเพราะกินพาราเซตามอลมากกว่า 12,500 มิลลิกรัมพร้อมกันทันทีในหนึ่งครั้ง
   ง. แสนสุขป่วยเพราะการกินพาราเซตามอลหลาย ๆ ขนาดทุก ๆ วัน ติดต่อกันเป็นเวลานาน ๆ

10.ข้อใดอธิบายสรุปได้ดีที่สุด

ก. ไม่ควรกินพาราเซตามอลตามขนาดที่ระบุในใบกำกับยา

ข. ควรใช้ยาพาราเซตามอลเพียงครั้งเดียวเพื่อความปลอดภัย

ค. ควรใช้ยาพาราเซตามอลตามขนาดที่ระบุในใบกำกับยา ไม่กินติดต่อกันนานๆ ควรดื่มน้ำมากๆ

ง. พบแพทย์ผู้เชี่ยวชาญโรคประสาททุกครั้งก่อนใช้ยาพาราเซตามอลเพื่อการรักษาอาการปวดศีรษะและลดไข้

สถานการณ์ที่ 3 ใช้ตอบคำถามข้อที่ 11-15

นางสุดสวย อายุ 24 ปี แต่งงานมานานกว่า 4 ปีแล้ว มีบุตรพิการทางสมองหนึ่งคนอายุ 3 ขวบ นางสุดสวยเริ่มติดยาบ้าหรือแอมเฟตามีนมาประมาณ 2 ปี โดยให้เหตุผลว่าเพื่อคลายความเศร้าและจะได้ทำงานในฐานะโบรคเกอร์ให้มากขึ้น กระทั่งเช้าวันหนึ่งนางสุดสวยมีอาการคลุ้มคลั่ง อาละวาด และใช้อาวุธมีคมฟันทำร้ายตัวเอง ทำให้เสียเลือดมาก ประกอบกับนางสุดสวยไม่ได้นอนและไม่กินอาหารมานานกว่าสองวัน จึงอ่อนเพลีย เป็นลมหมดสติ แล้วถูกส่งตัวรักษาด้วยอาการซึมเศร้ารุนแรง คิดทำลายตัวเองตลอดเวลา และเสียสติในที่สุด

11. จากสถานการณ์ที่ 3 ข้อใดกล่าวถึงปัญหาได้เหมาะสมที่สุด

ก. นางสุดสวยเสพติดยาแอมเฟตามีนแล้วทำให้บ้าคลั่ง

ข. นางสุดสวยเสพยาแอมเฟตามีนทำให้บุตรพิการทางสมอง

ค. อาชีพโบรคเกอร์ทำให้นางสุดสวยเครียดและกินไม่ได้จึงอาละวาดคลุ้มคลั่ง

ง. บุตรพิการและเสียเลือดมาก ทำให้นางสุดสวยเครียด ไม่กินอาหาร และต้องพึ่งแอมเฟตามีน

12. ข้อมูลเรื่องใดที่นักเรียนจะค้นเพิ่มเติมเพื่อความเข้าใจเกี่ยวกับพิษของแอมเฟตามีนตามสถานการณ์นี้

ก. การใช้ยาโปรแซครักษาโรคซึมเศร้าและฤทธิ์ไม่พึงประสงค์

ข. ผลของการให้เลือดและยาห้ามเลือดเพื่อรักษาอาการเสียเลือด

ค. ลักษณะอาการบ้าคลั่งและโรคซึมเศร้าในผู้ป่วยที่เสพแอมเฟตามีนนาน ๆ

ง. การเสียสติและคิดทำลายชีวิตตัวเองในผู้ป่วยโรคซึมเศร้าที่กินไม่ได้นอนไม่หลับ

13. มีข้อมูลยืนยันว่า “แอมเฟตามีนมีผลยับยั้งการทำงานของสารสื่อนำประสาทโดยเฉพาะสารสื่อความสุข หรือ โดพามีน ทำให้ผู้เสพมีความรู้สึกเศร้าหมอง ไม่เป็นสุข รู้สึกว่าตัวเองไม่มีค่า” จากสถานการณ์และข้อมูลข้างต้น ข้อใดเป็นเหตุเป็นผลที่สุด

ก. แอมเฟตามีนทำให้มีเลือดออก ซึมเศร้าและเสียสติ

ข. ผู้เสพแอมเฟตามีนสูญเสียโดพามีนทำให้เกิดอาการซึมเศร้า

ค. เด็กที่เกิดในครอบครัวที่พ่อเสพแอมเฟตามีนจะมีอาการสมองพิการ

ง. แอมเฟตามีนถูกขับออกนอกร่างกายทางเลือด ทำให้หมดสติและซึมเศร้า

14. จากสถานการณ์และข้อมูลที่มีทั้งหมด นางสุดสวยน่าจะ

ก. ทำร้ายตัวเองจนเสียชีวิตในที่สุด

ข. เป็นผู้ป่วยโรคสมองพิการพร้อมลูกที่โรงพยาบาลอย่างถาวร

ค. ยังคงไม่ได้กินไม่ได้นอนและอาละวาดคลุ้มคลั่งทำร้ายตัวเองตลอดเวลา

ง. การทำงานของสมองส่วนคิดเป็นเหตุเป็นผลและการรับรู้สึกภายในและภายนอกเสียหมดแล้ว

15. จากสถานการณ์และข้อมูลที่มีทั้งหมด ข้อใดอธิบายสรุปเกี่ยวกับแอมเฟตามีนได้ดีที่สุด

ก. แอมเฟตามีนเป็นสารเสพติดกดประสาททำให้ซึมเศร้า

ข. แอมเฟตามีนเป็นสารเสพติดกระตุ้นประสาททำให้คลุ้มคลั่งและซึมเศร้าหรือเสียสติในที่สุด

ค. แอมเฟตามีนเป็นสารกระตุ้นประสาททำให้ทำงานได้ทนนาน แต่ต้องใช้ให้ถูกขนาดและเหมาะสม

แอมเฟตามีนออกฤทธิ์กระตุ้นประสาทและกดประสาทในเวลาเดียวกันทำให้มีอาการบ้าคลั่งและซึมเศร้าสลับกันไปมา

SOME EXAMPLES OF STUDENTS' WORK

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