

DEVELOPMENT OF SCIENCE INSTRUCTIONAL MODEL EMPHASIZING CONTEXTUAL
APPROACH TO ENHANCE ANALYTICAL THINKING AND APPLICATION OF
KNOWLEDGE FOR LOWER SECONDARY SCHOOL STUDENTS



Presented in Partial Fulfillment of the Requirements for the
Doctor of Education Degree in Science Education
at Srinakharinwirot University
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The purpose of this study was to develop the science instructional model emphasizing contextual approach for lower secondary school students in order to enhance conceptual understanding, analytical thinking, and application of knowledge. This science instructional model consisted of five steps of learning namely 1) Focusing (F), 2) Exploring (E), 3) Analyzing (A), 4) Conceptual Developing (C), and 5) Applying (A) which has been called FEACA Model. A quasi-experimental research, pretest-posttest non-equivalent control group design, was used for evaluating the effectiveness of the model. The samples were two classrooms of the ninth-grade students. One classroom was serving as the experimental group taught with the FEACA Model whereas the other was serving as the control group taught with the traditional instruction. The research instruments consisted of 1) the conceptual understanding test which was 30 items of multiple choice questions with reliability at 0.78 and difficulty levels was between 0.23-0.75, 2) the analytical thinking test which was 25 items of multiple choice questions with reliability at 0.79 and difficulty levels was 0.25-0.73, 3) the application of knowledge test which was 12 items of open-ended questions with reliability at 0.76 and difficulty levels was 0.28-0.77, and 4) the opinion questionnaires toward the FEACA Model which was 20 items of five point rating scale questionnaires with reliability at 0.84. The findings suggested that students' conceptual understanding and analytical thinking posttest mean score were significantly higher than pretest mean score. Moreover, the FEACA Model was significantly better than the traditional instruction for promoting students' conceptual understanding, analytical thinking, and application of knowledge. Furthermore, students' opinions scores toward the FEACA Model were at high level of performance.

การพัฒนารูปแบบการเรียนการสอนวิทยาศาสตร์ที่เน้นวิธีการสอนโดยใช้บริบทเพื่อส่งเสริม
การคิดวิเคราะห์และการนำความรู้ไปใช้ สำหรับนักเรียนระดับมัธยมศึกษาตอนต้น



เสนอต่อบัณฑิตวิทยาลัย มหาวิทยาลัยศรีนครินทรวิโรฒ เพื่อเป็นส่วนหนึ่งของการศึกษา
ตามหลักสูตรปริญญาการศึกษาดุขฎิบัณฑิต สาขาวิชาวิทยาศาสตร์ศึกษา
มิถุนายน 2555

กิตติมา พันธุ์พุกษา. (2555). การพัฒนารูปแบบการเรียนการสอนวิทยาศาสตร์ที่เน้นวิธีการสอน โดยใช้บริบทเพื่อส่งเสริมการคิดวิเคราะห์และการนำความรู้ไปใช้ สำหรับนักเรียนระดับมัธยมศึกษาตอนต้น. ปรินญาณินพนธ์ กศ.ด. (วิทยาศาสตร์ศึกษา), กรุงเทพฯ : บัณฑิตวิทยาลัย มหาวิทยาลัยศรีนครินทรวิโรฒ. คณะกรรมการควบคุม: รองศาสตราจารย์ ดร.ณสรณ์ ผลโศภ, ว่าที่ร้อยตรี ดร.มนัส บุญประกอบ, ดร.จรรยา ดาสา.

การศึกษานี้มีวัตถุประสงค์เพื่อพัฒนารูปแบบการเรียนการสอนวิทยาศาสตร์ที่เน้นวิธีการสอน โดยใช้บริบทสำหรับนักเรียนระดับมัธยมศึกษาตอนต้น เพื่อส่งเสริมความเข้าใจในเนื้อหา การคิดวิเคราะห์ และการนำความรู้ไปใช้ รูปแบบการเรียนการสอนวิทยาศาสตร์นี้เรียกว่า FEACA Model ประกอบด้วย 5 ขั้นตอนของการเรียนรู้คือ 1) ขั้นมุ่งความสนใจ (F: Focusing) 2) ขั้นสำรวจตรวจสอบ (E: Exploring) 3) ขั้นวิเคราะห์ข้อมูล (A: Analyzing) 4) ขั้นพัฒนาแนวความคิด (C: Conceptual Developing) และ 5) ขั้นประยุกต์ใช้ (A: Applying) การวิจัยในครั้งนี้เป็นการวิจัยกึ่งทดลอง (Quasi-experimental Research) ดำเนินการตามแบบแผนการวิจัยแบบ Pretest-posttest Non-equivalent Control Group Design กลุ่มตัวอย่างคือนักเรียนชั้นมัธยมศึกษาปีที่ 3 จำนวน 2 ห้องเรียน ๗ ห้องเรียน เป็นกลุ่มทดลองซึ่งจัดการเรียนการสอนด้วย FEACA Model และอีกห้องเรียนหนึ่งเป็นกลุ่มควบคุมซึ่งจัดการเรียนการสอนแบบปกติ เครื่องมือวิจัยประกอบด้วย (1) แบบทดสอบวัดความเข้าใจในเนื้อหา เป็นแบบทดสอบชนิดเลือกตอบจำนวน 30 ข้อ มีค่าความเชื่อมั่นเท่ากับ 0.78 และค่าความยากอยู่ระหว่าง 0.23-0.75 (2) แบบทดสอบวัดการคิดวิเคราะห์ เป็นแบบทดสอบชนิดเลือกตอบจำนวน 25 ข้อ มีค่าความเชื่อมั่นเท่ากับ 0.79 และค่าความยากอยู่ระหว่าง 0.25-0.70 (3) แบบทดสอบวัดการนำความรู้ไปใช้ เป็นแบบทดสอบชนิดคำถามปลายเปิดจำนวน 12 ข้อ มีค่าความเชื่อมั่นเท่ากับ 0.76 และค่าความยากอยู่ระหว่าง 0.28-0.77 และ (4) แบบสอบถามความคิดเห็นของนักเรียนที่มีต่อ FEACA Model ซึ่งเป็นแบบสอบถามชนิดมาตราส่วนประมาณค่า 5 ระดับ จำนวน 20 ข้อ มีค่าความเชื่อมั่นเท่ากับ 0.84 ผลการวิจัยพบว่า นักเรียนที่เรียนด้วย FEACA Model มีคะแนนความเข้าใจในเนื้อหาและการคิดวิเคราะห์หลังเรียนสูงกว่าก่อนเรียนอย่างมีนัยสำคัญ นอกจากนี้ FEACA Model สามารถส่งเสริมความเข้าใจในเนื้อหา การคิดวิเคราะห์ และการนำความรู้ไปใช้ของนักเรียนได้ดีกว่าการเรียนการสอนแบบปกติอย่างมีนัยสำคัญ และความคิดเห็นของนักเรียนที่มีต่อ FEACA Model อยู่ในระดับสูง

The dissertation titled
“Development of Science Instructional Model Emphasizing Contextual Approach to Enhance
Analytical Thinking and Application of Knowledge for Lower Secondary School Students”

by
Kittima Panprueksa

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

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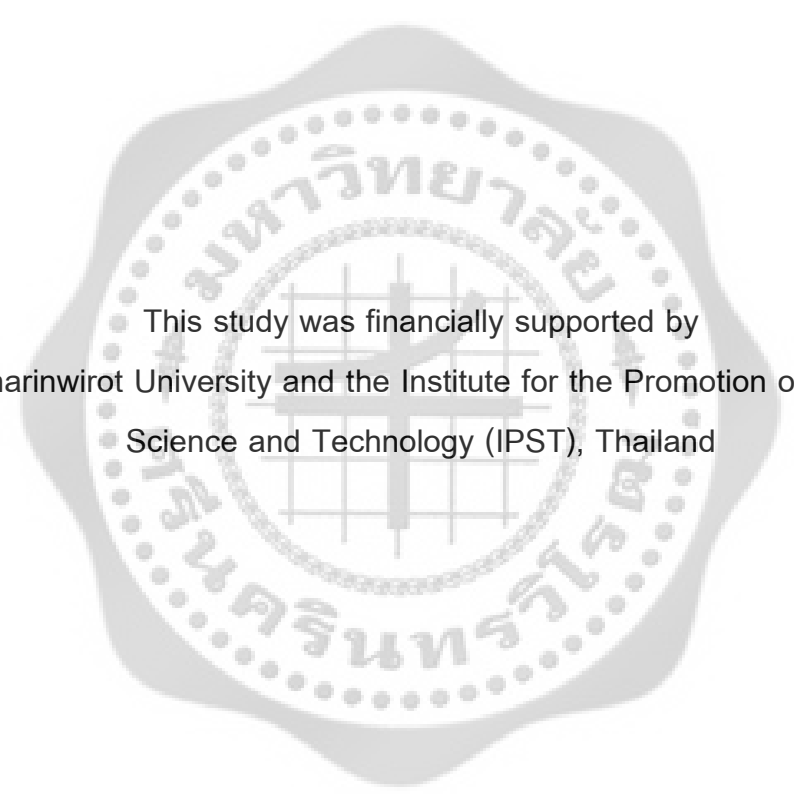
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TABLE OF CONTENTS

Chapter	Page
1 INTRODUCTION	
Background.....	1
Research Questions.....	5
Research Objectives.....	6
Significance of the Study.....	6
Scope of the Study.....	7
Definitions of Terms.....	8
Conceptual Framework of the Study.....	11
Research Hypotheses.....	12
2 REVIEW OF THE LITERATURE	
Constructivism.....	13
Situating Cognition.....	17
Contextual Approach.....	20
Analytical Thinking.....	33
Conceptual Understanding.....	39
Application of knowledge.....	44
The FEACA Model Development.....	50
3 METHODOLOGY	
Phase 1: Studying Basic Information for Developing Science Instructional Model.....	53
Phase 2: Developing the FEACA Model.....	55
Phase 3: Developing the Research Instruments.....	57
Learning Unit.....	57
Research Instruments for Learning Unit Evaluation.....	60

TABLE OF CONTENTS (continued)

Chapter	Page
3 METHODOLOGY (continued)	
Phase 4: Conducting a Pilot Study.....	64
Phase 5: Implementing the FEACA Model.....	65
Selecting Participants.....	66
Implementing.....	66
Phase 6: Evaluating the FEACA Model.....	67
Data Analysis.....	67
Statistics.....	68
4 FINDINGS	
The Results of the Science Instructional Model Development.....	73
The FEACA Model.....	73
The Learning Unit.....	75
The Results of a Pilot study.....	77
Time Arrangement.....	77
Instructional Process.....	78
Results of Using the Learning Unit.....	78
The Results of the FEACA Model Implementation.....	81
Testing the First Hypothesis.....	82
Testing the Second Hypothesis.....	82
Testing the Third Hypothesis.....	83
Testing the Fourth Hypothesis.....	84
Testing the Fifth Hypothesis.....	85
Testing the Sixth Hypothesis.....	86

TABLE OF CONTENTS (continued)

Chapter	Page
5 CONCLUSION AND DISCUSSION	
Research Objectives.....	88
Research Hypotheses.....	88
Research Instruments.....	89
Scope of the Study.....	89
Research Methodology.....	90
Conclusion and Discussion.....	95
Conceptual Understanding.....	95
Analytical Thinking.....	96
Application of Knowledge.....	96
Students' Opinions toward the FEACA Model.....	97
Recommendation.....	98
BIBLIOGRAPHY.....	100
APPENDIX	
Appendix A The Lists of Experts and Participating Teachers.....	110
A.1 The Lists of Experts.....	111
A.2 The List of Participating Teachers.....	111
Appendix B The Results of Evaluation of the Research Materials and Research Instruments.....	112
B.1 The Results of Evaluation of the Instructional Plans.....	113
B.2 The Results of Evaluation of the Conceptual Understanding Test Items.....	119
B.3 The Results of Evaluation of the Analytical Thinking Test Items	122

TABLE OF CONTENTS (continued)

Chapter	Page
APPENDIX (continued)	
B.4 The Results of Evaluation of the Application of Knowledge Test Items	127
B.5 The Results of Evaluation of the Opinions Questionnaire toward the FEACA	129
Appendix C The Research Instruments	132
C.1 The Example of Conceptual Understanding Test	133
C.2 The Example of Analytical Thinking Test	135
C.3 The Example of Application of Knowledge Test	137
C.4 The Opinions Questionnaire toward the FEACA Model	139
Appendix D The Learning Unit	141
D.1 The Teachers' Guideline	142
D.2 The Instructional Plans	159
VITAE	175

LIST OF TABLES

Table	Page
1 Analyzing Contextual Teaching and Learning Strategies.....	29
2 The Comparisons of Analytical Thinking in Bloom's Taxonomy and Marzano's Taxonomy.....	37
3 The Summary of Learning Unit.....	59
4 Point Values for Positive Items and Negative Items.....	63
5 The One Group Pretest-Posttest Design.....	65
6 The Pretest-Posttest Non-Equivalent Control Group Design.....	65
7 The Results of Evaluation Validity of the FEACA Model.....	74
8 The Lesson Plans Congruence Evaluation.....	76
9 The Revision of the Time Used in the Instructional Plans.....	77
10 The Results of Students' Conceptual Understanding in the Pilot Study.....	78
11 The Results of Students' Analytical Thinking in the Pilot Study.....	79
12 The Results of Students' Opinions toward the FEACA Model in the Pilot Study.....	80
13 The Comparisons of the Pretest and Posttest Mean Scores on Students' Conceptual Understanding of Experimental Group.....	82
14 The Comparisons of the Posttest Mean Scores on Students' Conceptual Understanding between Experimental Group and Control Group.....	83
15 The Comparisons of the Pretest and Posttest Mean Scores on Students' Analytical Thinking of Experimental Group.....	84
16 The Comparisons of the Posttest Mean Scores on Students' Analytical Thinking between Experimental Group and Control Group.....	84
17 The Comparisons of the Posttest Mean Scores on Students' Application of Knowledge between Experimental Group and Control Group.....	85
18 The Results of Students' Opinions toward the FEACA Model.....	86
19 The Results of Evaluation on IOC of Instructional Plan1: Acceleration.....	113

LIST OF TABLES (continued)

Table	Page
20 The Results of Evaluation on IOC of Instructional Plan2: Action and Reaction.....	114
21 The Results of Evaluation on IOC of Instructional Plan3: Friction.....	115
22 The Results of Evaluation on IOC of Instructional Plan4: Motion.....	116
23 The Results of Evaluation on IOC of Instructional Plan5: Buoyant Force	117
24 The Results of Evaluation on IOC of Instructional Plan6: Motion of Objects.....	118
25 The Results of Evaluation on IOC of the Conceptual Understanding Test Items.....	119
26 The Results of Evaluation on Item Difficulty (p) and Item Discrimination (r) of the Conceptual Understanding Test Items.....	121
27 The Results of Evaluation on IOC of the Analytical Thinking Test Items	122
28 The Results of Evaluation on Item Difficulty (p) and Item Discrimination (r) of the Analytical Thinking Test Items.....	126
29 The Results of Evaluation on IOC of the Application of Knowledge Test Items.....	127
30 The Results of Evaluation on Item Difficulty (p) and Item Discrimination (r) of the Application of Knowledge Test Items.....	128
31 The Results of Evaluation on IOC of the Opinions Questionnaire toward the FEACA Model Items.....	129
32 The Results of Evaluation on Item Discrimination (r) of the Opinions Questionnaire toward the FEACA Model Items.....	131

LIST OF FIGURES

Figure	Page
1 Conceptual Framework of the Study.....	11
2 Contextual Constructivist Model of Learning.....	22
3 Essential Element of the REACT Strategy.....	24
4 Model for Cycles of Learning that Integrate Contextual and Conceptual Knowledge.....	25
5 Flowchart of the Learning Sequence with a Contextual Approach.....	26
6 Context-Based Unit of Work Flowchart.....	27
7 An Integrated Knowledge Management Cycle.....	45
8 Framework of Research Methodology.....	54
9 Research Instruments Used in Each Period of the Study.....	67

CHAPTER 1

INTRODUCTION

Background

Science has been accepted to have an extreme influence on people and societies throughout the world because it is concerned with human's daily lives and livelihood. The countries advancing in science and technology can become the world's leaders in every aspect. The appliances and tools that make living and working easier are the result of scientific knowledge creatively applied together with knowledge from other fields. Science leads to the specific knowledge and understanding of many natural phenomena and the development of new technologies (Ministry of Education. 2008: 106). Scientific advances bring about rapid changes in the era of globalization. Many countries around the world have realized that the success of national development is caused by science and science education. Therefore, the improvement of quality of life has to place a high demand for scientific literacy on all citizens (International Council of Associations for Science Education (ICASE). 2009: online).

National advancement should emphasize the development of people not only on scientific literacy but also thinking. Thinking is a process that human usually use in everyday life, both simple and complex thinking. Thinking process makes people present their behavior and emotion as well as react in appropriate ways. In addition, thinking is an important tool for human to solve problems facing in daily life, acquire new information or knowledge, and decide which information is reliable for efficient survival in the knowledge-based society (Kosum; & Kamwatnang. 2001: 5). Furthermore, the use of thinking for innovative creation brings about comfortableness in living, as well as advancement of science and technology. Consequently, preparing people with thinking skills should be a central educational goal of every country.

Thailand also places importance on thinking skills. According to the Thai National Education Act B.E, 2542 (1999) and Amendments (Second National Education Act B.E. 2545 (2002)), it has been identified in section 24 that educational institutions should provide students with training in thinking process, management, confrontation with various situation,

and application of knowledge for preventing and solving problems, as well as prepare activities for learners to derive from real experience (Office of the National Education Commission (ONEC). 2003: 11). These correspond with the policy of the Ministry of Education in developing Thai children towards the 21st century. Emphasizing have been placed on morality, knowledge and skills in analytical and creative thinking, good physical and mental health, preference for Thai-ness, capability for teamwork and ability to live peace and harmony in the world community (Ministry of Education. 2008: 3). These show that one of the main goals of the national policy is to promote the thinking skills of all students.

There are many types thinking such as analytical thinking, synthesis thinking, critical thinking, creative thinking, and conceptual thinking etc. Considered as a fundamental thinking of others, analytical thinking is the essential thinking for learning and living of human. To achieve the desired result, problems facing in everyday life must be solved through analytical thinking correctly and efficiently. In the absence of analytical thinking, thinking and decision-making processes would become a bundle of confusion which leads to an erroneous conclusion (Jaruenwongsak. 2006). Because of its significance, Thai educational policy places emphasis on the enhancement of analytical thinking to all learners. As shown in the learners' key competencies, one of them is to inculcate students in analytical thinking capacity leading to the creation of bodies of knowledge or information for sensible decision-making regarding oneself and society (Ministry of Education. 2008: 6).

Although there is an attempt to promote analytical thinking on Thai students, their analytical thinking ability is still not satisfying especially in lower secondary education. According to the results of the Office for National Education Standards and Quality Assessment (Public Organization) (ONESQA), it has been found that students do not reach the fourth standard of learner standard on analytical thinking in external quality assessment of basic education (ONESQA. 2008: 11). Corresponding with the result of the National Institute of Educational Testing Service (Public Organization) (NIETS), the study has shown the decreases in the average scores of students who took the General Aptitude Test (GAT) which focuses on analytical thinking skills (Phetdee. 2009: online). All the results show that

Thai lower secondary school students are lacking of analytical thinking and need to be improved immediately.

Thai students not only lack of analytical thinking but also fundamental scientific conceptual understanding. The result of NIETS on the Ordinary National Educational Test (O-NET) has indicated the average science score of the ninth-grade students to be underneath 30 percent (NIETS. 2010: online). Correspondingly, the outcome of the International Association for the Evaluation of Education Achievement (IEA) on the Trends in International Mathematics and Science Study (TIMSS) 2007 has reported that the average science scores of the eighth-grade Thai students were lower than the international mean and lower than the previous assessment in 1999 (IEA. 2008: 47).

Furthermore, another indicator showing that Thai students were not excellent in both analytical thinking and science conceptual understanding was the result of the Programme for International Student Assessment (PISA) 2006. This programme assessed 15-years-old students on analytical thinking, understanding of fundamental scientific concept, as well as application of knowledge from what they have learned in science classroom to real-life problems. The results have shown that Thai students scored in science below the international mean and poorly as compared with Asian countries (Klainil; Dechsri; & Pramotene. 2008).

All the results above pointed that lower secondary Thai students did not meet both national and international standard. They performed below average and poorly as compared with students in other countries in both science conceptual understanding and analytical thinking. Moreover, they could not apply and link what they have learned in the science classroom with what they have seen in their daily lives. Therefore learning and teaching of science need to change and focus on the improvement of conceptual understanding, analytical thinking and application of knowledge by using students' everyday life experience as a tool.

According to constructivist learning theory, learning is an active process which people create their own new understanding and knowledge of the world based on the interaction of what they already know and believe, and the phenomena or ideas which they come into contact. When people encounter something new, they have to reconcile it with

previous ideas and experience and change what they believe or discard the new information (Educational Broadcasting Corporation. 2004: online). Research suggested that students often succeed in problems in everyday life at which fail in formal setting, and do better at problems expressed in everyday or familiar context rather than an obviously scientific one (Whitelegg; & Parry. 1999: 69).

Corresponding with Campbell; et al (1994), the ideas and concepts selected should enhance learners' appreciation of how the subject contributes to their lives or the lives of others around the world or helps them to acquire a better understanding of the natural environment. Moreover, setting science in context is seen as a mean of motivating more students to study science. It also expresses a desire to provide students with a more obvious picture of science and its role in people's lives, and also encourage them to connect science learning with the rest of their lives. This perspective suggested that a learning context requires related learning to an application in the real world.

One application of constructivist theory is known as contextual approach. This approach introduces real life context and application that students facing in their everyday lives before introduces the core science content to develop deeper understanding of scientific idea (Whitelegg; & Parry. 1999: 69). The contextual learning is based on the premise that learning is most effective when information is presented with in a framework that familiar to the students (Souders; & Prescott. 1999: 38). This approach is accepted to be an effective way to improve student's motivation, problem-solving, achievement (Glynn; & Koballa. 2005), attitude, understanding (Jong. 2008), application, and retention (Choi; & Johnson. 2005).

The goals of secondary science instruction are to help students understand basic principles and theories, as well as the nature, scope and limitation of science. At the same time, students are expected to acquire intellectual skills and should be able to apply the scientific process for solving problems. Furthermore, they should develop a keen interest in science and realize the correlation between science, technology, mankind and the environment. Ultimately, they must be able to apply their knowledge and understanding of science and technology for the benefit of their society and their own living (Soydhurum. 2001: 12).

In Thailand, teaching and learning in science classroom have long emphasized on “chalk and talk” pedagogy, rote learning and lecturing which teachers as the center of teaching-learning activities. Students generally learn science by traditional teaching method which provides less opportunity for them to participate and apply concepts and information in useful real life contexts. Students are disenchanted with science and find it unimportant, un-engaging, and irrelevant to their life (Rennie. 2006). Moreover, research has shown that traditional instruction makes students confused about the basic concepts of science (McDermott. 1991), leaves students poorly motivated (McCarthy; & Anderson. 2000; Murphy; & Whitelegg. 2006), and do not encourage students to develop analytical thinking skills.

From literature review, there were many researchers studying the effect of using contextual approach for teaching in upper secondary education, especially in physics and chemistry classrooms, but rarely found in lower secondary education. Furthermore, students in the lower secondary education could decide to study in the upper secondary education or vocational education after their finishing. Preparing lower secondary school students with science conceptual understanding, analytical thinking, and application of knowledge were important for further education.

Therefore, the purpose of this study was to develop science instructional model emphasizing contextual approach in order to enhance students' conceptual understanding, analytical thinking, and application of knowledge for lower secondary school students on force and motion concepts. The key components of contextual approach and analysis processes of Marzano have been used as a framework for developing the science instructional model which consisted of five steps of learning namely: Focusing, Exploring, Analyzing, Conceptual Developing, and Applying which has been called FEACA Model.

Research Questions

The research questions of this study are as follows:

1. Does the FEACA Model enhance students' conceptual understanding better than the traditional instruction?

2. Does the FEACA Model enhance students' analytical thinking better than the traditional instruction?
3. Does the FEACA Model enhance students' application of knowledge better than the traditional instruction?
4. What are the students' opinions toward the FEACA Model?

Research Objectives

The objectives of the study are summarized as follows:

1. To develop and implement the FEACA Model for lower secondary school students.
2. To make a comparison between conceptual understanding and analytical thinking of students before and after learning through the FEACA Model.
3. To make a comparison between conceptual understanding, analytical thinking, and application of knowledge of students who learn through the FEACA Model and those of students who learn through the traditional instruction.
4. To explore students' opinions toward the FEACA Model after learning through the FEACA Model.

Significance of the Study

This research focused on the development of science instructional model emphasizing contextual approach called FEACA Model which introduces science concept through situation that students facing in real life. The FEACA Model could promote students' conceptual understanding, analytical thinking, and application of knowledge which are important skills for the students in future education. Moreover, learning with contextual approach could help students notice the importance of science and realize that science is in their everyday lives. Therefore, learning through contextual approach could encourage a meaningful learning.

Additionally, the learning activities and instructional materials derived from this research could be used directly by science teachers for teaching scientific concepts about Force and Motion, addressing students' misconception and developing analytical thinking

and application of knowledge. Furthermore, the FEACA Model could be adapted for teaching other concepts in science classroom.

Scope of the Study

Population

The populations of this study were lower secondary school students who were studying in the first semester of 2011 academic year in Uthaithani province, Thailand.

Sample

The samples of this study were separated into three sections as follows:

1. The samples during the development of research instruments

The students participating during the development of research instruments were from Nongchangwittaya School located in Uthaithani province, Thailand. These included the ninth-grade students, for evaluating the analytical thinking test, and the tenth-grade students who already learned "Force and Motion" concept, for evaluating the conceptual understanding test and the application of knowledge test.

2. The samples during a pilot study

The students participating during a pilot study were one classroom of the ninth-grade students who were studying in the first semester of 2011 academic year in Kanchanapisekwithayalai Uthaithani School located in Uthaithani province, Thailand.

3. The samples during implementation

The students participating during implementation were two classrooms of the ninth-grade students which were mixed ability. They were studying in the first semester of 2011 academic year of Nongkhayangwittaya School in Uthaithani province, Thailand. One classroom was the experimental group taught with the FEACA Model whereas the other was the control group taught with the traditional instruction.

Variables of the Study

1. Independent Variables

1.1 Teaching with the FEACA Model

1.2 Teaching with the traditional instruction

2. Dependent Variables

- 2.1 Conceptual understanding.
- 2.2 Analytical thinking.
- 2.3 Application of knowledge.
- 2.4 Students' opinions toward the FEACA Model.

Content

The content for using in this study was developed based on the national science curriculum standard, Strand 4: Force and Motion, for the ninth-grade students. It consisted of six topics as follows: 1) Acceleration, 2) Action and Reaction, 3) Friction, 4) Moment, 5) Buoyant Force, and 6) Motion of Objects.

Definitions of Terms

1. **Contextual Approach** refers to a teaching method using real life contexts and situations which students facing in their everyday live as a starting point for developing understanding of scientific ideas. This method combines the complexity of applying scientific ideas to the everyday experience of the world which could promote students' application ability and encourage students' interest.

2. **The FEACA Model** refers to the science instructional model emphasizing contextual approach developed by researcher. This model presents science teaching steps by using real life context and situation in everyday life run the activities from the first step through the last step which aims to develop students' scientific conceptual understanding, analytical thinking, and application of knowledge. The model composed of five steps as follows:

Step 1: Focusing

The purposes of this step are to catch students' attention and diagnose their prior knowledge by engaging them with real life context. At this step, the everyday life situation will be presented as a starting point in order to recall student's experiences related to that situation and to check their prior knowledge about the concept they will learn in the class. Teacher encourages students to think by asking a question related to that situation. Students then answer the question and compare similarities and differences of their own

answers with their friends' answers as well as organize those answers into meaningful categories. Students communicate what they get by sharing with their peers. At the end of the step the answers will not be verified right or wrong, but they will be problems for investigating in the next step.

Step 2: Exploring

The purpose of this step is to give the students opportunity to investigate through hands-on and mind-on exploration which built upon the everyday life situation from the first step. At this step, the students will be separated into small groups and do experiment or activities for exploring the answer of the questions developed in first step. Teacher acts as a facilitator helping students if they meet any problems and checks whether the students obtain all necessary information for using in the next step.

Step 3: Analyzing

The purpose of this step is to give the students an opportunity to analyze data and construct knowledge on their own under the facilitating of a teacher. At this step, the students need to find the relationship of information from their observation by answering the questions and summarizing what they get for constructing their own knowledge. The students communicate their understanding by sharing with the whole class.

Step 4: Conceptual Developing

The purpose of this step is to construct correct conceptual understanding about that topic under the facilitating of a teacher. At this step, the students discuss the conclusion from the previous step and re-shape their understanding under facilitating of a teacher. Furthermore, students study more about the topic from document and relate the concepts they have learned with the situation in the first step. The roles of the teacher are to help the students constructing scientific conceptual understanding and correct all misconception.

Step 5: Applying

The purpose of this step is to apply scientific concept to new contexts. At this step, the students in each group apply conceptual understanding they have learned in the class to new contexts or real life situations and share with the whole class. The students also need to give the reason to explain the reasonableness of the information. The students

in other groups evaluate validity of that application and identify any errors in reasoning that has been presented.

3. Conceptual Understanding refers to understanding of students on the concepts of “Force and Motion” (Strand 4), standard Sc 4.1 and Sc. 4.2. It consists of six topics as follows: 1) Acceleration, 2) Action and Reaction, 3) Friction, 4) Moment, 5) Buoyant Force, and 6) Motion of Objects. Students’ Conceptual Understanding is measured by the conceptual understanding test which is 30 items of multiple choice questions. Some questions are adapted from the Force and Motion Conceptual Evaluation (Thornton; & Sokoloff. 1998: 338-352) and the rest are developed by the researcher.

4. Analytical Thinking refers to abilities in breaking down the information into its component parts, examining knowledge in fine detail, discovering and organizing the relationships of the parts and creating new conclusions. In this work, analytical thinking composed of matching, classifying, error analysis, generalizing, and specifying based on Marzano’s analysis processes (2001).

4.1 Matching refers to ability in identifying similarities and differences between knowledge components or situation.

4.2 Classifying refers to ability in organizing knowledge components or situation into meaningful categories.

4.3 Error Analysis refers to ability in explaining the reasonableness of knowledge or situation, judging the arguments, and identifying the illusion in reasoning.

4.4 Generalizing refers to ability in finding relationship and constructing new generalization from information that is already known.

4.5 Specifying refers to ability in generating new application of a known generalization and making predictions based on that application.

Students’ Analytical Thinking is measured by the Analytical Thinking Test which is 25 items of multiple choice questions developed by the researcher.

5. Application of Knowledge refers to ability to utilize the knowledge learned in science classroom for other situation. Students’ application of knowledge is measured by Application of Knowledge Test which is 12 items of open-ended questions developed by the researcher.

6. **Students' Opinions toward the FEACA Model** refers to feeling or thoughts of students toward the FEACA Model as well as their impression and suggestions for the model. Students' Opinions toward the FEACA Model is measured by the Opinions Questionnaires toward the FEACA Model which is 20 items of five point rating Likert scale questionnaire and an open-ended question asking about students' opinions toward the FEACA Model developed by the researcher.

7. **The Traditional Instruction** refers to the regular teaching method of the science teacher who teaches science in the control group.

Conceptual Framework of the Study

The conceptual framework of this study was developed as a consequence of the literature review based on contextual approach. The learning unit was developed based on the FEACA Model for enhancing students' conceptual understanding on Force and Motion, analytical thinking, and application of knowledge. The conceptual framework is shown in FIGURE 1.

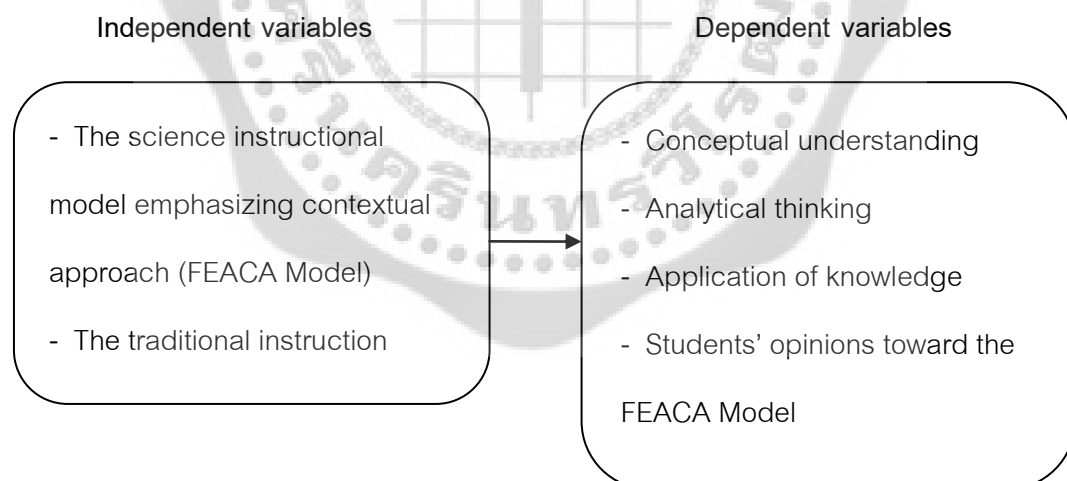
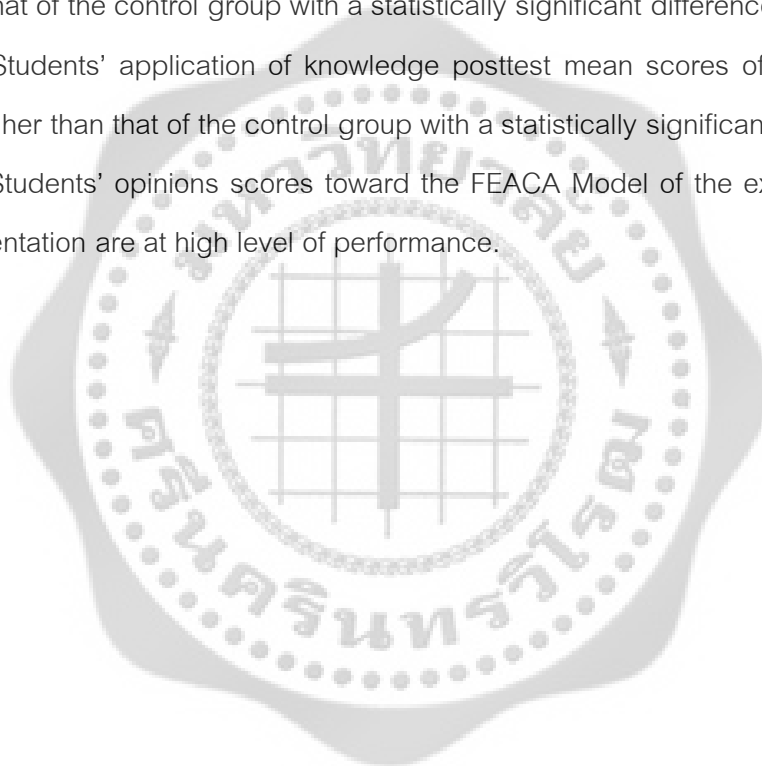


FIGURE 1 CONCEPTUAL FRAMEWORK OF THE STUDY

Research Hypotheses

1. Students' conceptual understanding posttest mean scores of the experimental group are higher than pretest mean scores with a statistically significant difference.
2. Students' conceptual understanding posttest mean scores of the experimental group are higher than that of the control group with a statistically significant difference.
3. Students' analytical thinking posttest mean scores of the experimental group are higher than pretest mean scores with a statistically significant difference.
4. Students' analytical thinking posttest mean scores of the experimental group are higher than that of the control group with a statistically significant difference.
5. Students' application of knowledge posttest mean scores of the experimental group are higher than that of the control group with a statistically significant difference.
6. Students' opinions scores toward the FEACA Model of the experimental group after implementation are at high level of performance.



CHAPTER 2

REVIEW OF THE LITERATURE

This chapter presents a review of the available literature for developing theoretical and methodological frameworks in this study. The main areas are as follows:

1. Constructivism
2. Situated Cognition
3. Contextual Approach
4. Conceptual Understanding
5. Analytical Thinking
6. Application of Knowledge
7. The FEACA Model Development

Constructivism

The view that knowledge cannot be transmitted but must be constructed by the mental activity of learners, which refers to constructivism, underpins contemporary perspective on science education (Driver; & Oldham. 1986: 5). This part presents more details of constructivism learning theory.

1. Definitions of Constructivism

Constructivism is a learning theory that involves in explaining how the learners construct their own knowledge (Eggen; & Kauchak. 2001) and based on the work of several philosophers and educators such as John Dewey, Lev Vygotsky, Jean Piaget, and Jerome Bruner. This theory places more emphasis on the learners to construct their own understanding and new learning exists in the context of prior understanding (Eggen; & Kauchak. 2001). Learning is not knowledge transferring, but it is a construction of knowledge by the learners. Students can actively and purposefully construct their own knowledge to make sense of scientific phenomena by using their existing knowledge and the new information. In this way, learning is seen as the modification of the existing knowledge (Bell. 1991).

2. Characteristics of Constructivism

Simpson (2001) explained four characteristics of constructivism that influence learning which consist of:

1. Learners construct their own understanding: students interpret stimuli on the basis of what they already know and construct understanding that make sense to them.
2. New learning depends on current understanding: new learning is interpreted in the immediate context of current understanding. It is first learned as isolated information which is connected to existing knowledge later.
3. Learning is facilitated by social interaction: social interaction provides opportunities for students to articulate their own ideas, compare them to others, and change them if necessary.
4. Situated learning within authentic task: learning can occur by involving learners in completion of authentic tasks which are anchored within a context meaningful to them. Authentic tasks can simulate real world problematic situations and provide students with practice in thinking in realistic, life-like situation. It also increases students' motivation to learn.

Hein (1991) described the characteristics that influence learning according to constructivism learning theory as follows:

1. Learning is an active process which student uses sensory input and constructs meaning of it. The more traditional formulation of this idea involves the term of the active learner that the learner needs to do something. Learning is not the passive acceptance of knowledge which exists out there, but it involves the learners engaging with the world.
2. People learn to learn as they learn: learning consists of both constructing meaning and constructing systems of meaning.
3. The crucial action of constructing meaning is mental which happens in the mind. Hands-on experience may be necessary for learning of children, but it is insufficient. Providing activities which engage the mind as well as the hands would be more effective.

4. Learning involves language: On the empirical level, researchers have noted that people talk to themselves as they learn. On a more general level, there is a collection of arguments that language and learning are inextricably intertwined.

5. Learning is a social activity: learning is intimately associated with other people. If teachers recognize this principle, students are more likely to be successful in learning.

6. Learning is contextual: students do not learn facts and theories separate from the rest of their lives, but they learn in relationship to what else they know, what they believe. This is actually a result of the idea that learning is active and social cannot disconnect learning from lives.

7. One needs knowledge to learn: it is not possible to assimilate new knowledge without having some structure developed from previous knowledge to build on. The more students know, the more they can learn. Therefore any effort to teach must be connected to the state of the learners and provide a path into the subject for the learner based on learner's previous knowledge.

8. It takes time to learn: learning is not instantaneous. Significant learning needs to revisit ideas, ponder them try them out, play with them and use them.

9. Motivation is a key component in learning which helps learning, and also essential for learning.

Brooks and Brooks (1993) summarized a large segment of the literatures on descriptions of constructivist teachers. They considered of a constructivist teacher as someone who will:

1. Encourage and accept student autonomy and initiative.
2. Use a wide variety of materials, including raw data, primary sources, and interactive materials and encourage students to use them.
3. Inquire about students' understandings of concepts before sharing their own understanding of those concepts.
4. Encourage students to engage in dialogue with the teacher and with one another.

5. Encourage students' inquiry by asking thoughtful, open-ended questions, encourage students to ask questions to each other, and seek elaboration of students' initial responses.

6. Engage students in experiences that show contradictions to initial understandings and then encourage discussion.

7. Provide time for students to construct relationships and create metaphors.

8. Assess students' understanding through application and performance of open-structured tasks.

3. Implication of Constructivism

The four general characteristics of constructivism that Simpson expressed can be applied to the constructivist classroom. The first thing is to bring out students' prior knowledge and understanding especially to diagnose existing misconceptions. The second step is the intervention by teachers to mediate the learning of students with purposive activity. The third is to establish social situations in which students can make sense of experiments in terms of what is already known. The last one is a diversity of opportunities for students to represent their knowledge in a variety of assessment techniques that should be based on authentic learning assignments instead of separate test situations, and should focus on the process of learning as much as on the final outcome (Simpson, 2001).

Mayer (1992) suggested that learners construct new knowledge by selecting specific aspects of incoming information to consider, organizing the selected information in various ways, and relating them to form new conceptual knowledge. The process of selection, organization and integration of information are automatic, but they become more effective as children learn to monitor and regulate their own learning and as they build up a bank of knowledge and experiences.

Students' prior knowledge is very important as the basis for constructing new knowledge. Students come to class with experiences from all sorts of events, places, and people in their lives. Sewell (2002) described four different ways students deal with new information that differs from their previous understanding or knowledge which compose of 1) delete the preexisting knowledge; 2) modify the preexisting knowledge so that it fits the new

information; 3) modify the new information so that it fits the old knowledge; and 4) reject the new information.

Another approach related to science education is Saunders' four step approach. This approach consists of 1) hand-on investigative labs; 2) active cognitive involvement; 3) work in small groups; and 4) higher level assessment. The approach suggests that teacher cannot convey knowledge through lectures. The learner must construct it in their own mind. The teacher cannot modify the student's cognitive structure, only student can. However, the teacher can assist students with cognitive restructuring by placing them in challenging situations (Saunders. 1992)

In summary, constructivism emphasizes how students learn and construct their own knowledge. It indicates that knowledge appears from active engagement with familiar problems or environments, not from passively taking simple information by the students. In addition, construction of knowledge is also influenced by students' existing knowledge, experiences, abilities, beliefs, and attitudes. Therefore, teachers' role is to create situation and learning experience that engage and support students to explore, explain, evaluate, communicate, and apply these experiences.

Situated Cognition

While situated cognition has gained recognition in the field of educational psychology in the late twentieth century (Brown; Collins; & Duguid. 1989), it draws a variety of perspectives. Recent perspectives have focused on the concept of identity formation (Lave; & Wenger. 1991) as people negotiate meaning through interactions within communities of practice (Clancey. 1993). This part presents more details of situated cognition.

1. Definitions of Situated Cognition

Brown, Collins, and Duguid. (1989) defined "situated cognition" as the relationship between existing knowledge of the individual and the situation in which it is acquired. It is organized from three themes in theories of cognition and learning as follows:

1. Cognition is situated in certain physical and social contexts. How a person learns a particular set of knowledge and skills depend on the situation in which he or she

learns them. It is the fundamental part of what is learned and how that person transfers that knowledge.

2. Cognition is social in nature. Interactions with other people are the major factors of what is learned and how that learning takes place. Many successful school programs have viewed learning as cooperative, where groups rather than individuals and products are important and knowledge is distributed among all class members (Rogoff. 1991); and

3. Cognition is distributed over the individual, other people, symbolic and physical environment.

Anderson; Reder; & Simon (1996: 5) argued four positions that can be attributed to situated cognition theory: 1) Action is grounded in the concrete situation in which it occurs; 2) Knowledge is not transferred between tasks. Transfer of learning from one situation to another is not consistently predictable, and the ability to do so is a skill that must be learned; 3) Training by abstraction is little used; and 4) Instruction must be done in complex social environments. They focused on knowledge transferring that can occur only when the individual has developed an abstract representational knowledge, which can be applied to multiple situations. In contrast, from the situated perspective, participation in activity systems is an important key because the transfer of knowledge is possible when students are given the knowledge in one situation which can then occur in similar but unfamiliar situations in the school, the community or the workplace contexts (Greeno. 1997).

Situated learning emphasizes the idea that much of what is learned is specific to the situation in which it is learned. Situated learning greatly emphasizes the relationship between what is learned in classroom and what is needed outside the classroom (Greeno. 1997). Situated cognition aims at letting the peers learn knowledge and skills in contexts where they are applicable (Brown; Collins; & Duguid. 1989). Some advantages of the situated cognition approach are: 1) By linking together specific contexts and the knowledge to be learned, peers learn conditions under which knowledge should be applied; 2) Situations foster creative thinking. Peers often learn how the knowledge has been applied in new situations; 3) Situation leads to the acquired knowledge being more practical in nature.

In summary, knowledge is situated, being in part a product of the activity, context, and culture in which it is developed and used (Brown; Collins; & Duguid. 1989: 32).

2. Implication of Situated Cognition

Situated cognition implies that students should acquire knowledge and skills in meaningful contexts. Brown, Collins, and Duguid (1989) have proposed a model for transferring classroom into meaningful contexts or environments for learning, which is an authentic instruction. Authentic activities are to be differentiated from school activities which do not share contextual features with related out-of-school tasks and often fail to support transference to an out-of-school setting. Teachers must do the following: make the process visible to the student; situate abstract tasks in authentic contexts so that the students understand the relevance of the work; vary the diversity of situations; and articulate the common aspects so that the students can transfer what they have learned.

Collins, Brown, and Newman (1987) explained the model of instruction for enhancing student intellectual processes which emphasize cognitive rather than physical skills. It contains five components: 1) Modeling - involves an expert's carrying out of the task so that student can observe and build a conceptual model of the processes that are required to accomplish the task; 2) Coaching - consists of observing students while they are carrying out a task and offering hints, feedback, modeling, reminders, etc; 3) Articulation - includes any methods of getting students to articulate their knowledge, reasoning, or problem-solving processes; 4) Reflection – enables students to compare their own problem-solving processes with those of an expert or another student; 5) Exploration - involves pushing students into a mode of problem-solving on their own interest. Forcing them to explore is critical if they are to learn how to frame questions or problems that are interesting and can be solved by themselves.

Situated learning uses the same components as the cognitive apprenticeship to enhance students' cognitive abilities. On the process of the modeling, the instructor shows students how to complete tasks or solve problems while verbalizing the activity. However, in contrast to typical school instruction, the activity is modeled within the context of real world situations. For example, if a lesson deals with the concept of recycling, activities for students should be designed related to the real problems such as development of a

community recycling program. As an introduction to this lesson, the instructors are expected to work through a similar problem with the class to model the thinking processes to be used. By modeling the desired intellectual processes, students will discover that there are many ways to solve problems, which experts make mistakes, and seemingly simple problems are very complex in the real world (Hill; & Smith. 1998).

In conclusion, situated cognition describes learning and thinking which are always situated. It includes the context in which learning takes place and the activities that occur, not just a content that has a direct and significant influence on what has been learned. Situated cognition implies that students should learn knowledge and skills in meaningful contexts, situated abstract tasks in authentic contexts, so that they can apply what they learn to the diverse situations such as work, home, and communities. In order to enhance students' retention and application, the students need opportunities to learn in the context of everyday life as much as possible. In addition, learning science in schools should better be contextualized or situated in meaningful settings to make what student learns in school more accessible and valuable in other contexts.

Constructivist and situated cognition views illustrate that learning cannot be separated from the context in which knowledge occurs and can be applicable. Students should acquire knowledge and skills through meaningful contexts which they are familiar with. Therefore, meaningful contexts are able to define the various science concepts as teaching and learning occurs. Constructivism and situated cognition theoretical views of learning bring about the ideas of contextual approach.

Contextual Approach

Over the last two decades many research studies have explored the effect of context and its importance in psychological and educational research (Holman; & Pilling. 2004; Whitelegg; & Edwards. 2001; Tippins. 2003). A contextual approach for teaching science involves teaching through real life contexts by combining the complexity of applying science ideas to the everyday experience of the world which aims to develop students' application ability, and is intended to encourage the student active in the learning process (Holman; & Pilling. 2004).

The impact of contextual approach has been significant and it is now widespread used. Countries in which materials and courses with a contextual approach are in use include the USA, England, Australia, the Netherlands, Belgium, Brazil, Hong Kong, New Zealand, Russia, Scotland, South Africa and Swaziland (Bennett; Lubben; & Hogarth. 2006).

1. Definitions of Contextual Approach

The ideas of a contextual approach have been defined by different countries and different researchers and educators in several meanings. Whitelegg and Parry (1999: 68) suggested that context-based learning can have several meanings. At its broadest, it means the social and cultural environment in which the student, teacher and institution are situated. For a narrower view of context, it might focus on an application of a science theory for the purposes of illumination and reinforcement.

The Office of Vocational and Adult Education defined the term of Contextual Teaching and Learning (CTL) as teaching that enables learning in which students employ their academic understandings and abilities in a variety of in-and out-of-school contexts to solve simulated or real-world problems, both alone and with others. In addition, Glynn and Koballa (2005: 75) identified the context-based physics as integrating physics concepts and process skills in real-world contexts.

Howey (1999:19) described that contextual teaching and learning is a conception of teaching and learning that helps teachers relate subject matter content to real world situation and motivates students to make connections between knowledge and its applications to their lives as family members, citizens, students, and workers. Bennett, Lubben, and Hogarth (2006: 348) explained that context-based approach are approaches accepted in science teaching where contexts and applications of science are used as the starting point for the development of scientific ideas. This contrasts with the more traditional approaches that cover scientific ideas first, before looking at applications.

Souders and Prescott (1999: 38) stated that the contextual learning is based on the premise that learning is most effective when information is presented within a framework that familiar to the student. Lubben, Campbell, and Dlamini (1996) defined that contextualization is linking science to student everyday life and experiences which focused on events

common enough for all student to be able to relate to, such as a car failing to start, lightning strikes and dispute over the quality of maize meal. So teaching contextually involves using the context rather than content or concepts to drive the teaching (Whitelegg; & Parry. 1999).

The concept of contextual teaching and learning frequently draws the idea that science, mathematics, and other kinds of learning can more powerfully engage students when they are connected to workplace contexts. From this perspective, the emphasis is on making science more relevant and useful to the lives of children through applications of concepts and real-life examples across diverse workplace settings (Huntley; Jacobs; & Weinberg. 1999).

Similarly Finkelstein (2001) reported that students can build an understanding of content in a context, and context mediates student understanding of content as a contextual constructivist model of learning (see FIGURE 2).

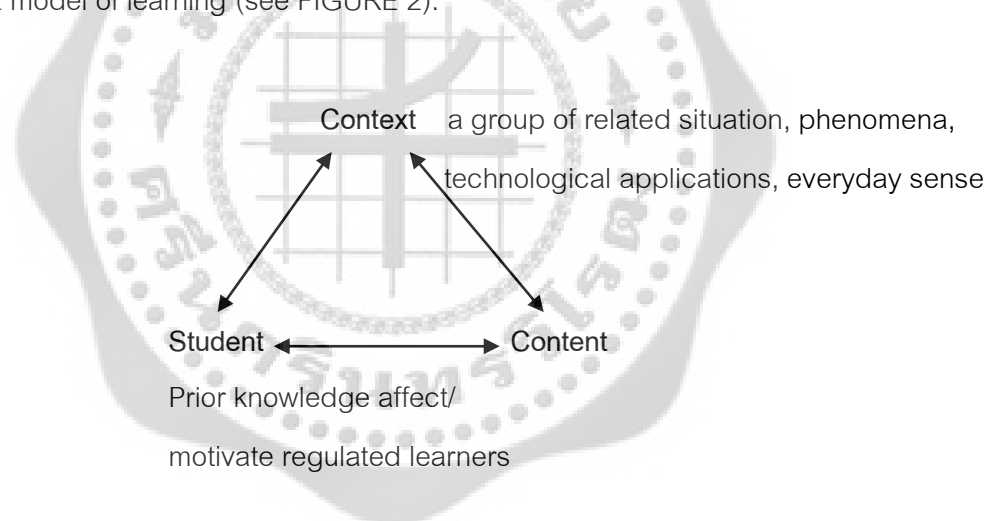


FIGURE 2 CONTEXTUAL CONSTRUCTIVIST MODEL OF LEARNING

Source: Finkelstein. (2001). Context in the Context of Physics and Learning. (online)

From above, a contextual approach is describe in many terms such as prior knowledge, motivation, regulation learners, and meaningful learning which persuade that a contextual approach is based on a constructivist learning theory. A contextual approach

further describes that learning occurs in multiple contexts and teaching needs to be supported in the various life contexts of students.

2. Meaning of Context

Several researchers have described the term of context in different meanings, depended on how it is used. Context can mean the social and physical setting in where the learning takes place such as a classroom, a laboratory, a computer lab, or a worksite (CORD. 1999). Whitelegg and Parry (1999) described context as a model used to provide a more concrete illustration of a concept, for example, Ball and Track Model is a context for learning about laws of motion. Gunstone (1997) proposed that learning occurs in the context of previous experiences and out-of-school activities, which means context can be the prior learning that students bring to the lesson. He also described context as an illustration or application of a pure science concept, for example, teaching about inertia following by a discussion of the need of seat belts.

A group of related situations, phenomena, technological applications and social issues are used as context of learning. Besides, a real life situation, real world, everyday sense, and surrounding are the potential context that can help students make sense of scientific phenomena through their prior knowledge (Beasley. 2002).

Therefore, meaning of context can refer to the social and physical setting, model, previous experience, the technological applications, and everyday familiar topic. These entire contexts help student realizes the value of science in the ways of explanations, applications, and finding out the solutions and making connection of science explanation with real life experiences.

3. Contextual teaching and learning strategies

In this part, several strategies using contextual approach for teaching and learning science will be presented to show effectiveness of contextual approach in science classroom.

One of teaching strategies for contextual teaching and learning is suggested by Center for Occupational Research and Development (CORD). CORD described contextual teaching strategies as the REACT strategy. This strategy focuses on teaching and learning in context that will be structured to encourage five essential forms of learning: Relating,

Experiencing, Applying, Cooperating, and Transferring. Relating is the way of learning in the context of one's life experiences or preexisting knowledge. It is the most powerful contextual teaching strategy and also the heart of constructivism. Experiencing is learning by doing through exploration, discovery, and invention. If students do not have relevant experience or prior knowledge, teachers can overcome this obstacle and help the students construct new knowledge with hands-on experiences that take place inside the classroom. Applying is learning by putting the concepts to use in real life activities. It helps student to see the value of leaning. Cooperating is learning in the context of sharing, responding, and communicating with other learners. It is a primary instructional strategy in contextual teaching. Transferring is the using of knowledge in a new context or novel situation that has not been covered in class (CORD. 1999). This strategic teaching model could be concluded as in FIGURE 3.

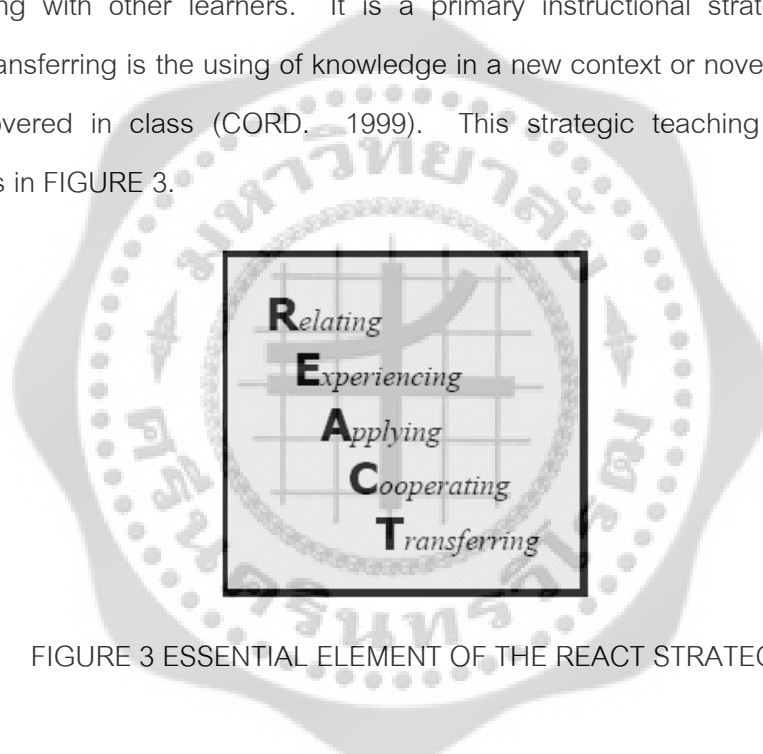


FIGURE 3 ESSENTIAL ELEMENT OF THE REACT STRATEGY

Source: Center for Occupational Research and Development (CORD). (1999).

Teaching Science Contextually: The Cornerstone of Tech Prep. p. 3.

Kortland (2007) explained four subsequent phases for the teaching – learning of specific context: Phase 1 - Orienting and evoking a global interest and motive for a study of the topic at hand; Phase 2 - Narrowing down this global motive to a content-specifically needed for more knowledge; Phase 3 - Extending the students' knowledge, in the view of global motive and the more specifically formulated knowledge need; Phase 4: Applying this knowledge in situations the knowledge was extended for.

Hipkins, Joyce, and Bull (2000: online) developed the context based cycle of learning science as can be seen in FIGURE 4:

<u>Step One</u> Begin with a familiar context - explore its features in a manner that engages the children/ consolidates familiarity (stories, direct exploration etc).	<u>Step Two</u> Identify relevant patterns within the context, drawing attention to salient features and building vocabulary that will be needed for the intended conceptual focus.
<u>Step Four</u> Where appropriate, continue on to develop a more advanced conceptual understanding (but often this stage will be skipped with young children). Return to the context to check new understandings and/or apply new ideas to other contexts.	<u>Step Three</u> Introduce the provisional concepts (the 'foothills for learning') that make sense of these patterns within a theoretical science framework. Return to the context again (if not proceeding to step four).

FIGURE 4 MODEL FOR CYCLES OF LEARNING THAT INTEGRATE CONTEXTUAL AND CONCEPTUAL KNOWLEDGE

Source: Hipkins; Joyce; & Bull. (2000). *Modeling the Complexity of Concept/ Context Interactions in Science Learning*. (online)

Kruatong (2007: 116-117) developed the four steps in the learning sequence (FIGURE 5) for a lesson plan that adopts a contextual approach. Step 1: Start with a context – this means the context is introduced before the content is taught to focus students' attention on the learning situation. Step 2: Investigate through the context-based problem – students are encouraged to answer questions or solve problems from the first step by experiment, demonstration, reading assignments. Step 3: Identify concepts through the context – students are encouraged to report the results of their investigations to the class, discuss, and make summaries of the concepts. Step 4: Apply concepts to new contexts –

students are presented with new contexts which correspond to the concept they have learned.

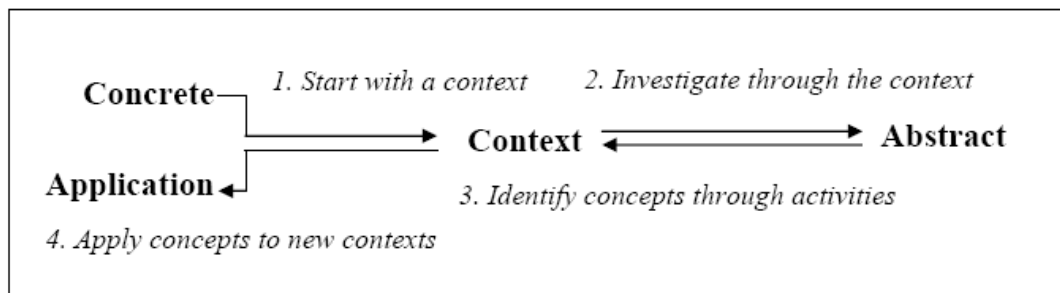


FIGURE 5 FLOWCHART OF THE LEARNING SEQUENCE WITH A CONTEXTUAL APPROACH

Source: Kruatong. (2007). *The Development of High School Students Understanding and Application of Heat and Thermodynamics Concepts through a Contextual Approach*. p.115.

The SMILE (Science and Math Investigative Learning Experiences) program at Oregon State University has developed an instructional framework called REAL (Realistic Experiences Active Learning). This framework was developed for real-world, problem-based studies that can be used in a variety of settings. The REAL framework is based on the following structural guidelines: 1) Background knowledge – students should start by acquiring the vocabulary that relates to the chosen problem, and learning the scientific concepts and principles underlying the problem; 2) Problem exposition – the problems should be the current social interest that can be collected, analyzed, and presented in a realistic context; 3) Data collection – students should have an opportunity to observe how scientists collect appropriate data and should collect data themselves; 4) Data analysis – students should be guided directly by professional mentors in analyzing data relevant to the problem; 5) Data synthesis – students should work in teams under the guidance of the professional mentor to develop solutions; 6) Solution presentation – students should prepare and deliver a presentation explaining their proposed solution based on their scientific

findings; 7) Career information – students should learn about career opportunities from the scientists and other mentors (Bloomfield; Dahl; & Pasch. 1996: 33). This framework composes of the same step as in scientific process.

Beasley (2002: online) showed the major steps in the learning sequence flowchart (FIGURE 6) for context-based design beginning with the context being revealed through to the finalization of learning as evidenced in student presentation and reports.

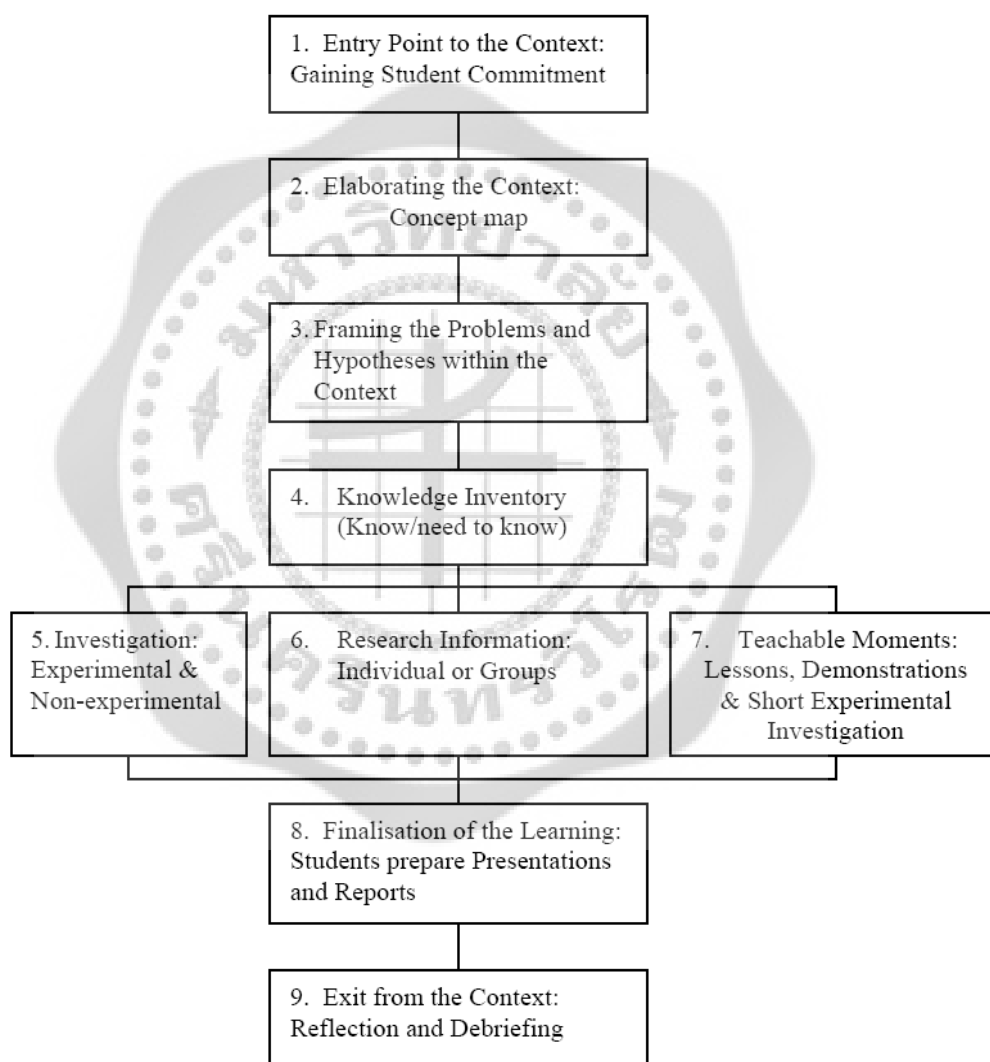


FIGURE 6 CONTEXT-BASED UNIT OF WORK FLOWCHART

Source: Beasley; & Warren. (2002). From Context to Concept: The Implications for the Teaching of Chemistry. (online)

In conclusion, several research studies attempt to verify and confirm effectiveness of contextual teaching and learning strategies in the classroom. From all teaching and learning strategies above, the contextual approach could be analyzed into five essential features as shown in TABLE 1.

The results of analyzing, contextual teaching and learning strategies could be summarized and synthesized into five important features consisting of:

1. Students will be engaged with context or real life experience to catch their attention
2. Students have the opportunity to do hands-on experience for exploring and collecting data.
3. Students develop their conceptual understandings by themselves under the facilitating of a teacher.
4. Students share and communicate their ideas with other students.
5. Students apply their knowledge they have learned in the class to other contexts.



TABLE 1 ANALYZING CONTEXTUAL TEACHING AND LEARNING STRATEGIES

Model	REACT strategy of CORD (1999)	REAL of SMILE (1996)	Basley's Model (2002)	Kruatong 's Model (2007)	Hipkins, Joyce & Bull's Model (2000)	Kortland 's Model (2007)	Frequency	The Important Features of Contextual Approach
- Background knowledge		✓					1	
- Vocabulary								
- Relating, Start with context								
- Questions, Problems	✓	✓	✓	✓	✓	✓	6	Students will be engaged with context or real life experience to catch their attention.
- Focus on students' attention								
- Experiencing, Explore, Discovery, and Invention								Students have the opportunity to do hands- on experience for exploring and collecting data.
- Hands-on experience, Data Collection	✓	✓	✓	✓	✓		5	

TABLE 1 (continued)

Model	REACT strategy of CORD (1999)	REAL of SMILE (1996)	Basley's Model (2002)	Kruatong' s Model (2007)	Hipkins, Joyce & Bull' s Model (2000)	Kortland 's Model (2007)	Frequency	The Important Features of Contextual Approach
- Data Analysis		✓					1	
- Data Synthesis, Identify Concept, Developing Conceptual Understanding		✓		✓	✓	✓	4	Students develop their own conceptual understandings under the facilitating of a teacher.
- Applying: Putting the concepts to use in real life activities	✓						1	
- Cooperating, Sharing, Responding, Communicating, Discussion, Presentation	✓	✓	✓	✓			4	Students share and communicate their idea with other students.

TABLE 1 (continued)

Model	REACT strategy of CORD (1999)	REAL of SMILE (1996)	Basley's Model (2002)	Kruatong' s Model (2007)	Hipkins, Joyce & Bull's Model (2000)	Kortland 's Model (2007)	Frequency	The Important Features of Contextual Approach
- Transferring: Using of knowledge in a new context or novel situation	✓	✓		✓	✓	✓	5	Students apply their knowledge they have learned in the class to other contexts.
- Reflecting and Debriefing			✓				1	

4. Research related to Contextual Approach

Whitelegg and Edwards (2001) investigated the effects of learning physics using an everyday life approach and examined the transfer of phenomenon physics concept across the different real-life contexts, e.g. Jazz and Pop Unit to study sound waves and Physics for Sport Unit to study forces and Newton's law. They found that students felt that these approaches made the physics more understandable and interesting. Students were able to see how physics concepts relate to their interest outside.

Bennett and Lubben (2006) developed context-based courses for upper high school students called Salters Advanced Chemistry. The results of this study indicated that students responded positively to the context-based approach adopted in Salters Advanced Chemistry, and developed levels of understanding of chemical ideas comparable to those taking more conventional courses.

Gutwill-Wise (2001) worked with university students following introductory chemistry courses by comparing students who had followed the context-based approach of *ChemConnections* with matched groups of students who had followed a traditional approach to chemistry. The study found that in both institutions students who followed the context-based approach emerged with a better understanding of chemistry than their peers who followed a traditional approach.

Whitelegg and Parry (1999) developed the Supported Learning in Physics Project (SLIPP) which is an Open University-led Curriculum development initiative for post-16 students in physics. This project used specially written texts to provide physics learning for students based on real-life contexts and had the potential to help students to transfer their understanding between contexts and also reinforced their learning by enabling students to revisit the same physics concepts in a variety of real-life contexts.

Song and Black (1992) examined the effects of task contexts on students' performances in science process skills. The results showed that students' performance in interpretation skill in everyday contexts was better than in scientific contexts. It was argued that the students' interpretation skill may be used mainly in their everyday life situations.

Lubben, Campbell and Dlamini (1996) conducted research with Swazi secondary students to contextualize lessons on circuit electricity, air, and respiratory. They found that

contextualized lessons influenced students' motivation, interest, participation, and concept development. Similarly, Rennie and Parker (1996) investigated the effects of the present contexts in physics problems by comparing the performance of physics students on two sets of match problems. They found that students performed and understood better on the tasks with context because problems with context are generally perceived to be more interesting. So providing the context is relevant and not contrived for students.

Kruatong (2007) used contextual approach to develop high school students' understanding and application of heat and thermodynamics concepts. The results showed that understanding and application of students were enhanced through the presentation of heat and thermodynamics concept.

In conclusion, various researches illustrated the effectiveness of applying contextual in science classroom. This approach motivated students' interesting in learning science and increase attitude toward science. Furthermore, understanding of science concepts, science process skills, and application of knowledge were improved via this teaching and learning approach. Therefore, this approach should be one of the good teaching and learning methods that influences students' learning.

Analytical Thinking

Considered as a fundamental thinking of others, analytical thinking is the essential thinking for learning and living of human. To achieve the desired result, problems facing in everyday life must be solved through analytical thinking correctly and efficiently. This part presents more details of analytical thinking.

1. The Definitions of Analytical Thinking

Several educators and researchers have studied and defined the meaning of analytical thinking in many ways. Spencer and Spencer (2008) explained that analytical thinking involves understanding a situation by breaking it apart into smaller pieces, or tracing the implications of a situation in a step-by-step casual way. It includes organizing the parts of a problem or situation in a systematic way; making systematic comparisons of different features or aspects; setting priorities on a rational basis; and identifying time sequences, causal relationships, or If -Then relationships.

Amer (2005) characterized analytical thinking as powerful thinking tool for understanding the parts of a situation. It can be defined as an ability to examine and break down facts and thoughts into their strengths and weaknesses: and develop a capacity to think in a thoughtful, discerning way, solve problems, analyze data, recall and use information.

A famous educator, Benjamin Bloom, has developed taxonomy of educational objectives called Bloom's Taxonomy. Bloom classified six levels of important intellectual behavior in learning consisting of knowledge, comprehension, application, analysis, synthesis, and evaluation. For analysis, it emphasizes the breakdown of the information into its component parts, the detection of the relationships of the parts, and the way they are organized.

Marzano (2001: 10) also developed the six levels of the New Taxonomy consisting of retrieval, comprehension, analysis, knowledge utilization, metacognition, and self-system thinking. For analysis, it involves examining knowledge in fine detail and generating new conclusions. By engaging in these processes, learners can use what they are learning to create new insights and invent ways of using what they have learned in new situations.

Therefore, analytical thinking can be defined as various aspects concerning a thinking process used to break down the information into its component parts, examine knowledge in fine detail, discover and organize the relationships between the parts, and generate new conclusions. These are necessary skills for students to use both in the class and in their daily life.

2. Levels of Analytical Thinking

In Bloom's Taxonomy, analysis can be divided into three levels consisting of Analysis of Elements, Analysis of Relationships, and Analysis of Organizational Principles. At the first level, students are expected to break down the material into its component parts, and identify or classify the element of the communication. At the second level students are required to explicitly make the relationships between the elements, and determine their connections and interactions. The third level involves recognition of the organizational principles, arrangement, and structure, which hold together the communication as a whole (Bloom. 1956: 145).

Marzano (2001: 10) explained that the analysis processes involve examining knowledge in fine detail and generating new conclusions. By engaging in these processes, learners can use what they are learning to create new insights and invent ways of using what they have learned in new situations. There are five cognitive processes in analysis consisting of matching, classifying, error analysis, generalizing, and specifying.

1. Matching

Matching processes deal with the identification of similarities and differences between knowledge components. This is a basis of other types of analysis processes. The process of matching may be simple or complex, depending on the demands of the task.

The strategies of developing matching process that foster a high degree of analytic thinking include the following basic steps:

- 1.1 Choosing the items to be analyzed
- 1.2 Identifying the attributes or characteristics to be analyzed
- 1.3 Determining how the attributes and characteristics are alike and different
- 1.4 Stating the similarities and differences as precisely as possible

2. Classifying

Classification refers to organizing knowledge into meaningful categories. Similar to matching, it is basic to human thought. Although learners use the process of classification naturally, this process can be very challenging. Specific steps in the classification involve the following components:

- 2.1 Selecting the item to be classified.
- 2.2 Identifying the important characteristics of that item.
- 2.3 Naming a superordinate category to which the item belongs, and explaining why it belongs in that category.
- 2.4 Identifying any subordinate categories for the item and explaining how they are related.

As these steps illustrated, a student must be able to identify knowledge that is superordinate to it and knowledge that is subordinate to it. This goes beyond simply organizing knowledge into similar categories. Therefore, classification in the New Taxonomy forces the learner to organize knowledge into hierarchic structures.

3. Error Analysis

The analytic process of error analysis addresses the logic or reasonableness of knowledge. The existence of this cognitive function implies that information must be considered reasonable for an individual to accept validity of it. People naturally and quickly make judgments regarding how reasonable knowledge is. However, error analysis as an analytic skill within the New Taxonomy involves (a) consciously judging the validity of the knowledge based on explicit criteria and (b) identifying any errors in reasoning that have been presented.

4. Generalizing

Generalizing is the process of constructing new generalizations from information that is already known which can be conducted both deductively and inductively. This is a set of steps students might follow when generalizing:

- 4.1 Focusing on specific pieces of information or observations.
- 4.2 Finding patterns or connections in the information that has been identified.
- 4.3 Creating a general statement that explains the patterns or connections that have been observed.
- 4.4 Collecting more observations or examples to see if the works have generalized in all situations and change it as necessary.

5. Specifying

Specifying is the counterpart to generalizing. It is the process of generating new applications of a known generalization or principle. Where the analytic process of generalizing is more inductive, the analytic process of specifying tends to be more deductive in nature. This is a process that might be followed during specification:

- 5.1 Identifying the specific situation that is being considered or studied.
- 5.2 Choosing the generalizations or principles that applied to the specific situation.
- 5.3 Ensuring that the specific situation matches the conditions that have to be in place for those generalizations or principles to apply.

5.4 Identifying what is known about the specific situation, that is, what conclusions can be drawn or what predictions can be made.

In conclusion, analytical thinking in Bloom Taxonomy and Marzano's Taxonomy can be combined as shown in TABLE 2.

TABLE 2 THE COMPARISONS OF ANALYTICAL THINKING IN BLOOM'S TAXONOMY AND MARZANO'S TAXONOMY

Bloom's Taxonomy	Marzano's Taxonomy
Analysis of elements	Matching
	Classifying
Analysis of relationships	Error analysis
Analysis of organizational principles	Generalizing
	Specifying

1. Analysis of Elements of Bloom's Taxonomy can be arranged in the same group with Matching and Classifying of Marzano's Taxonomy. They emphasize on the abilities to separate similarity or difference of the component parts or situation, and organize each part into meaningful categories.

2. Analysis of Relationships of Bloom's Taxonomy and Error Analysis of Marzano's Taxonomy should be arranged in the same group. They are abilities to make explicit relationships between the old and new information for reasonable conclusion.

3. Analysis of Organizational Principles of Bloom's Taxonomy can be arranged in the same group with Generalizing and Specifying of Marzano's Taxonomy. These are abilities to apply knowledge, principle, and theory to new situation: and predict what will occur in the future.

In addition, the cognitive process of analysis in Marzano's Taxonomy incorporates elements from at least three levels of Bloom's Taxonomy. Matching in Marzano's Taxonomy appears to be similar to the analysis of relationships within the

analysis of Bloom's Taxonomy. Classification in Marzano's Taxonomy appears to be similar to identifying a set of abstract relations within the synthesis of Bloom's Taxonomy. Error analysis in Marzano's Taxonomy is similar to judgments in terms of internal evidence within the evaluation of Bloom's Taxonomy. It is also similar to analysis of organizing principles within the analysis of Bloom's Taxonomy. Generalizing and specifying in Marzano's Taxonomy appear to be similar to or embedded in many components of the analysis, synthesis, and evaluation of Bloom's Taxonomy. In short, analysis within Marzano's Taxonomy incorporates a variety of aspects of the three highest levels of Bloom's Taxonomy.

3. Research related to Analytical Thinking

Siribunnam and Tayraukham (2009) studied the effects of 7-E, KWL, and conventional instruction on analytical thinking, learning achievement, and attitudes toward chemistry learning of the eleventh grade students. The result showed that students who learned by using the 7-E learning cycle have gained analytical thinking, science learning achievement, and attitudes toward chemistry learning higher than students who learned by KWL learning and the conventional approach. Therefore, teachers should be supported to implement the 7-E learning cycle in science teaching in the classroom.

Sathavonmanee (2005) developed activities based on three main principals including individuality, democracy, and practice, in the enrichment program on the fifth grade students. The study shows that the activities can enhance students' analytical thinking skill in 5 areas which are Matching, Classifying, Error Analysis, Generalizing and Specifying.

Poosiris (2007) studied the use of the approach based on Dewey's scientific method on analytical thinking of the ninth grade students and found that there were 80 percent of students who passed the criteria on analytical thinking test.

Phophat (2007) studied on the analytical thinking of students by using science activities learning packages on concept mapping. The samples of this research were the students in the ninth grade of Banwungkata School. The outcome showed that the analytical thinking ability of the students taught with science activities learning packages on concept mapping was higher than before and significant at the .01 level.

Nonsrichai (2007) studied the analytical thinking and achievement of the eleventh grade students in studying biology through inquiry cycle (5E). The result showed that teaching by using inquiry cycle promoted students' analytical thinking in studying biology which a core of all students passed the prescribed criteria.

In conclusion, several researches indicated that analytical thinking is a very important skill and could be developed through various instructional methods, approaches, and techniques. Therefore, teacher should provide appropriate activities for encouraging students to think analytically.

Conceptual Understanding

Teaching for understanding is a goal of instruction in every classroom, especially in the science classroom. Teacher should emphasize how to create a learning environment for students to learn with understanding. Many researchers have tried to explain what it means to learn with understanding and teach for understanding.

1. Definitions of Conceptual Understanding

Conceptual understanding can be described in terms of breadth and depth. Breadth refers to the extent distributed and represents the major part of a specific domain. On the other hand, depth refers to the knowledge of scientific principles that describes the relationship among the concepts. Breadth and Depth are related to each other and are important aspects of conceptual understanding (Alao; & Guthrie. 1999: 244).

Carpenter and Lehrer (1999) have described that understanding is the most important aspect of learning. When students obtain knowledge with understanding, they can apply that knowledge to learn new topics and solve unfamiliar problems. If they do not understand, they cannot apply their skill to solve unfamiliar problems, and extend their knowledge to new topics.

Abraham and Williamson (1994: 152) have identified criteria to classify students' responses and make comparisons on the degree of understanding as following:

1. Sound Understanding (SU): Valid responses for each concept statement are developed which represented the sound understanding of that concept.

2. Partial Understanding (PU): Responses demonstrating partial understanding of the concept are characterized by the student mentioning at least one of the components of the scientifically accepted concept.

3. Partial Understanding with Specific Misconception (PU/SM): Response that shows understanding of the concept, but also contains a misconception.

4. Specific Misconceptions (SM): Responses that include illogical or incorrect information.

5. No Understanding (NU): These responses can be characterized by one of the following manner: repeating the question, containing irrelevant information or an unclear response, replying "I don't know", or no response was given to the statement.

2. The Development of Conceptual Understanding

Science concepts are central to the science instruction: and the students understanding these concepts are important to the successful teaching and learning. Without science concepts, students would be nearly impossible to follow much of the public discussion of scientific results or public policy issues pertaining to science and technology (Enger; & Yager. 2001: 2). Therefore, in order to help students constructing an understanding of the natural world, students' prior knowledge should be the starting point for the instruction.

Research indicated that in order to develop conceptual understanding, students should have concrete experience with concepts before moving to abstractions: and they need opportunities to try and do, not just read about science. The evidence that science concepts have been learned is evidenced most strongly when students can use the concepts in a real-life or real-world situation (Enger; & Yager. 2001: 3).

Carpenter and Lehrer (1999) proposed and discussed on how understanding is developed into five forms of mental activity that consist of:

1. Constructing relationships

People construct meaning for a new idea or process by relating it to ideas or processes that they already understand. If teachers can help their students build their knowledge and relate what they have known to what they are studying in the classroom, they are likely to understand better. For example, if students can relate an everyday activity

such as breaking a bike with friction to a concept that they learn in the classroom, they will understand this topic better.

2. Extending and applying knowledge

It is not enough to develop understanding by adding new concepts to the existing knowledge. Developing understanding involves connecting new knowledge to the prior knowledge and integrating knowledge structures. This structuring of knowledge can make learning with understanding generative. When knowledge is highly structured, new knowledge can be related to the existing networks of knowledge. Moreover, knowledge that is received from learning with understanding should be learned in ways that clarify how it can be used.

3. Reflecting about experiences

Reflection involves the conscious examination of one's own actions and thoughts. Reflection plays an important role in solving unfamiliar problems. Problem solving is a relation between prior knowledge and a condition of a problematic situation. Students will have a better chance of achieving this skill if reflection is a part of the knowledge-acquirement process.

4. Articulating what one knows

Articulation involves the communication or expression of one's knowledge. It is an important goal of education and also a benchmark of understanding. To articulate our ideas, we must reflect on them in order to identify and describe critical elements. Articulation requires reflection and can be thought of as a public form of reflection.

5. Making knowledge one's own

Understanding involves the construction of knowledge by individuals through their own activities so that they develop a personal investment in building knowledge. They cannot understand their knowledge because someone has told them or explained to them, but they need to adopt an opinion that knowledge is evolving and provisional. Students author their own learning. They develop a tendency to understand and try very hard to understand because understanding becomes important to them.

Gabel (2003: 71) has identified several effective teaching strategies to promote the conceptual understanding of science. These teaching strategies can be incorporated into various teaching-learning situations.

Learning Cycle Approach

The learning cycle approach involves three phases: exploration, invention, and application. Its application produces a better content achievement, improved thinking skills, and more positive attitudes toward science. This approach has been adapted for using in high school. The exploration phase includes providing students with items that they use to explore a given concept with few directives. An interactive teacher-centered phase describing relevant concepts follows. After students understand the concept, they apply it to a new situation in the application phase. The addition of a prediction phase before the exploration, and an evaluation phase after the application, make the Learning Cycle Approach more effective.

Science/Technology/Society (STS)

STS integrates science concepts with knowledge of technology and fosters an awareness of societal implications. This approach not only increases students' knowledge of facts, concepts, and principles but also helps students learn to analyze data and test hypotheses, uses their creativity, and develops positive attitudes toward science.

Real-Life Situations

This approach uses real-life situations that do not necessarily include technological or societal problems for teaching science. It increases students' knowledge of concepts and interest in science as well as improves problem-solving skills.

Analogies

Using analogies in science teaching promotes conceptual understanding. A student can gain a better understanding of the principle by comparing that principle with examination that is familiar.

Wait-Time

"Wait-time" refers to the time that a teacher waits to call on a student for a response after posing a question, even though the answer given is correct before calling on another student to respond. The technique of waiting between three and seven seconds

after asking the students a question provides time to think. Research found that increasing wait-time can positively affect achievement in both elementary and secondary classrooms.

Concept Mapping

Another technique accepted to improve understanding of science is concept mapping. Concept maps are schematic diagrams that use word to show the relation of one concept to another. During an instruction, using concept maps requires students to focus on the relationships among concepts so that students' long-term memories will accord with the scientific view. After the instruction, teachers can ask students to make concept maps of the topic studied to determine if they have understood the relationship, or if an additional instruction is needed.

Inquiry

Inquiry was thought to be an important part of science teaching in K-12 schools. Students can use inquiry not only to understand new concept, but also learn the same processes that scientist using in discovering new knowledge, by asking questions, observing, inferring, predicting, classifying, controlling variables, measuring and making charts and graphs. As presented in Inquiry and the National Science Education Standards, the essential features of classroom inquiry include engaging students through scientifically oriented questions, obtaining evidence related to the questions, formulating explanations from the evidence, evaluating the explanation in light of other possible explanation, and communicating and justifying their explanations to others.

3. Research related to Conceptual Understanding

Kruatong (2007) used contextual approach to develop high school students' understanding of heat and thermodynamics concepts. The results showed that the students' understanding was enhanced through the presentation of heat and thermodynamics concepts in the context of situation students identified with, and by students being asked to identify contrasts and comparisons between concepts across the contexts.

Khongpugdee (2010) studied effects of teaching astronomy based on inquiry method using Earth Moon Sun System Model (EMS-Model) innovation on the ninth grade

students, and found that this model can improve students' astronomy conceptual understanding.

Johnson, Siegler, and Alibali (2001) studied the use of an iterative process to develop conceptual understanding and procedural skill in Mathematics. Two experiments were conducted with the fifth and sixth grade students learning about decimal fractions. The outcome illustrated that this process promoted students' conceptual understanding.

McConnell et al. (2006) developed concept tests for geosciences for using in a wide range of classroom settings, including large introductory general education Earth Science courses for non-majors at open enrollment institutions, smaller physics geology classes suitable for majors at private colleges, and in introductory geology laboratory settings. The results of pre- and post-classes Geoscience Concept Inventory (GCI) testing and qualitative feedback from students and instructors showed that the concept tests increased attendance, improved student satisfaction, and enhanced student achievements.

Wild and Trundle (2010) studied the misconceptions of students with visual impairment about seasonal change. The students who participated in traditional instruction exhibited alternative conceptions before and after instruction, whereas those who participated in inquiry-based instruction had alternative conceptions before instruction and scientific understandings after the instruction.

In conclusion, conceptual understanding is the main goal of science teaching. Several researches have studied and investigated appropriate strategies to help students understand fundamental concept of science. Teacher's role is to design several activities and use appropriate strategies for supporting students to achieve that goal.

Application of Knowledge

After learning content knowledge, application of knowledge is the next step of every classroom. In order to apply knowledge, students have to actually understand what they learn in the class, not just memorize. Draskovic and Jovovic (2008) addressed that retrieval alone is not enough to apply knowledge; and the success of knowledge application appears to be a function of the characteristics of the individual, the knowledge content, the purpose of reuse for the particular task at hand, and the organizational context or culture.

1. Definition of Application of Knowledge

Several educators have studied and identified definition of application in many ways. As Bloom (1956) explained in application levels of Bloom's Taxonomy, students should be able to use the material in new situations, which means applying concepts, principles, rules, theories, and laws to find solutions to new problems that they have not seen before.

Mazarno (2001) explained that knowledge utilization, the final level of cognitive processes, is the use of knowledge. This process requires students to apply or use knowledge when they wish to accomplish in specific situations.

Knowledge application refers to the actual use of knowledge that has been grasped or created and put in the knowledge management cycle as shown in FIGURE 7

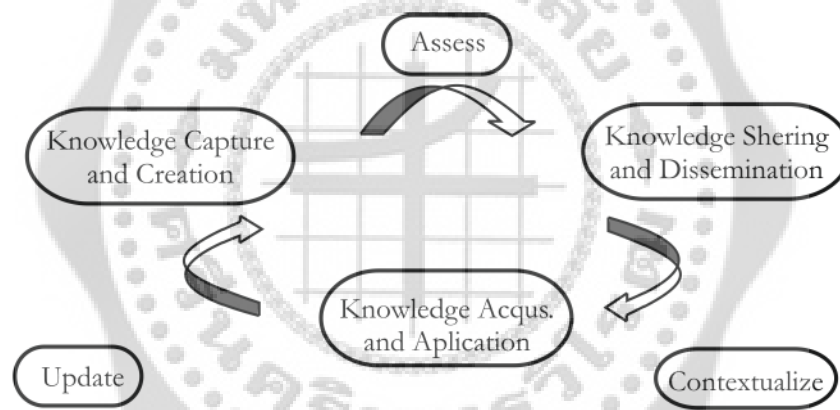


FIGURE 7 AN INTEGRATED KNOWLEDGE MANAGEMENT CYCLE

Source: Draskovic; & Jovovic. (2008). Building Successful Knowledge Organization Through Knowledge Application at the Individual and Organizational Levels. p. 62.

Therefore, the definition of application can be defined as learner's abilities in employing knowledge, principles, theories, and laws which they have learned in the classroom to decide and solve problem facing in new situation or daily life.

2. Categories of Application of Knowledge

Marzano (2001) has proposed four general categories of knowledge application processes consisting of decision making, problem solving, experimental inquiry, and investigation.

1. Decision Making

The process of decision making is used when an individual must select between two or more alternatives. Steps commonly associated with the process of decision making include:

- 1.1 Identification of alternatives
- 1.2 Assignment of values to alternatives
- 1.3 Determination of probability of success
- 1.4 Determination of alternatives having highest value and highest

probability of success

2. Problem Solving

The process of problem solving is used when an individual attempts to accomplish a goal for which an obstacle exists. Steps connected with problem solving consist of:

- 2.1 Identification of obstacle to goal
- 2.2 Possible re-analysis of goal
- 2.3 Identification of alternatives
- 2.4 Evaluation of alternatives
- 2.5 Selection and execution of alternatives

3. Experimental Inquiry

Experimental inquiry is the process of generating and testing hypotheses for the purpose of understanding some physical or psychological phenomena. The steps related with the experimental inquiry contain:

- 3.1 Making predictions based on known or hypothesized principles
- 3.2 Designing a way to test the predictions
- 3.3 Evaluating the validity of the principles based on the outcome of the test

4. Investigation

Investigation is the process of generating and testing hypotheses about past, present, or future events. Steps associated with the process of investigation include:

4.1 Identifying what is known or agreed upon regarding the phenomenon under investigation

4.2 Identifying areas of confusion or controversy regarding the Phenomenon

4.3 Providing an answer for the confusion or controversy

4.4 Presenting a logical argument for the proposed answer

3. Research related to Application of Knowledge

Kruatong (2007) used contextual approach to develop high school students' application of heat and thermodynamics concepts. The results showed that application abilities of student were improved through this approach. The use of a situation as a learning context gave the students an opportunity to apply concepts they have learned to new situation at the end of a lesson.

Deejaras (2002) studied physics application in the daily life of 456 twelfth grade students in 13 schools of Samutprakarn province by classification of school size, grade average, and sex. The instrument used was the application of Physics knowledge in 5 areas, 15 mechanical science items, 6 light and sound wave items, 4 atom and nuclear physics items, 5 heat items, and 10 electro-magnet items. It has been found that the ability of students to apply physics knowledge to their daily life was at the middle level. The ability to apply physics knowledge to daily life of students who studied in different sizes was different at the .05 level of significant except for that of students who studied in the extra large school size and large school size. Moreover, the ability of male and female students to apply physics knowledge was different at the .05 level of significant.

Suvanprateep (2005) studied physics applications in the daily life of High Diploma Level Major Industrial Student in Rajamongala University of Technology and compared an ability to apply Physics Applications by classification of regional, major, and gender. The results showed that the ability of students to apply physics knowledge was at middle level accomplishment with the average percentage of 63.58. The ability of students who studied

in different regions to apply physics knowledge was different at the .05 level of significant; and the ability of the students who studied in different majors to apply physics knowledge was not different with reliability of 95 percent. Furthermore, the ability of male and female students to apply physics knowledge was not different with reliability of 95 percent.

Cheentham (1995) studied scientific application in the unit of organism, physical environment, energy and chemicals in everyday life of the fifth grade students in cooperating schools for developing the curriculum under the office of Chahoengsao Provincial Primary Education. The results showed that the total mean score was 27.28 or 68.19 percent. In addition, females gained more score than males at the significant level of .05 for their scientific application in everyday life, and students whose parents differed in their occupation made no difference in their scientific application in everyday life.

Suriyo (2001) studied and compared the application of science course knowledge in daily life of the ninth-grade students in Chachoengsao Province with sex, parents' occupation, parents' education, and school size differences. The results showed that the students' application of science course knowledge in daily life was at the medium level. The students with different sex showed statistically significant difference at the .05 level in application of science course knowledge in daily life. The students with different parents' occupation and parents' education showed statistically significant difference at the .05 level in application of science course knowledge in daily life. In addition, the students who studied in different school size showed statistically significant difference at the .05 level in application of science course knowledge in daily life.

Chunthup (2000) studied and compared the ability in using science knowledge for daily life of the ninth grade students in Chumporn Province concerned with levels of school and sex differences which comprised of 5 topics, namely food, health, safety, energy, and natural resource and environmental conservation. The results indicated that the ability of students in using science knowledge in all topics and overall was at the medium level except in food topic which shown to be at the high level. The students who studied in different levels of school showed statistically significant difference at the .01 level in ability to use science knowledge in all topics and overall except in food topic which was not

difference. Furthermore, the students with different sex showed statistically significant difference at the .01 level in ability in using science knowledge for daily life.

Champugdee (2002) studied relationship between scientific achievement and behavior of using the scientific knowledge in the ninth grade students' daily life in Lopburi. The results showed that the scientific achievement of the ninth grade students was at the low level, and the behavior of using the scientific knowledge in the daily life was also at the low level. In addition, the scientific achievement and the behavior of using the scientific knowledge in daily life of students had positive relationship with significance at .01 level, the correlation was 0.155.

Wongtanom (2004) studied and compared awareness and an ability in using science and technology knowledge for daily life of the ninth grade students in Samutsongkram Province, classified into academic achievement, domicile and schools under the different educational departments, and also studied the relationship between awareness and ability in using science and technology knowledge for daily life of the students. The results indicated that the students had high level of awareness in using science and technology knowledge for daily life. The students with different academic achievement had the statistically significant difference at the .05 level of awareness in using science and technology knowledge for daily life. The students with different domicile and schools under the different educational departments had the statistically significant different at the .01 level of awareness in using science and technology knowledge for daily life. The students showed the ability in using science and technology knowledge for daily life at the medium level. The students with different academic achievement and school under the different educational departments had the statistically significant different at the .01 level of the ability in using science and technology knowledge for daily life. In addition, the relationship between the awareness and the ability in using science and technology knowledge for daily life of students had the statistically significant different at the .01 level.

Sriputon (2001) studied an ability to apply science knowledge in daily life of students in the ninth grade in St. Paul de Chartres group. The results illustrated that the students got an average ability score for employment of science knowledge in a daily life over half of the total score. Student in a high accomplishment group in science study had

higher average scores of ability to apply science knowledge in a daily life than students in a low accomplishment group in science study at the .01 level of significant. Furthermore, student in Mathayomsuksa 3 at school in St. Paul de Chartres group in Bangkok and its vicinity had higher average scores of ability to apply of science knowledge in a daily life than those who were living outside Bangkok at the .01 level of significant.

Tunpiriyakul (2003) studied chemical knowledge-applying ability in daily life of high vocation education certificate students under the vocational education college division in Bangkok. The results indicated that higher vocational education certificate students from education college division in Bangkok had an ability to apply the chemical knowledge in their daily lives at moderate level. The comparison of students' average ability in applying the chemical knowledge to their daily lives were not different with the confidentiality of 95 percent, between those two groups of students who were studying in accounting and marketing.

In summary, the application of knowledge is an important ability for students involving the use of concepts not only in a familiar context but also in new problems. Students can apply knowledge to the different level depend upon several factors such as achievement, sex etc. Students who can apply what they have learned to new situation provide evidence that they have an understanding of a concept. Therefore, teacher not only uses appropriate teaching method but also provides students several learning activities to enhance students' learning ability.

The FEACA Model Development

From all literature review, the science instructional model was developed to promote conceptual understanding, analytical thinking, and application of knowledge. The conceptual framework for developing the model based on five important features of contextual approach which consisted of:

1. Students will be engaged with context or real life experience to catch their attention
2. Students have the opportunity to do hands-on experience for exploring and collecting data.

3. Students develop their conceptual understandings by themselves under the facilitating of a teacher.

4. Students share and communicate their ideas with other students.

5. Students apply their knowledge they have learned in the class to other contexts.

The research studies indicated that contextual approach could promote conceptual understandings and application of knowledge. Not only conceptual understandings and applications of knowledge but also analytical thinking is an important feature that learners need to be improved. Consequently, it is necessary to include analysis process as the additional key component in order to place more emphasize on the development of analytical thinking of the learners. Many educators have described how to develop analytical thinking; an outstanding one is defined by Marzano. From his point of view, analysis processes, which are a part of the New Taxonomy, can be divided into five types, namely, matching, classifying, error analysis, generalizing and specifying. Therefore, the science instructional model based on five features of contextual approach and Marzano's analysis processes was developed to enhance student's conceptual understandings, analytical thinking and application of knowledge. This science instructional model or FEACA Model consists of five steps of learning: Focusing, Exploring, Analyzing, Conceptual Developing, and Applying.

Step 1: Focusing

The purposes of this step are to catch students' attention and diagnose their prior knowledge by engaging them with real life context. At this step, the everyday life situation will be presented as a starting point in order to recall student's experiences related to that situation and check their prior knowledge about the concept they will learn in the class. Teacher stimulates students to think by asking a question related to that situation. Students answer the question and compare similarities and differences of their own answers with their friends' answers as well as organize those answers into meaningful categories. Students communicate what they get by sharing with their peers. At the end of the step the answers will not be verified right or wrong, but it will be the problem for investigated in the next step.

Step 2: Exploring

The purpose of this step is to give students opportunity to investigate through hands-on and mind-on exploration which built upon the everyday life situation from the first step. At this step, students will be separated into small groups and do experiments or activities for exploring the answer of the first step. Teacher acts as a facilitator helping students if they meet any problems and checks whether students obtain all necessary information for using in the next step.

Step 3: Analyzing

The purpose of this step is to give students an opportunity to analyze data and construct knowledge by their own under the facilitating of a teacher. At this step, students find the relationship of information from their observation by answering the questions and summarizing what they get for constructing their own knowledge. Students communicate their understanding by sharing with the whole class.

Step 4: Conceptual Developing

The purpose of this step is to construct correct conceptual understanding about that topic under the facilitating of a teacher. At this step, students discuss the conclusion from the previous step and re-shape their understanding under facilitating of a teacher. Furthermore, students study more about the topic from a document and relate the concept they have learned with situation in the first step. The roles of a teacher are to help students to construct scientific conceptual understanding and correct all misconception.

Step 5: Applying

The purpose of this step is to apply scientific concept to new contexts. At this step, students in each group apply conceptual understanding they have learned in the class to new contexts or real life situations and share with the whole class and also need to give the reason to explain the reasonableness of information. Students in other groups evaluate validity of that application and identify any errors in reasoning that have been presented.

Therefore, the FEACA model should help improving scientific conceptual understanding and application of knowledge of students. Moreover, this model emphasized the development of analysis processes which should enhance analytical thinking of students.

CHAPTER 3

METHODOLOGY

This chapter describes the methodology used in this study including, the development and evaluation of the science instructional model emphasizing contextual approach called FEACA model in order to enhance conceptual understanding, analytical thinking and application of knowledge for lower secondary school students. The methodology used in this study consists of six phases as follows:

Phase 1: Studying Basic Information for Developing Science Instructional Model

Phase 2: Developing the FEACA Model

Phase 3: Developing the Research Instruments

Phase 4: Conducting a Pilot Study

Phase 5: Implementing the FEACA Model

Phase 6: Evaluating the FEACA Model

The framework of research methodology can be seen in FIGURE 8

Phase 1: Studying Basic Information for Developing Science Instructional Model

The main purpose of this phase was to study the basic information and problems of science teaching and learning in Thailand for designing the draft science instructional model. First, consideration of the basic information concerning the Thailand's National Education Act B.E. 2542 (1999) and Amendments (Second National Education Act B.E. 2545 (2002)), and the Thai Basic Education Core Curriculum B.E. 2551 (2008) found that the main goals of educational policy emphasized the promotion of science conceptual understanding, science process skills, thinking ability, as well as scientific attitude to all students.

Second, the investigation of research and documents about the problems of science teaching and learning for the lower secondary school students found that traditional instruction could not promote conceptual understanding and analytical thinking of the lower secondary school students in Thailand.

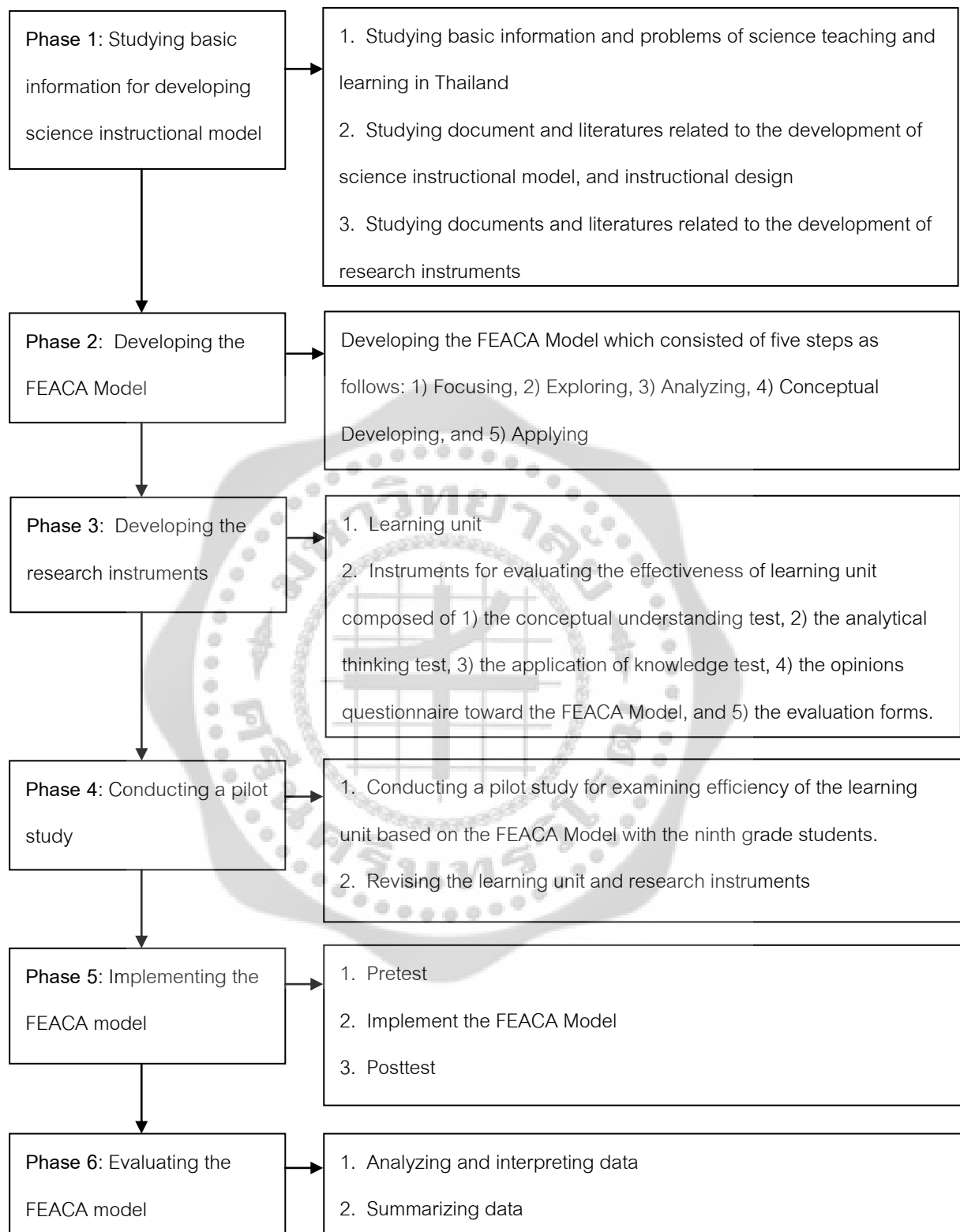


FIGURE 8 FRAMEWORK OF RESEARCH METHODOLOGY

Third, the consideration of learning theories and science instruction method enhances student's conceptual understanding and analytical thinking. The contextual approach integrated with Marzano's analysis processes has been chosen to be the main conceptual framework for the development of science instructional model

Phase 2: Developing the FEACA Model

The purpose of this phase was to design the draft science instructional model. The contextual approach and Marzano's analysis processes were used to be the conceptual framework for developing the model. The model was used to promote students' conceptual understanding, analytical thinking, and application of knowledge. The processes of developing the instructional model were as follows:

1. Studying related literatures concerning the learning theories, science instruction method, contextual approach, instructional model development, as well as conceptual understanding, analytical thinking, and application of knowledge development.
2. Analyzing essential components of the contextual approach from the contextual teaching and learning strategies of previous researches (see TABLE 1).
3. Developing the draft of the model based on essential features of contextual approach and Marzano's analysis processes in order to enhance conceptual understanding, analytical thinking, and application of knowledge. This model comprised of five steps of learning called FEACA Model.
4. Verifying the appropriateness and the consistency of the draft FEACA Model by advisors and revising following their comments and suggestions.
5. Examining the efficiency of the draft FEACA Model by five experts. The experts considered validity of the FEACA Model by using the Index of Consistency (IOC) and suggested some modification of the documents. The results of evaluating the FEACA Model are shown in Chapter 4.
6. Revising the FEACA Model based on comments and suggestions of the experts.

The final FEACA Model after revising comprised of five steps of learning, namely, Focusing, Exploring, Analyzing, Conceptual Developing and Applying. The details of each step were as follows:

Step 1: Focusing

The purposes of this step are to catch students' attention and diagnose their prior knowledge by engaging them with real life context. At this step, the everyday life situation will be presented as a starting point in order to recall student's experiences related to that situation and check their prior knowledge about the concept they will learn in the class. Teacher encourages students to think by asking a question related to that situation. Students answer the question and compare similarities and differences of their own answers with their friends' answers as well as organize those answers into meaningful categories. Students communicate what they get by sharing with their peers. At the end of the step the answers will not be verified right or wrong, but it will be the problem for investigating in the next step.

Step 2: Exploring

The purpose of this step is to give students opportunity to investigate through hands-on and mind-on exploration which built upon the everyday life situation from the first step. At this step, students will be separated into small groups and do experiments or activities for exploring the answer of the questions developed in first step. Teacher acts as a facilitator helping students if they meet any problems and checks whether students obtain all necessary information for using in the next step.

Step 3: Analyzing

The purpose of this step is to give students an opportunity to analyze data and construct knowledge by their own under the facilitating of a teacher. At this step, the students find the relationship of information from their observation by answering the questions and summarizing what they get for constructing their own knowledge. Students communicate their understanding by sharing with the whole class.

Step 4: Conceptual Developing

The purpose of this step is to construct correct conceptual understanding about that topic under the facilitating of a teacher. At this step, the students discuss the conclusion from the previous step and re-shape their understanding under the facilitating of a teacher. Furthermore, students study more about the topic from documents and relate the concepts they have learned with the situation in the first step. The roles of the teacher are to help students to construct scientific conceptual understanding and correct all misconception.

Step 5: Applying

The purpose of this step is to apply scientific concept to new contexts. At this step, the students in each group apply conceptual understanding they have learned in the class to new contexts or real life situations and share with the whole class. The students also need to give the reason to explain the reasonableness of the information. The students in other groups then evaluate validity of that application and identify any errors in reasoning that have been presented.

Phase 3: Developing Research Instruments

Instruments for using in this study were classified into two parts which were learning unit and instruments for learning unit evaluation as follows:

1 Learning Unit

The learning unit was developed according to the five steps of the FEACA Model. The documents involving in the learning unit consisted of teacher's guide and instructional plans. The processes of developing of the learning unit were as follows:

1.1 Studying and analyzing related documents concerning the Thai National Science Curriculum Standards in the Basic Education Core Curriculum B.E. 2551 (A.D. 2008), strategies for developing learning unit, assessment and evaluation, and research instruments development.

1.2 Determining contents for using in the learning unit. This learning unit focused on Strand 4: Force and Motion which is one of eight Strands of the Thai National Science Curriculum Standards in the Basic Education Core Curriculum B.E. 2551 (A.D. 2008). The following were two standards with indicators of each standard for the ninth-grade in this Strand (Ministry of Education. 2008: 127-130).

Standard Sc4.1: Understanding of the nature of electromagnetic, gravitational and nuclear forces; having investigative process for seeking knowledge; and applying acquired knowledge for useful and ethical purposes

Indicators

Sc4.1 Gr 9/1	Explain acceleration and effects of resultant forces acting on objects
Sc4.1 Gr 9/2	Experiment and explain action and reaction forces between objects, and apply the knowledge gained for useful purposes.

Sc4.1 Gr 9/3 Experiment and explain buoyant forces acting on liquid.

Standard Sc4.2: Understanding of characteristics and various types of motion of natural objects; having investigative process for seeking knowledge and scientific reasoning; and communicating acquired knowledge for useful purposes

Indicators

Sc4.2 Gr 9/1 Experiment and explain differences between static, friction and forces, and apply the knowledge gained for useful purposes

Sc4.2 Gr 9/2 Experiment and explain moment of forces, and apply the knowledge gained for useful purposes.

Sc4.2 Gr 9/3 Observe and explain motions of objects in a straight line and in curves.

Therefore, the contents in this learning unit consisted of six topics namely: 1) Acceleration, 2) Action and Reaction, 3) Friction, 4) Moment, 5) Buoyant Force, and 6) Motion of Objects.

1.3 Determining of learning unit components which were title, objectives, concepts, materials and equipment, instructional activities, and assessments.

1.4 Developing draft of the learning unit consisted of teacher's guide and instructional plans as follows:

Teacher's guide: The teacher's guide was written in order to provide teacher necessary information about the guidelines for using the FEACA Model in classroom as well as teacher's and student's roles.

Instructional plans: The instructional plans were developed based on the FEACA Model. Each instructional plan consisted of Standard, Indicators, Main Concept, Learning Objectives, Content, Learning Activities, Learning Materials, Assessment and Evaluation, and Student's worksheets

1.5 Verifying the appropriateness and the consistency of the learning unit by advisors and revising following their comments and suggestions.

1.6 Examining efficiency of the leaning unit by five experts. The Index of Consistency (IOC) was used to analyze validity of the leaning unit. The results of evaluating the learning unit are shown in Chapter 4.

1.7 Revising the learning unit according to comments and suggestions of the experts.

TABLE 3 THE SUMMARY OF LEARNING UNIT

Week	Instructional Plan	Tasks	Periods
1	Introduction and pretest	- Introduction - The conceptual understanding test - The analytical thinking test	3
2	Instructional plan 1: Acceleration	- Activity 1.1 "Fast or Slow" - Activity 1.2 "Changing Velocity" - Activity 1.3 "Exercise"	2
3	Instructional plan 2: Action and Reaction	- Activity 2.1 "Moving Chair" - Activity 2.2 "Spring Scale" - Activity 2.3 "Balloon Car" - Activity 2.4 "Exercise"	3
4	Instructional plan 3: Friction	- Activity 3.1 "Types of Friction" - Activity 3.2 "Factors effecting Friction" - Activity 3.3 "Exercise"	3
5	Instructional plan 4: Moment	- Activity 4.1 "Motion of a Book" - Activity 4.2 "Stability of Lever" - Activity 4.3 "Tools in Dairy Life" - Activity 4.4 "Exercise"	3
6	Instructional plan 5: Buoyant Force	- Activity 5.1 "Buoyant Force" - Activity 5.2 "Sink or Float" - Activity 5.3 "Exercise"	3
7	Instructional plan 6: Motion of Objects	- Activity 6.1 "Motion in Dairy Life" - Activity 6.2 "Motion of Objects" - Activity 6.3 "Exercise"	2
8	Posttest	- The conceptual understanding test - The analytical thinking test - The application of knowledge test - The opinion questionnaires toward the FEACA Model	3
Total			22

2 Research Instruments for Learning Unit Evaluation

The research instruments for collecting data comprised of conceptual understanding test, analytical thinking test, application of knowledge test, and students' opinion questionnaires toward the FEACA Model. The processes of developing each research tools were as follows:

2.1 The Conceptual Understanding Test

The conceptual understanding test was used to assess students' understanding the main concepts on "Force and Motion". The content areas comprised of Acceleration, Action and Reaction, Friction, Moment, Buoyant Force, and Motion of Objects. The processes of developing the conceptual understanding test were as follows:

2.1.1 Studying the construction of the conceptual understanding test and relevant documents.

2.1.2 Analyzing contents and constructing the conceptual understanding test on "Force and Motion". The test composed of 60 items of multiple choice questions, each of which had four alternative choices consisted of only one correct answer and three possible answers based upon students' misconceptions about the topics. Some items were adapted from the Force and Motion Conceptual Evaluation (Thornton; & Sokoloff. 1998: 338-352).

2.1.3 Verifying the appropriateness and consistency of the conceptual understanding test by advisors and revising following their comments and suggestions.

2.1.4 Examining efficiency of the conceptual understanding test by three experts. The Index of Consistency (IOC) was used to analyze content validity of the test. After all items have been examined by three experts, 56 items that gained the index value more than 0.5 were selected to be used for the next steps (Appendix B.2).

2.1.5 Revising the test according to comments and suggestions of the experts.

2.1.6 Trying out the conceptual understanding test with 150 tenth-grade students who had already studied force and motion concept in Nongchangwittaya School. The students' scores were analyzed to gain item difficulty (p) and item discrimination (r) of each item. After the test had been tried out, 30 items were selected. The p value ranked

from 0.23 to 0.75 and the r value ranked from 0.21 to 0.63. More details about item difficulty and item discrimination are presented in Appendix B.2.

2.1.7 Examining the reliability of the test. The selected items were analyzed the reliability by using Kuder-Richardson 20 (KR-20) coefficient. The reliability of the test was 0.78.

2.2 The Analytical Thinking Test

The analytical thinking test was used to assess students' analytical thinking based on Marzano's analytical thinking which comprised of matching, classifying, error analysis, generalizing, and specifying. The processes of developing the test were as the following steps:

2.2.1 Studying the construction of the analytical thinking test according to Marzano's analytical thinking and the relevant documents.

2.2.2 Analyzing contents and constructing the analytical thinking test following five components of Marzano's analytical thinking. The test composed of 50 items of multiple choice questions, each of which had four alternative choices and one correct answer.

2.2.3 Verifying the appropriateness and consistency of the test by advisors and revising following their comments and suggestions.

2.2.4 Examining efficiency of the analytical thinking test by five experts. The Index of Consistency (IOC) was used to analyze the content validity of the test. After all items have been examined by five experts, 50 items that gained the index value more than 0.5 were selected to be used for the next steps (Appendix B.3).

2.2.5 Revising the analytical thinking test according to comments and suggestions of the experts.

2.2.6 Trying out the analytical thinking test with 106 ninth-grade students from Nongchangwittaya School. The students' scores were analyzed to gain item difficulty (p) and item discrimination (r) of each item. After the test had been tried out, 25 items were selected. The p value ranked from 0.25 to 0.73 and the r value ranked from 0.22 to 0.70. More details about item difficulty and item discrimination are presented in Appendix B.3.

2.2.7 Examining the reliability of the test. The selected items were analyzed the reliability by using Kuder-Richardson 20 (KR-20) coefficient. The finding showed that the reliability of the analytical thinking test was 0.79.

2.3 The Application of Knowledge Test

The application of knowledge test was used to assess students' application of knowledge in the main concepts on "Force and Motion" which were Acceleration, Action and Reaction, Friction, Moment Buoyant Force, and Motion of Objects. The processes of developing the test were as follows:

2.3.1 Studying the construction of the application of knowledge test and the relevant documents.

2.3.2 Analyzing contents as well as constructing the application of knowledge test and scoring rubrics of the test. The test contained 18 items of open-ended questions.

2.3.3 Verifying the appropriateness and consistency of the application of knowledge test by advisors and revising following their comments and suggestions.

2.3.4 Examining efficiency of the application of knowledge test by three experts and revising the test according to comments and suggestions of the experts. The Index of Consistency (IOC) was used to analyze content validity of the test. Each of the experts evaluated all of items and suggested some modification. After all items had been examined by the three experts, 18 items that gained the index value more than 0.5 were selected to be used for the next steps (Appendix B.4).

2.3.5 Revising the application of knowledge test according to comments and suggestions of the experts.

2.3.6 Trying out the application of knowledge test with 106 ninth-grade students in Nongchangwittaya School.

2.3.7 Analyzing the item difficulty (p) and item discrimination (r) of each item. The students' application of knowledge scores were analyzed to gain item difficulty (p) and item discrimination (r) of each item. After the test had been tried out, 12 items were selected. The p value ranked from 0.28 to 0.77 and the r value ranked from 0.26 to 0.69. More details about item difficulty and item discrimination are presented in Appendix B.4.

2.3.8 Examining the reliability of the test. The selected items were analyzed the reliability by using the Alpha Coefficient of Cronbach. The finding showed that the reliability of the test was 0.76.

2.4 The Opinions Questionnaire toward the FEACA Model

The opinions questionnaire toward the FEACA Model was used to collect data regarding the students' opinions toward the FEACA Model. The processes of developing this questionnaire were as follows:

2.4.1 Studying the construction of opinions questionnaire and relevant documents.

2.4.2 Constructing the opinions questionnaire toward the FEACA Model consisting of two parts. The first part comprised of 20 items of the five-point rating Likert Scale consisting of positive items and negative items (see TABLE 4). The second part was an open-ended question asking about students' opinions toward the science FEACA Model.

TABLE 4 POINT VALUES FOR POSITIVE ITEMS AND NEGATIVE ITEMS

Interpretation	Positive Items	Negative Items
Very high level	5	1
High level	4	2
Modulation	3	3
Low level	2	4
Very low level	1	5

2.4.3 Verifying the appropriateness and the consistency of the students' opinions questionnaire toward the FEACA Model by advisors and revising following their comments and suggestions.

2.4.4 Examining efficiency of the students' opinions questionnaire toward the FEACA Model by five experts and revising the test according to the comments and suggestions of the experts. The Index of Consistency (IOC) was used to analyze content validity of the test. Each of the experts evaluated all of items and suggested some

modification. After all items have been examined by the three experts, 20 items that gained the index value more than 0.5 were selected to be used for the next steps (Appendix B.5).

2.4.5 Revising the students' opinions questionnaire toward the FEACA Model according to comments and suggestions of the experts.

2.4.6 Trying out the students' opinions questionnaire toward the FEACA Model with 34 ninth-grade students in Kanchanapisekwithayalai Uthaithani School who received teaching by the researcher while conducting the pilot study.

2.4.7 Analyzing the item discrimination (r) of each item. The students' opinions questionnaire toward the FEACA Model scores was analyzed to gain item discrimination (r) of each item. After the test has been tried out, 20 items were selected. The r value ranked from 0.25 to 0.66. More details about item discrimination were presented in Appendix B.5.

2.4.8 Examining the reliability of the test. The selected items were analyzed the reliability by using the Alpha Coefficient of Cronbach. The finding showed that the reliability of the test was 0.84.

Phase 4: Conducting a pilot study

The efficiency of the FEACA Model and assessment tools were examined by conducting a pilot study. The purpose of this phase was to check congruence of the learning unit to see if all components were well fit together. This process checked out all research instruments, and research procedures. This stage helped researcher to reveal the problems that might happen during implementing the final draft. In this step, learning unit was used with one classroom of the ninth-grade students in Kanchanapisekwithayalai Uthaithani School. The one group pretest-posttest design was used for conducting a pilot study. The FEACA Model was served as the independent variable, while the results of students' conceptual understanding, analytical thinking, application of knowledge, and opinions toward the FEACA Model were served as the dependent variables (see TABLE 5). The results of conducting a pilot study are shown in Chapter 4.

TABLE 5 THE ONE GROUP PRETEST-POSTTEST DESIGN

Pretest	treatment	Posttest
T_1	X	T_2

The symbols indicate as follows:

T_1 is pretest

X is teaching by using the FEACA model

T_2 is posttest

Phase 5: Implementing the FEACA Model

This study was a quasi-experimental research, Non-equivalent Control Group Pretest-posttest Design. The teaching with the FEACA Model was used as the experimental group, and the teaching with the tradition instruction was used as the control group and both groups were served as independent variables. The results of students' conceptual understanding, analytical thinking, application of knowledge, and opinions toward the FEACA Model were served as the dependent variables (see TABLE 6).

TABLE 6 THE PRETEST-POSTTEST NON-EQUIVALENT CONTROL GROUP DESIGN

	Pretest	treatment	Posttest
E	T_1	X	T_2
C	T_1	$\sim X$	T_2

The symbols indicate as follows:

E is experimental group

C is control group

T_1 is pretest

X is teaching by using the FEACA model

$\sim X$ is teaching by using the traditional instruction

T_2 is posttest

The science instructional model emphasizing contextual approach was applied to a real classroom following these steps;

1. Selecting Participants

The students participating during implementation were two classrooms of the ninth-grade students who were mixed ability. They were studying in the first semester of 2011 academic year of Nongkhayangwittaya School in Uthaithani province, Thailand. This school was selected by purposive sampling from schools where the executive agrees to use the learning unit and used the Basic Education Core Curriculum B.E. 2551 (A.D. 2008) for the ninth-grade students. There are only some schools using this curriculum for the ninth-grade students, and all schools will use this curriculum in the first semester of 2012.

The conceptual understanding test and the analytical thinking test were administered with four classrooms of the ninth-grade in Nongkhayangwittaya School. Mean ($\bar{x}$) and Standard deviation (S.D) of the pretest conceptual understanding scores and the pretest analytical thinking scores of four classrooms were analyzed one-way analysis of variance (One-way ANOVA) by using the F-test and found that there were no statistically significant difference between each other, both the conceptual understanding and the analytical thinking. The four classrooms were separated into two groups depended on the number of students, group 1: Gr. 9/1 and Gr. 9/2 and group 2: Gr. 9/3 and Gr. 9/4. The second group was selected by using simple random sampling. At last, the Gr. 9/4 was selected as the experimental group and the Gr. 9/3 was selected as the control group by using simple random sampling.

2. Implementing

After the participants were selected and separated into two groups, the treatments were applied in each group as follows:

2.1 The learning unit developed based on the FEACA Model was applied to the Gr. 9/4 students whereas the traditional instruction was applied to the Gr. 9/3 students for 8 weeks.

2.2 The conceptual understanding test, the analytical thinking test, and the application of knowledge test were applied to the students in both groups after the implementation.

2.3 The opinions questionnaire toward the FEACA Model was applied to the Gr. 9/4 students after using the FEACA Model.

The procedure and research instruments in this step are presented in FIGURE 9.

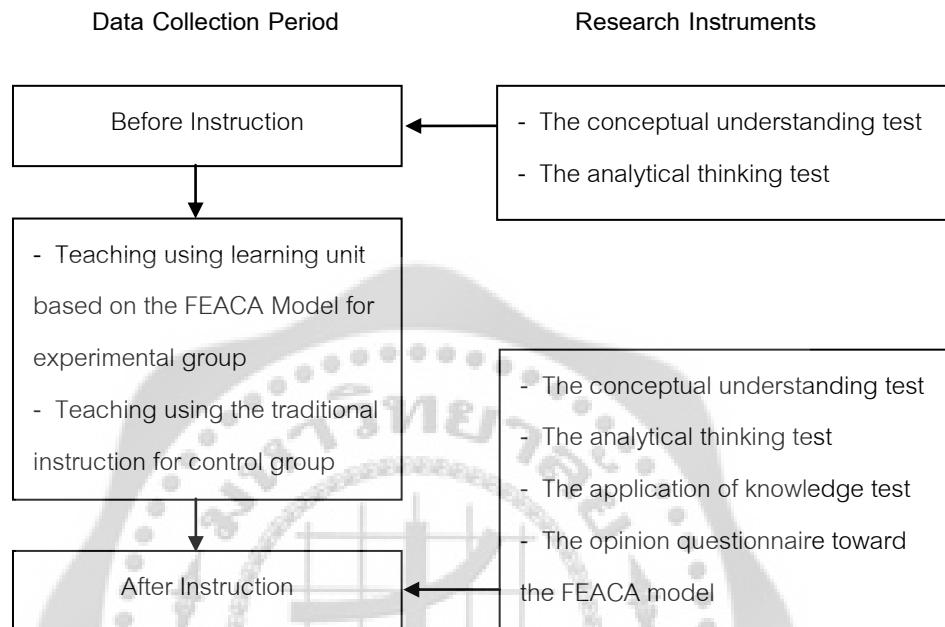


FIGURE 9 RESEARCH INSTRUMENTS USED IN EACH PERIOD OF THE STUDY

Phase 6: Evaluating the FEACA Model

In this section, the effectiveness of the FEACA Model was determined by examining conceptual understanding, analytical thinking, application of knowledge, and students' opinions toward the FEACA Model. The results are shown in Chapter 4.

1. Data Analysis

The purpose of this phase was to assess the effectiveness of the FEACA Model after implementation. The collected data were analyzed for verifying the effectiveness of the FEACA Model by answering six hypotheses as follows:

6.1 Students' conceptual understanding posttest mean scores of the experimental group were higher than the pretest mean scores with a statistically significant difference.

6.2 Students' conceptual understanding posttest mean scores of the experimental group are higher than that of the control group with a statistically significant difference.

6.3 Students' analytical thinking posttest mean scores of the experimental group are higher than the pretest mean scores with a statistically significant difference.

6.4 Students' analytical thinking posttest mean scores of the experimental group are higher than that of the control group with a statistically significant difference.

6.5 Students' application of knowledge posttest mean scores of the experimental group are higher than that of the control group with a statistically significant difference.

6.6 Students' opinions scores toward the FEACA Model of the experimental group after implementation are at high level of performance.

2. Statistics

The quantitative data was analyzed by statistical methods. The statistics using in this study were as follows:

2.1 Basic statistics

The basic statistics used in this study were as follows:

2.1.1 Mean

The mean was used to evaluated

$$\bar{X} = \frac{\sum X}{N}$$

$\bar{X}$ is Mean

$\sum X$ is the summation of the total scores

N is the number of students

2.1.2 Standard Deviation

$$S.D. = \sqrt{\frac{N \sum X^2 - (\sum X)^2}{N(N-1)}}$$

$S.D.$ is Stand Deviation

$\sum X^2$ is The total scores of each student

$(\sum X)^2$ is The total scores

N is The number of students

2.2 Statistics for Evaluating the Learning Unit

The developed materials in this study were analyzed as follows:

2.2.1 The Index of Consistency (IOC)

The IOC was used to evaluate the congruence of draft FEACA Model, learning unit, conceptual understanding test, analytical thinking test, application of knowledge test, and opinions questionnaire toward the FEACA Model. Each response from the questionnaire of three level rating scales was weighed by the experts as follows:

The consistency level	Scale value (points)
Consistent	+1
Unsure	0
Inconsistent	-1

The data of IOC evaluation form were analyzed to find the Index of Consistency (IOC) using the following formula:

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

IOC is the Index of Consistency

$\sum R$ is the summation of experts' opinion marks

N is the number of experts

Note 0.75 – 1.00 = strongly congruence

0.50 – 0.75 = congruence

Less than 0.50 = have to modify

2.2.2 The Item Difficulty (p)

Analyzing the item difficulty (p) of the conceptual understanding test, the analytical thinking test and the application of knowledge test were used the formula as follows:

$$p = \frac{R}{N}$$

p is the item difficulty

R is the number of students answering the item correctly

N is the total number of students answering the test

2.2.3 The Item Discrimination (r)

Analyzing the test item of discrimination (r) of the conceptual understanding test and the analytical thinking test were computed by using the formula as follows:

$$r = \frac{(R_U - R_L)}{N}$$

r is the item discrimination

R_U is the number of students in the top group that got the item correct

R_L is the number of students in the bottom group that got the item correct

N is the number of students in the top group or the bottom Group

2.2.4 The Reliability of the Research Instruments

2.2.4.1 The reliability of the conceptual understanding test and the analytical thinking test were computed by using the Kuder and Richardson formula 20: KR-20 as shown below:

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

r_{tt} is the reliability of the test

k is the number of items in the tests

p is the ratio of right answer in each item = $\frac{\text{total of right item}}{\text{total of students}}$

q is the ratio of wrong in each item = $1 - p$

s_t^2 is the variance of whole tests

2.2.4.2 The reliability of the application of knowledge test and the opinions questionnaire toward the FEACA Model were computed by using the Cronbach's coefficient alpha. The formula was shown below:

$$\alpha = \frac{k}{k-1} \left\{ 1 - \frac{\sum s_i^2}{s_t^2} \right\}$$

α is the reliability of the test

k is the number of items in the test

s_i^2 is the variance of each item

s_t^2 is the variance of whole test

2.3 Statistics for Testing Research Hypotheses

3.1 The dependent sample t-test was applied to compare pretest and posttest mean scores of the students' conceptual understanding and analytical thinking in experimental group for testing the first and the third hypotheses.

3.2 The independent sample t-test was applied to compare posttest mean scores of the students' conceptual understanding, analytical thinking and application of knowledge between the experimental group and the control group for testing the second, the fourth, and the fifth hypotheses.

3.3 The basic statistic was applied to analyze mean scores of the students' opinions toward the FEACA Model of the experimental group. The mean score of the students' opinions toward the FEACA Model was evaluated comparing to the criteria score. The five category scores were as follows:

The mean score 4.51-5.00 interpreted as a very high level of agreement.

The mean score 3.51-4.50 interpreted as a high level of agreement.

The mean score 2.51-3.50 interpreted as a moderate level of agreement.

The mean score 1.51-2.50 interpreted as a low level of agreement.

The mean score 1.00-1.50 interpreted as a very low level of agreement.



CHAPTER 4

FINDINGS

This chapter presents the results of the study on the development of the science instructional model and also the implementation of this model on students' conceptual understanding, analytical thinking, application of knowledge, and opinions toward the science instructional model. The finding of the study included three main sections as follows: 1) the results of the science instructional model development, 2) the results of a pilot study, and 3) the results of the science instructional model implementation.

The Results of the Science Instructional Model Development

The draft science instructional model was classified into two main parts as follows: 1) the FEACA model and 2) the learning unit

1. The FEACA Model

The FEACA model was developed based on the key features of contextual approach and analysis processes of Marzano which consisted of five steps of learning, namely, Focusing, Exploring, Analyzing, Conceptual Developing, and Applying.

The draft FEACA model was evaluated by advisors and five experts to check the validity of the model. After gathering the data, the FEACA Model evaluation forms were analyzed Item of Consistency (IOC). The results of experts' consideration are shown in TABLE 7.

The results have shown that IOC of almost all items were more than 0.75 which meant the items were strongly congruence, and only one item was 0.60 which meant congruence. In conclusion, there was consistency in every aspect of the FEACA Model. These meant the FEACA Model was appropriate to be the science instructional model for using in the science classroom.

TABLE 7 THE RESULTS OF EVALUATION VALIDITY OF THE FEACA MODEL

Lists of Evaluation	N = 5					IOC	Interpretation
	E ₁	E ₂	E ₃	E ₄	E ₅		
1. The goals of learning management consistent with problems and importance.	1	1	0	0	1	0.60	Congruence
2. The goals of learning management consistent with the FEACA Model.	1	1	1	1	1	1.00	Strongly congruence
3. The FEACA Model consistent with basic idea.	1	1	1	1	1	1.00	Strongly congruence
4. Learning steps in the FEACA Model consistent with science instructional management.	1	1	0	1	1	0.80	Strongly congruence
5. Each step of the FEACA Model has consistency.	1	1	1	1	1	1.00	Strongly congruence
6. Activities in Focusing step were appropriate.	1	1	1	1	1	1.00	Strongly congruence
7. Activities in Exploring step were appropriate.	1	1	1	1	1	1.00	Strongly congruence
8. Activities in Analyzing step were appropriate.	1	1	1	1	1	1.00	Strongly congruence
9. Activities in Conceptual Developing step were appropriate.	1	1	1	1	1	1.00	Strongly congruence
10. Activities in Applying step were appropriate.	1	1	1	1	1	1.00	Strongly congruence
11. The FEACA Model was appropriate for content of learning unit.	1	1	1	1	1	1.00	Strongly congruence
12. The FEACA Model was appropriate for using.	1	1	1	1	1	1.00	Strongly congruence

Suggestions from the experts

In addition to the evaluation shown above, the experts also gave suggestions for the model improvement as follows:

1. The goals of the FEACA Model lacked of the development of scientific attitude that was mentioned in the basic core curriculum.

2. The evaluation method should be clearly mentioned in each step of the FEACA Model.

3. Teacher's role and student's role in each step should be clearly stated for the benefit of the model using in the classroom.

2. The Learning Unit

The draft learning unit was developed according to the FEACA model consisted of teacher's guide and instructional plans.

The draft instructional plans were evaluated by five experts to check the validity of the instructional plans. After gathering the data, the instructional plans evaluation forms were analyzed Index of Consistency (IOC). The results of the Index of Consistency (IOC) from evaluating the congruence of the instructional plans components are presented in TABLE 8. More detail of each instructional plan is shown in APPENDIX B.2.

The results have shown that IOC of many instructional plans were more than 0.75 which meant the items were strongly congruence, and only some item was 0.60 which meant congruence. In conclusion, there was consistency in every aspect of the learning unit. This meant the learning unit was appropriate for using in the science classroom.

Suggestions from the experts

1. The goals of learning did not cover the learning indicators in some instructional plans.

2. In the goals of learning, the experiment should be separated from summary and the explanation should be used instead of the summary. For the goals of experiment, it should clearly state what students have to do such as designing the experiment or doing the experiment.

3. Instructional plan 1 press more emphasize on calculation in students' worksheet.

4. Indicator for using in evaluation part should be experimental report.

5. In some instructional plan, the conclusion of the experiment could not lead to the conceptual understanding development.

6. The analyzing step should add more discussion.

TABLE 8 THE LESSON PLANS CONGRUENCE EVALUATION

List of evaluation	IOC of Instructional Plans					
	E ₁	E ₂	E ₃	E ₄	E ₅	E ₆
1. The learning goals consistent with indicators and the purposes of the science instructional model.	0.60	0.80	0.60	0.60	0.60	0.80
2. Learning activities consistent with the science instructional model.	1.00	1.00	1.00	1.00	1.00	1.00
3. Learning activities in Focusing step were appropriate.	1.00	1.00	1.00	1.00	1.00	1.00
4. Learning activities in Exploring step were appropriate.	1.00	1.00	1.00	1.00	1.00	0.80
5. Learning activities in Analyzing step were appropriate.	1.00	1.00	0.80	1.00	1.00	1.00
6. Learning activities in Conceptual Developing step were appropriate.	1.00	1.00	0.80	1.00	1.00	0.80
7. Learning activities in Applying step were appropriate.	1.00	1.00	0.80	1.00	1.00	1.00
8. Instructional materials were appropriate for learning activities.	1.00	1.00	1.00	1.00	1.00	1.00
9. Assessment and evaluation consistent with the learning goals.	1.00	0.80	0.80	0.80	0.80	1.00
10. Contents were appropriate for learners.	1.00	1.00	1.00	1.00	1.00	1.00
11. Content was correct.	1.00	1.00	1.00	1.00	1.00	1.00
12. Time allocation in learning unit was appropriate for contents.	1.00	0.80	1.00	1.00	1.00	1.00

The Results of a Pilot Study

Regarding to the experts' comments and suggestions, the draft learning unit was revised and then applied to the classroom in order to obtain the feedback from the students as well as some information that was useful for the next revision after a pilot study

A pilot study was conducted within 8 weeks, three learning periods a week, during June 2011 through August 2011 in the first semester of the 2011 academic year with one classroom of ninth-grade students at Kanchanapisekwithayalai Uthaithani School, Uthaithani province, Thailand. The learning unit based on the FEACA Model was applied to students for checking appropriateness of time arrangement, and instructional processes. The details were shown as follows:

1. Time Arrangement

Time arrangement for each instructional plan was revised as shown in TABLE 9

TABLE 9 THE REVISION OF THE TIME USED IN THE INSTRUCTIONAL PLANS

Week	Instructional Plan	Number of period used	
		The 1 st draft	Revised one
1	Introduction and pretest	3	2
2	Instructional plan 1: Acceleration	2	2
3	Instructional plan 2: Action and Reaction	3	3
4	Instructional plan 3: Friction	3	3
5	Instructional plan 4: Moment	3	3
6	Instructional plan 5: Buoyant Force	3	3
7	Instructional plan 6: Motion of Objects	2	2
8	Posttest	3	3
	Total	22	21

2. Instructional Process

According to the culture of Thai students, it was quite difficult to stimulate students' participating in the activities because they were quiet students. Therefore, in each step of instruction, the instructors have to ask more questions and identify which students have to answer the question.

3. Results of Using the Learning Unit

After applying the learning unit, the results of evaluating the learning unit on a pilot study on students' conceptual understanding, analytical thinking, application of knowledge, and opinions toward the FEACA Model were as follows:

3.1 Conceptual Understanding

After applying the FEACA Model on the pilot study, the pretest and posttest scores of students' conceptual understanding were collected and analyzed. The results of the comparison of the pretest and posttest mean scores of students' conceptual understanding are shown in TABLE 10.

TABLE 10 THE RESULTS OF STUDENTS' CONCEPTUAL UNDERSTANDING IN THE PILOT STUDY

Score	N	Mean	S.D.	Mean of Difference	t	p
Pretest	34	7.585	2.991	4.024	8.462 [*]	.000
Posttest	34	11.610	4.080			

$$t_{(.05; df 33)} = 2.034$$

The results of the dependent samples t-test have shown that the students' conceptual understanding posttest mean scores were higher than the pretest mean scores with a statistically significant difference at .05 level. The finding from analyzing data implied that the FEACA Model was effective to enhance students' conceptual understanding on force and motion concept.

3.2 Analytical Thinking

After applying the FEACA Model on the pilot study, the pretest and posttest scores of students' analytical thinking were collected and analyzed. The results of the comparison of the pretest and posttest mean scores of students' analytical thinking are shown in TABLE 11.

TABLE 11 THE RESULTS OF STUDENTS' ANALYTICAL THINKING IN THE PILOT STUDY

Score	N	Mean	S.D.	Mean of Difference	t	p
Pretest	34	9.415	4.995	3.024	7.524 [*]	.000
Posttest	34	12.439	4.129			

$$t_{(.05; df 33)} = 2.034$$

The results of the dependent samples t-test have shown that students' analytical thinking posttest mean scores were higher than the pretest mean scores with a statistically significant difference at .05 level. The finding from analyzing data implied that the FEACA Model was effective to enhance students' analytical thinking.

3.3 Opinions toward the FEACA Model

After applying the FEACA Model on the pilot study, the students' opinions toward the FEACA Model scores after learning were collected and analyzed. The results of students' opinions toward the FEACA Model are shown in TABLE 12.

TABLE 12 THE RESULTS OF STUDENTS' OPINIONS TOWARD THE FEACA MODEL IN
THE PILOT SUTDY

Lists of Evaluation	Mean	S.D.	Interpretation
1. Learning by using situation in daily life help students understand more about science content.	4.18	0.66	High
2. Learning by using situation in daily life make students seen that science is easy.	3.65	0.77	High
3. Learning by using situation in daily life make students seen that science is around us.	4.00	0.95	High
4. Learning by using situation in daily life make students feel bored because they have already known about that.	3.35	1.10	Modulate
5. Learning by using situation in daily life make students more interested in science.	4.12	0.84	High
6. Learning by using situation in daily life make students want to learn more about science.	4.06	0.81	High
7. Learning activities make students feel uncomfortable when they were asked questions.	3.11	1.20	Modulate
8. Learning activities help student to compare the similarity and the difference of things.	3.82	0.97	High
9. Learning activities help students to classify by using appropriate criteria.	3.85	0.88	High
10. Learning activities help students to analyze correct or wrong data.	3.74	0.83	High
11. Learning activities help students to conclude the experiment from collecting data.	4.03	0.87	High
12. Learning activities help student to apply the knowledge.	4.03	0.67	High
13. Learning activities help students to using the knowledge in daily life.	4.15	0.74	High

TABLE 12 (continued)

Lists of Evaluation	Mean	S.D.	Interpretation
14. Instructional activities consistent with dairy life.	4.03	0.90	High
15. Students feel uncomfortable when presenting the work in front of the class.	2.94	1.25	Modulate
16. Students have opportunity to share their ideas.	4.00	0.85	High
17. Learning activities are variety and interesting.	4.21	0.81	High
18. While learning, students would like the class to finish.	3.12	1.07	Modulate
19. Students feel happy when learning science	4.12	0.88	High
20. Students are bored when doing the science experiment	3.62	1.48	High

From the analyzing data, it was found that the students' opinions toward the FEACA Model were at the high level of agreement. Some item was at the modulate level of agreement.

After conducting the pilot study, the learning unit was revised according to the problems found in the classroom. The advisors verified the revisions before using in implementation phase.

The Results of the FEACA Model Implementation

The implementation was conducted within 8 weeks, three learning periods a week, during August 2011 through September 2011 in the first semester of the 2011 academic year with two classrooms of the ninth-grade students at Nongkhayangwittaya School, Uthaitani Province, Thailand. One classroom was served as an experimental group taught with the FEACA Model, and the other was served as a control group taught with the traditional instruction. The conceptual understanding, analytical thinking, application of knowledge, and opinions toward the FEACA Model were collected by using the following instruments: the conceptual understanding test, the analytical thinking test, the application

of knowledge test, and the opinions questionnaire toward the FEACA Model. The results from analyzing the quantitative data were used to test the following research hypotheses:

2.1 Testing the First Hypothesis

The first hypothesis stated that students' conceptual understanding posttest mean scores of the experimental group are higher than the pretest mean scores with a statistically significant difference.

The results of the comparison of students' conceptual understanding mean scores before and after the implementation of the experimental group are shown in TABLE 13.

TABLE 13 THE COMPARISONS OF THE PRETEST AND POSTTEST MEAN SCORES ON STUDENTS' CONCEPTUAL UNDERSTANDING OF EXPERIMENTAL GROUP

Score	N	Mean	S.D.	Mean of Difference	t	p
Pretest	29	7.379	2.441	6.138	4.600**	0.000
Posttest	29	13.517	4.380			

$$t_{(.01; df 28)} = 1.701$$

The results of the dependent samples t-test indicated that the students' conceptual understanding posttest mean scores were higher than the pretest mean scores with a statistically significant difference at .01 level which were consistent with the first hypothesis. The finding from analyzing data implied that the FEACA Model was effective to enhance students' conceptual understanding on force and motion concept.

2.2 Testing the Second Hypothesis

The comparison of conceptual understanding posttest mean scores of the experimental group and the control group was examined to test the second hypothesis. The second hypothesis stated that students' conceptual understanding posttest mean scores of the experimental group are higher than that of the control group with a statistically significant difference. The results of testing the second hypothesis are shown in TABLE 14.

TABLE 14 THE COMPARISONS OF THE POSTTEST MEAN SCORES ON STUDENTS' CONCEPTUAL UNDERSTANDING BETWEEN EXPERIMENTAL GROUP AND CONTROL GROUP

Score	N	Mean	S.D.	Mean of Difference	t	p
Experimental group	29	13.517	4.380	3.828	2.121**	0.000
Control group	29	9.690	2.106			

$$t_{(.01; df 28)} = 1.701$$

The results of the independent sample t-test illustrated that students' conceptual understanding posttest mean scores of the experimental group were higher than that of the control group with a statistically significant difference at .01 level which were consistent with the second hypothesis. The finding from the analyzed data implied that the FEACA Model was effective to enhance students' conceptual understanding on force and motion concept better than the traditional instruction.

2.3 Testing the Third Hypothesis

The comparison of analytical thinking before and after the implementation of the FEACA Model was examined to test the third hypothesis. The third hypothesis stated that students' analytical thinking posttest mean scores of the experimental group are higher than the pretest mean scores with a statistically significant difference.

The results of the comparison of students' conceptual understanding mean scores before and after the implementation of the experimental group are shown in TABLE 15

TABLE 15 THE COMPARISONS OF THE PRETEST AND POSTTEST MEAN SCORES ON STUDENTS' ANALYTICAL THINKING OF EXPERIMENTAL GROUP

Score	N	Mean	S.D.	Mean of Difference	t	p
Pretest	29	10.138	3.125	3.103	3.254**	0.000
Posttest	29	13.241	4.172			

$$t_{(.01; df 28)} = 1.701$$

The results of the dependent samples t-test indicated that students' analytical thinking posttest mean scores were higher than the pretest mean scores with a statistically significant difference at .01 level which were consistent with the third hypothesis. The finding from the analyzed data implied that the FEACA Model was effective to enhance students' analytical thinking for the lower secondary school students.

2.4 Testing the Fourth Hypothesis

The comparison of the analytical thinking posttest mean scores of the experimental group and the control group was examined to test the fourth hypothesis. The fourth hypothesis stated that students' analytical thinking posttest mean scores of the experimental group are higher than that of the control group with a statistically significant difference.

The results of comparison of students' analytical thinking posttest mean scores between the experimental group and the control group are shown in TABLE 16

TABLE 16 THE COMPARISONS OF THE POSTTEST MEAN SCORES ON STUDENTS' ANALYTICAL THINKING BETWEEN EXPERIMENTAL GROUP AND CONTROL GROUP

Score	N	Mean	S.D.	Mean of Difference	t	p
Experimental group	29	13.241	4.172	2.448	2.454*	0.000
Control group	29	10.793	3.385			

$$t_{(.05; df 28)} = 2.048$$

The results of the independent sample t-test indicated that the students' analytical thinking posttest mean scores of experimental group were higher than that of the control group with a statistically significant difference at .05 level which were consistent with the fourth hypothesis. The finding from the analyzed data implied that the FEACA Model was effective to enhance students' analytical thinking better than the traditional instruction.

2.5 Testing the Fifth Hypothesis

The comparison of the application of knowledge posttest mean scores of the experimental group and the control group was examined to test the fifth hypothesis. The fifth hypothesis stated that students' application of knowledge posttest mean scores of the experimental group is higher than that of the control group with a statistically significant difference.

The results of the comparison of students' application of knowledge posttest mean scores between the experimental group and the control group are shown in TABLE 17

TABLE 17 THE COMPARISONS OF THE POSTTEST MEAN SCORES ON STUDENTS' APPLICATION OF KNOWLEDGE BETWEEN EXPERIMENTAL GROUP AND GONTROL GROUP

Score	N	Mean	S.D.	Mean of Difference	t	p
Experimental group	29	11.00	5.568	2.759	2.293*	0.000
Control group	29	8.241	3.313			

$$t_{(.05; df 28)} = 2.048$$

The results of the independent sample t-test illustrated that the students' application of knowledge posttest mean scores of the experimental group were higher than that of the control group with a statistically significant difference at .05 level which were consistent with the fifth hypothesis. The finding from the analyzed data implied that the

FEACA Model was effective to enhance students' application of knowledge better than the traditional instruction.

2.6 Testing the Sixth Hypothesis

The investigation of students' opinions toward the FEACA Model after the implementing was examined to test the sixth hypothesis. The sixth hypothesis stated that students' opinions scores toward the FEACA Model of the experimental group after implementation are at high level of performance.

The results of students' opinions toward the FEACA Model are shown in TABLE 18

TABLE 18 THE RESULTS OF STUDENTS' OPINIONS TOWARD THE FEACA MODEL

Lists of Evaluation	Mean	S.D.	Interpretation
1. Learning by using situation in daily life help students understand more about science content.	4.55	0.63	Very high
2. Learning by using situation in daily life make students seen that science is easy.	4.21	0.71	High
3. Learning by using situation in daily life make students seen that science is around us.	4.55	0.63	Very high
4. Learning by using situation in daily life make students feel bored because they have already known about that.	3.79	1.32	High
5. Learning by using situation in daily life make students more interested in science.	4.38	0.68	High
6. Learning by using situation in daily life make students want to learn more about science.	4.48	0.74	High
7. Learning activities make students feel uncomfortable when they were asked questions.	3.90	0.93	High
8. Learning activities help student to compare the similarity and the difference of things.	4.34	0.67	High
9. Learning activities help students to classify by using appropriate criteria.	4.24	0.69	High

TABLE 18 (continued)

Lists of Evaluation	Mean	S.D.	Interpretation
10. Learning activities help students to analyze correct or wrong data.	4.07	0.84	High
11. Learning activities help students to conclude the experiment from collecting data.	4.41	0.68	High
12. Learning activities help student to apply the knowledge.	4.41	0.68	High
13. Learning activities help students to using the knowledge in daily life.	4.55	0.51	Very high
14. Instructional activities consistent with daily life.	4.31	0.76	High
15. Students feel uncomfortable when presenting the work in front of the class.	3.69	1.31	High
16. Students have opportunity to share their ideas.	4.28	0.65	High
17. Learning activities are variety and interesting.	4.55	0.74	Very high
18. While learning, students would like the class to finish.	3.72	1.44	High
19. Students feel happy when learning science	4.66	0.55	Very high
20. Students are bored when doing the science experiment	4.38	1.26	High

From the analyzing, it was found that the students' opinions toward the FEACA Model were at the high level of agreement. Some item was at the very high level of agreement.

All the results indicated that the FEACA Model developed by research was effective to promote students' conceptual understanding, analytical thinking, and application of knowledge better than the traditional instruction. Additionally, students' opinions toward the FEACA Model was high level of agreement

CHAPTER 5

CONCLUSION AND DISCUSSION

This chapter represents a summary of the study followed by conclusion, discussion, and recommendation based upon the development and implementation of the FEACA Model on a learning unit covering the topic of “Force and Motion” for lower secondary school students by presenting to the following topics:

Research Objectives

The objectives of the study are summarized as follows:

1. To develop and implement the FEACA Model for lower secondary school students.
2. To make a comparison between conceptual understanding and analytical thinking of students before and after learning through the FEACA Model.
3. To make a comparison between conceptual understanding, analytical thinking, and application of knowledge of students who learn through the FEACA Model and those of students who learn through the traditional instruction
4. To explore students' opinions toward the FEACA Model after learning through the FEACA Model.

Research Hypotheses

The research hypotheses of this study are as follows:

1. Students' conceptual understanding posttest mean scores of the experimental group are higher than the pretest mean scores with a statistically significant difference.
2. Students' conceptual understanding posttest mean scores of the experimental group are higher than that of the control group with a statistically significant difference.
3. Students' analytical thinking posttest mean scores of the experimental group are higher than the pretest mean scores with a statistically significant difference.
4. Students' analytical thinking posttest mean scores of the experimental group are higher than that of the control group with a statistically significant difference.

5. Students' application of knowledge posttest mean scores of the experimental group are higher than that of the control group with a statistically significant difference.

6. Students' opinions scores toward the FEACA Model of the experimental group after the implementation are at high level of performance.

Research Instruments

The research instruments in this study consisted of the following topics:

1. The Conceptual Understanding Test which was 30 items of multiple choice questions with reliability at 0.78 and difficulty levels was between 0.23-0.75

2. The Analytical Thinking Test which was 25 items of multiple choice questions with reliability at 0.79 and difficulty levels was 0.25-0.73

3. The Application of Knowledge Test which was 12 items of open-ended questions with reliability at 0.76 and difficulty levels was 0.28-0.77

4. The Opinions Questionnaires toward the FEACA Model which was 20 items of five point rating scale questionnaires with reliability at 0.84.

Scope of the Study

Population

The populations of this study were the lower secondary school students who were studying in the first semester of the 2011 academic year in Uthaithani province, Thailand.

Sample

The students participating during the implementation were two classrooms of the ninth-grade students which were mixed ability. They were studying in the first semester of the 2011 academic year of Nongkhayangwittaya School in Uthaithani province, Thailand. One classroom was the experimental group taught with the FEACA Model whereas the other was the control group taught with the traditional instruction.

Sampling

The conceptual understanding test and the analytical thinking test were administered with four classrooms of the ninth-grade in Nongkhayangwittaya School. Mean

$(\bar{X})$ and Standard deviation (S.D) of the pretest conceptual understanding scores and the pretest analytical thinking scores of four classrooms were analyzed one-way analysis of variance (One-way ANOVA) by using the F-test and found that there were no statistically significant difference between each other, both the conceptual understanding and the analytical thinking. The four classrooms were separated into two groups depended on the number of students, group 1: Gr. 9/1 and Gr. 9/2 and group 2: Gr. 9/3 and Gr. 9/4. The second group was selected by using simple random sampling. At last, the Gr. 9/4 was selected as the experimental group and the Gr. 9/3 was selected as the control group by using simple random sampling.

Variables of the Study

1. Independent Variables

- 1.1 Teaching with the FEACA Model
- 1.2 Teaching with the traditional instruction

2. Dependent Variables

- 2.1 Conceptual understanding.
- 2.2 Analytical thinking.
- 2.3 Application of knowledge.
- 2.4 Students' opinions toward the FEACA Model.

Content

The content for using in this study was developed based on the national science curriculum standard, Strand 4: Force and Motion, for the ninth-grade students. It consisted of six topics as follows: 1) Acceleration, 2) Action and Reaction, 3) Friction, 4) Moment, 5) Buoyant Force, and 6) Motion of Objects.

Research Methodology

The research methodology used in this study consisted of six phases as follows:

Phase 1: Studying Basic Information for Developing Science Instructional Model

The basic information concerning the Thailand's National Education Act B.E. 2542 (1999) and Amendments (Second National Education Act B.E. 2545 (2002)), and the Thai Basic Education Core Curriculum B.E. 2551 (2008) emphasized the promotion of

science conceptual understanding, science process skills, thinking ability, as well as scientific attitude to all students. From the investigation of research and document found that traditional instructional could not enhance conceptual understanding and analytical thinking of the lower secondary school students. Therefore, the learning theories and science instructional method were investigated for solving the problems.

Phase 2: Developing the FEACA Model

The contextual approach and Marzano's analysis processes were used to be the conceptual framework for developing the FEACA Model. The model was used to promote students' conceptual understanding, analytical thinking, and application of knowledge. The draft of the model was examined the efficiency by five experts and revised based on their comments and suggestions. This model consisted of five steps of learning namely 1) Focusing, 2) Exploring, 3) Analyzing, 4) Conceptual Developing, and 5) Applying. The details of each step were as follows:

Step 1: Focusing

The purposes of this step are to catch students' attention and diagnose their prior knowledge by engaging them with real life context. At this step, the everyday life situation will be presented as a starting point in order to recall student's experiences related to that situation and check their prior knowledge about the concept they will learn in the class. Teacher encourages students to think by asking a question related to that situation. Students answer the question and compare similarities and differences of their own answers with their friends' answers as well as organize those answers into meaningful categories. Students communicate what they get by sharing with their peers. At the end of the step the answers will not be verified right or wrong, but it will be the problem for investigating in the next step.

Step 2: Exploring

The purpose of this step is to give students opportunity to investigate through hands-on and mind-on exploration which built upon the everyday life situation from the first step. At this step, students will be separated into small groups and do experiments or activities for exploring the answer of the questions developed in first step. Teacher acts as

a facilitator helping students if they meet any problems and checks whether students obtain all necessary information for using in the next step.

Step 3: Analyzing

The purpose of this step is to give students an opportunity to analyze data and construct knowledge by their own under the facilitating of a teacher. At this step, the students find the relationship of information from their observation by answering the questions and summarizing what they get for constructing their own knowledge. Students communicate their understanding by sharing with the whole class.

Step 4: Conceptual Developing

The purpose of this step is to construct correct conceptual understanding about that topic under the facilitating of a teacher. At this step, the students discuss the conclusion from the previous step and re-shape their understanding under the facilitating of a teacher. Furthermore, students study more about the topic from documents and relate the concepts they have learned with the situation in the first step. The roles of the teacher are to help students to construct scientific conceptual understanding and correct all misconception.

Step 5: Applying

The purpose of this step is to apply scientific concept to new contexts. At this step, the students in each group apply conceptual understanding they have learned in the class to new contexts or real life situations and share with the whole class. The students also need to give the reason to explain the reasonableness of the information. The students in other groups then evaluate validity of that application and identify any errors in reasoning that have been presented.

Phase 3: Developing the Research Instruments

The research instruments for using in this study were as follows:

1. The Learning Unit

The learning unit was developed according to the five steps of the FEACA Model. The documents involving in the learning unit consisted of teacher's guide and instructional plans.

2. The Conceptual Understanding Test

The conceptual understanding test was used to assess students' understanding the main concepts on "Force and Motion". The content areas comprised of Acceleration, Action and Reaction, Friction, Moment, Buoyant Force, and Motion of Objects. The test composed of 30 items of multiple choice questions, each of which had four alternative choices consisted of only one correct answer and three possible answers based upon students' misconceptions about the topics. The reliability of the test was 0.78. The p value ranked from 0.23 to 0.75 and the r value ranked from 0.21 to 0.63.

3. The Analytical Thinking Test

The analytical thinking test was developed based on Marzano's analytical thinking which comprised of matching, classifying, error analysis, generalizing, and specifying. The test composed of 25 items of multiple choice questions, each of which had four alternative choices and one correct answer. The reliability of the test was 0.79. The p value ranked from 0.25 to 0.73 and the r value ranked from 0.22 to 0.70.

4. The Application of Knowledge Test

The application of knowledge test was developed based on the main concepts on "Force and Motion" which were Acceleration, Action and Reaction, Friction, Moment Buoyant Force, and Motion of Objects. The test contained 12 items of open-ended questions. The reliability of the test was 0.76. The p value ranked from 0.28 to 0.77 and the r value ranked from 0.26 to 0.69.

5. The Opinions Questionnaires toward the FEACA Model

The opinions questionnaires toward the FEACA Model comprised of 20 items of the five-point rating Likert Scale consisting of positive items and negative items. The reliability of the test was 0.84 and the r value ranked from 0.25 to 0.66.

Phase 4: Conducting a Pilot Study

The efficiency of the FEACA Model and assessment tools were examined by conducting a pilot study. This process checked out and revised all research instruments and research procedures before using in the implementation phase.

Phase 5: Implementing the FEACA Model

This study was a quasi-experimental research, Non-equivalent Control Group Pretest-posttest Design. The teaching with the FEACA Model was used as the experimental group, and the teaching with the tradition instruction was used as the control group and both groups were served as independent variables. The results of students' conceptual understanding, analytical thinking, application of knowledge, and opinions toward the FEACA Model were served as the dependent variables. After the conceptual understanding test and the analytical thinking were used to collect data in both groups, the learning unit developed based on the FEACA Model was applied to the Gr.9/4 students whereas the traditional instruction was applied to the Gr.9/3 students for 8 weeks. The conceptual understanding test, the analytical thinking test, and the application of knowledge test were applied to the students in both groups after the implementation. For the Gr. 9/4 students, the opinions questionnaire toward the FEACA Model was applied to them after using the FEACA Model.

Phase 6: Evaluating the FEACA Model

The collected data were analyzed for verifying the effectiveness of the FEACA Model by answering six hypotheses as follows:

1. Students' conceptual understanding posttest mean scores of the experimental group were higher than the pretest mean scores with a statistically significant difference.
2. Students' conceptual understanding posttest mean scores of the experimental group are higher than that of the control group with a statistically significant difference.
3. Students' analytical thinking posttest mean scores of the experimental group are higher than the pretest mean scores with a statistically significant difference.
4. Students' analytical thinking posttest mean scores of the experimental group are higher than that of the control group with a statistically significant difference.
5. Students' application of knowledge posttest mean scores of the experimental group are higher than that of the control group with a statistically significant difference.

6. Students' opinions scores toward the FEACA Model of the experimental group after implementation are at high level of performance.

Conclusion and Discussion

The conclusion and discussion of the research results include conceptual understanding, analytical thinking, application of knowledge, and students' opinions toward the FEACA Model.

1. Conceptual Understanding

Considering conceptual understanding of students who were taught with the FEACA Model, the posttest mean scores were higher than the pretest mean scores at the .01 level of significance. Similar to the result of Lubben, Campbell, and Dlamini (1996), they conducted research with Swazi secondary students to contextualized lessons on circuit electricity, air, and respiratory and found that the contextualized lessons influenced students' motivation and interest, concept development and participation. Moreover, Kruatong (2007) used the contextual approach to develop high school students' understanding and application of heat and thermodynamics concepts. The results showed that the students' understanding and application of knowledge were enhanced through the contextual approach.

Furthermore, the conceptual understanding posttest mean scores of students who were taught with the FEACA Model were higher than that of students who were taught with the traditional instruction at the .01 level of significance. The result in this part was similar to the finding of Bennett and Lubben (2006). They developed context-based courses for the upper high school students called Salters Advanced Chemistry. Their results indicated that the students developed levels of understanding of chemical ideas comparable to those taking more conventional course. Similarly, Gutwill-Wise (2001) compared the students who had followed the context-based approach of ChemConnections with matched groups of the students who had followed a traditional approach to chemistry. The study found that in both groups, the students who followed the context-based approach emerged with a better understanding of chemistry than their peers who followed a traditional approach.

Therefore, all the results above confirmed the potency of the FEACA Model developed based on contextual approach to be more effective than the traditional instruction in terms of promoting scientific conceptual understanding of the students.

2. Analytical Thinking

Considering analytical thinking of students who were taught with the FEACA Model, the posttest mean scores were higher than the pretest mean scores at the .01 level of significance. In addition, the analytical thinking posttest mean scores of the students who were taught with the FEACA Model were higher than that of students who were taught with the traditional instruction at the .05 level of significance.

The result of this part was similar to the finding of Harris, et al. (1995) and Macklin and Fosmire (2003), they used problem-based learning which based on a real life situation in their workshop and found that it could promote critical and analytical thinking of the participants. Correspondingly, the study of has developed a Competency-based Education and Training Programs which emphasized on a real life situation, and found that these programs could develop analytical thinking and the capacity to solve problems. Furthermore, the research explained that context encouraged the development of analytical thinking, critical thinking, and problem solving skills (Orange, 2002).

Accordingly, all the results confirmed that the FEACA Model based on contextual approach could enhance the students' analytical thinking better than the traditional instruction.

3. Application of Knowledge

Considering application of knowledge, the posttest mean scores of students who were taught with the FECA Model were higher than that of students who were taught with the traditional instruction at the .05 level of significance. This result was similar to the finding of Tunpiriyakul (2003). He studied the chemical knowledge-applying ability in daily life of the high vocation education certificate students. The results indicated that higher vocational education certificate students had the ability to apply the chemical knowledge in their daily lives at the moderate level. The comparison of the students' average ability in applying the chemical knowledge to their daily lives was not different with the confidentiality

of 95 percent, between those two groups of students who were studying in accounting and marketing.

Additionally, Kruatong (2007) used contextual approach to develop high school students' application of heat and thermodynamics concepts. The results showed that the application abilities of student were improved through this approach. The use of a situation as a learning context gave the students an opportunity to apply concepts they have learned to a new situation at the end of the lesson.

Thereby, the FEACA Model could promote students' application of knowledge better than the traditional instruction.

4. Students' Opinions toward the FEACA Model

Considering the opinions toward the FEACA Model, the students' opinions toward the FEACA Model after the implementation were analyzed. It was found that the students' opinions toward the FEACA Model were at the high level and some item were at the highest level.

All the results confirmed that the FEACA Model was a suitable model to teach students in science classroom because this instructional model provided students with opportunities to gain deeper understanding in scientific concepts as well as enhanced analytical thinking and application of knowledge. Therefore, the learning activities of the FEACA Model were the good activities for the science classroom.

The results of this study revealed that the FEACA Model was effective as a mean to develop conceptual understanding, analytical thinking and application of knowledge. Additionally, its finding revealed that the FEACA Model was effective and could be used in the classroom. This outcome will be used as a basic knowledge for educators and science teachers to guide their thinking to develop instructional strategies. Moreover, the FEACA Model will be an alternative pedagogy for science teachers to promote students to gain a deepened knowledge, develop analytical thinking and foster the scientific attitudes. This will prepare the students to get more readiness to confront the social change and get a higher quality of life in community.

Recommendation

1. Recommendation for School Administrators

The finding suggested that the FEACA Model was effective to enhance students' conceptual understanding, analytical thinking, and application of knowledge. Therefore, the school administrators should encourage and support teachers to develop their own learning unit based on the FEACA Model. Moreover, this model could help promoting the PISA scores because the PISA test focused on the real life situations. Therefore, administrators should press more emphasis on the instruction by using the FEACA Model in science classroom.

2. Recommendation for Teachers

2.1 Before using this science instructional model in the classroom, the teachers should read and clearly understand the teacher's guide before using so they know what to do in each step for helping students achieve the goals of learning.

2.2 For the most successful strategy of applying this science instructional model in the classroom, the teachers should act as facilitators to suggest and provide activities for the learners while the learners are encouraged to learn independently inside and outside the classroom and throughout their lives.

2.3 Science teacher who adapts the FEACA Model with other concepts should concern with the difficulty and appropriateness of the concepts by choosing the context or real life situation that go along with the concepts, and motivate the students to get more readiness for learning.

2.4 The use of the FEACA Model applied the familial experiments used in normal class but rearranged the processes of instruction. This showed that the teacher could still use familial experiment but also promote students' conceptual understanding and analytical thinking by using the FEACA Model.

3. Recommendation for Further Studies

3.1 Further studies should consider the content change from Force and Motion to other physics concepts. Also, further studies should change the concept from physics to

chemistry, biology, or any other science areas even the other subjects that have different nature from science.

3.2 In each step of the FEACA Model, there were still some problems especially about the time allocation. There was the limitation of time in which the students wanted to spend more time for discussion and reach to the goal of each step. So, further studies should allocate the time for each step more suitably.

3.3 Further studies should apply the science instructional model emphasizing contextual approach for developing other higher order of thinking such as creative thinking, critical thinking, or problem solving.





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Appendix A

The Lists of Experts and Participating Teachers

A.1 The Lists of Experts

A.2 The List of Participating Teachers

A.1 The List of Experts

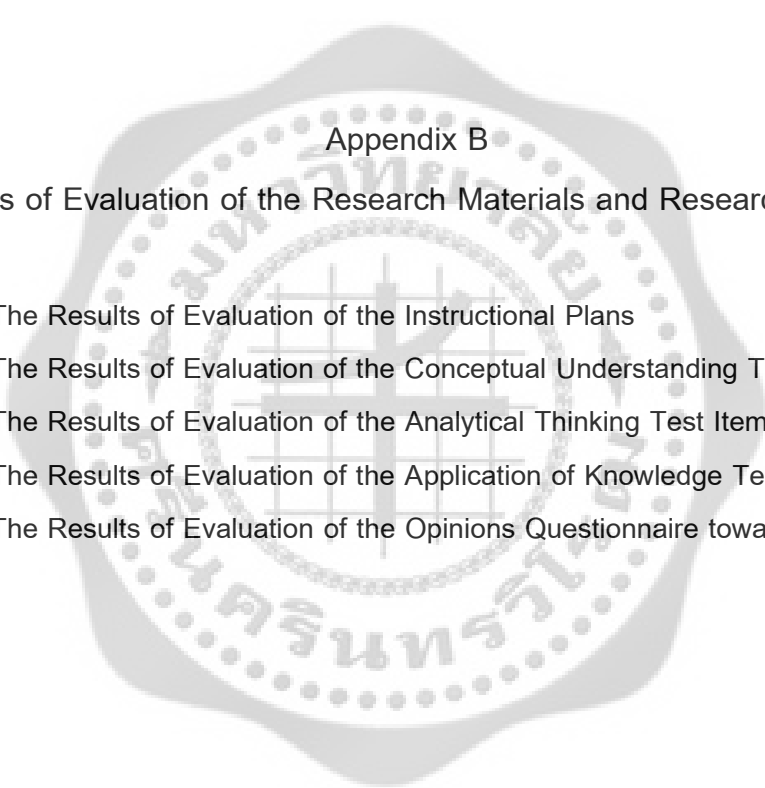
There are five experts who verified the quality of the draft FEACA Model, learning unit and instruments for collecting data.

1. Dr. Pramuan Siripunkaew
The Institute for the Promotion of Teaching Science, and Technology (IPST)
2. Assoc. Prof. Dr. Prapansiri Susaorat
Division of Elementary, Faculty of Education, Srinakharinwirot University
3. Assist. Prof. Buncha Silpasakulsuk
Department of Physics, Faculty of Science, Srinakharinwirot University
4. Dr. Sompratana Wongboonnuk
Department of General Science, Faculty of Science, Srinakharinwirot University
5. Kru Somchai Durongpinon
Samsenwittayalai School, Bangkok

A.2 The Lists of Participating Teachers

There are three teachers who excellently helped in collaborating and providing the necessary materials during collecting data in school.

1. Kru Paiboon Pakdi
Nongchangwittaya School, Uthaithani
2. Kru Chanidapa Muangmi
Kanchanapisekwittayalai Uthaithani School, Uthaithani
3. Kru Tipparat Chuearod
Nongkhayangwittaya School, Uthaithani



Appendix B

The Results of Evaluation of the Research Materials and Research Instruments

B.1 The Results of Evaluation of the Instructional Plans

B.2 The Results of Evaluation of the Conceptual Understanding Test Items

B.3 The Results of Evaluation of the Analytical Thinking Test Items

B.4 The Results of Evaluation of the Application of Knowledge Test Items

B.5 The Results of Evaluation of the Opinions Questionnaire toward th FEACA

Model Items

B.1 The Results of Evaluation of the Instructional Plans

TABLE 19 THE RESULTS OF EVALUATION ON IOC OF INSTRUCTIONAL PLAN 1:
ACCELERATION

Lists of Evaluation	N = 5					IOC	Interpretation
	E ₁	E ₂	E ₃	E ₄	E ₅		
1. The learning goals consistent with indicators and the purposes of the FEACA Model.	1	0	0	1	1	0.60	Congruence
2. Learning activities consistent with the FEACA Model.	1	1	1	1	1	1.00	Strongly congruence
3. Learning activities in Focusing step were appropriate.	1	1	1	1	1	1.00	Strongly congruence
4. Learning activities in Exploring step were appropriate.	1	1	1	1	1	1.00	Strongly congruence
5. Learning activities in Analyzing step were appropriate.	1	1	1	1	1	1.00	Strongly congruence
6. Learning activities in Conceptual Developing step were appropriate.	1	1	1	1	1	1.00	Strongly congruence
7. Learning activities in Applying step were appropriate.	1	1	1	1	1	1.00	Strongly congruence
8. Instructional materials were appropriate for learning activities.	1	1	1	1	1	1.00	Strongly congruence
9. Assessment and evaluation consistent with the learning goals.	1	1	1	1	1	1.00	Strongly congruence
10. Contents were appropriate for learners.	1	1	1	1	1	1.00	Strongly congruence
11. Content was correct.	1	1	1	1	1	1.00	Strongly congruence
12. Time allocation in learning unit was appropriate for contents.	1	1	1	1	1	1.00	Strongly congruence

TABLE 20 THE RESULTS OF EVALUATION ON IOC OF INSTRUCTIONAL PLAN 2: ACTION AND REACTION

Lists of evaluation	N = 5					IOC	Interpretation
	E ₁	E ₂	E ₃	E ₄	E ₅		
1. The learning goals consistent with indicators and the purposes of the FEACA Model.	1	1	0	1	1	0.80	Strongly congruence
2. Learning activities consistent with the FEACA Model.	1	1	1	1	1	1.00	Strongly congruence
3. Learning activities in Focusing step were appropriate.	1	1	1	1	1	1.00	Strongly congruence
4. Learning activities in Exploring step were appropriate.	1	1	1	1	1	1.00	Strongly congruence
5. Learning activities in Analyzing step were appropriate.	1	1	1	1	1	1.00	Strongly congruence
6. Learning activities in Conceptual Developing step were appropriate.	1	1	1	1	1	1.00	Strongly congruence
7. Learning activities in Applying step were appropriate.	1	1	1	1	1	1.00	Strongly congruence
8. Instructional materials were appropriate for learning activities.	1	1	1	1	1	1.00	Strongly congruence
9. Assessment and evaluation consistent with the learning goals.	1	1	0	1	1	0.80	Strongly congruence
10. Contents were appropriate for learners.	1	1	1	1	1	1.00	Strongly congruence
11. Content was correct.	1	1	1	1	1	1.00	Strongly congruence
12. Time allocation in learning unit was appropriate for contents.	1	1	1	1	1	1.00	Strongly congruence

TABLE 21 THE RESULTS OF EVALUATION ON IOC OF INSTRUCTIONAL PLAN 3:

FRICTION

Lists of Evaluation	N = 5					IOC	Interpretation
	E ₁	E ₂	E ₃	E ₄	E ₅		
1. The learning goals consistent with indicators and the purposes of the FEACA Model.	1	1	-1	1	1	0.60	Congruence
2. Learning activities consistent with the FEACA Model.	1	1	0	1	1	1.00	Strongly congruence
3. Learning activities in Focusing step were appropriate.	1	1	1	1	1	1.00	Strongly congruence
4. Learning activities in Exploring step were appropriate.	1	1	1	1	1	1.00	Strongly congruence
5. Learning activities in Analyzing step were appropriate.	1	1	0	1	1	0.80	Strongly congruence
6. Learning activities in Conceptual Developing step were appropriate.	1	1	0	1	1	0.80	Strongly congruence
7. Learning activities in Applying step were appropriate.	1	1	0	1	1	0.80	Strongly congruence
8. Instructional materials were appropriate for learning activities.	1	1	1	1	1	1.00	Strongly congruence
9. Assessment and evaluation consistent with the learning goals.	1	1	0	1	1	0.80	Strongly congruence
10. Contents were appropriate for learners.	1	1	1	1	1	1.00	Strongly congruence
11. Content was correct.	1	1	1	1	1	1.00	Strongly congruence
12. Time allocation in learning unit was appropriate for contents.	1	1	1	1	1	1.00	Strongly congruence

TABLE 22 THE RESULTS OF EVALUATION ON IOC OF INSTRUCTIONAL PLAN 4: MOTION

Lists of Evaluation	N = 5					IOC	Interpretation
	E ₁	E ₂	E ₃	E ₄	E ₅		
1. The learning goals consistent with indicators and the purposes of the FEACA Model.	1	1	-1	1	1	0.60	Congruence
2. Learning activities consistent with the FEACA Model.	1	1	1	1	1	1.00	Strongly congruence
3. Learning activities in Focusing step were appropriate.	1	1	1	1	1	1.00	Strongly congruence
4. Learning activities in Exploring step were appropriate.	1	1	1	1	1	1.00	Strongly congruence
5. Learning activities in Analyzing step were appropriate.	1	1	1	1	1	1.00	Strongly congruence
6. Learning activities in Conceptual Developing step were appropriate.	1	1	1	1	1	1.00	Strongly congruence
7. Learning activities in Applying step were appropriate.	1	1	1	1	1	1.00	Strongly congruence
8. Instructional materials were appropriate for learning activities.	1	1	1	1	1	1.00	Strongly congruence
9. Assessment and evaluation consistent with the learning goals.	1	1	0	1	1	0.80	Strongly congruence
10. Contents were appropriate for learners.	1	1	1	1	1	1.00	Strongly congruence
11. Content was correct.	1	1	1	1	1	1.00	Strongly congruence
12. Time allocation in learning unit was appropriate for contents.	1	1	1	1	1	1.00	Strongly congruence

TABLE 23 THE RESULTS OF EVALUATION ON IOC OF INSTRUCTIONAL PLAN 5:
BUOYANT FORCE

Lists of Evaluation	N = 5					IOC	Interpretation
	E ₁	E ₂	E ₃	E ₄	E ₅		
1. The learning goals consistent with indicators and the purposes of the FEACA Model.	1	1	-1	1	1	0.60	Congruence
2. Learning activities consistent with the FEACA Model.	1	1	1	1	1	1.00	Strongly congruence
3. Learning activities in Focusing step were appropriate.	1	1	1	1	1	1.00	Strongly congruence
4. Learning activities in Exploring step were appropriate.	1	1	1	1	1	1.00	Strongly congruence
5. Learning activities in Analyzing step were appropriate.	1	1	1	1	1	1.00	Strongly congruence
6. Learning activities in Conceptual Developing step were appropriate.	1	1	1	1	1	1.00	Strongly congruence
7. Learning activities in Applying step were appropriate.	1	1	1	1	1	1.00	Strongly congruence
8. Instructional materials were appropriate for learning activities.	1	1	1	1	1	1.00	Strongly congruence
9. Assessment and evaluation consistent with the learning goals.	1	1	0	1	1	0.80	Strongly congruence
10. Contents were appropriate for learners.	1	1	1	1	1	1.00	Strongly congruence
11. Content was correct.	1	1	1	1	1	1.00	Strongly congruence
12. Time allocation in learning unit was appropriate for contents.	1	1	1	1	1	1.00	Strongly congruence

TABLE 24 THE RESULTS OF EVALUATION ON IOC OF INSTRUCTIONAL PLAN 6: MOTION OF OBJECTS

Lists of Evaluation	N = 5					IOC	Interpretation
	E ₁	E ₂	E ₃	E ₄	E ₅		
1. The learning goals consistent with indicators and the purposes of the FEACA Model.	1	1	0	1	1	0.80	Strongly congruence
2. Learning activities consistent with the FEACA Model.	1	1	1	1	1	1.00	Strongly congruence
3. Learning activities in Focusing step were appropriate.	1	1	1	1	1	1.00	Strongly congruence
4. Learning activities in Exploring step were appropriate.	1	1	0	1	1	0.80	Strongly congruence
5. Learning activities in Analyzing step were appropriate.	1	1	1	1	1	1.00	Strongly congruence
6. Learning activities in Conceptual Developing step were appropriate.	1	1	0	1	1	0.80	Strongly congruence
7. Learning activities in Applying step were appropriate.	1	1	1	1	1	1.00	Strongly congruence
8. Instructional materials were appropriate for learning activities.	1	1	1	1	1	1.00	Strongly congruence
9. Assessment and evaluation consistent with the learning goals.	1	1	1	1	1	1.00	Strongly congruence
10. Contents were appropriate for learners.	1	1	1	1	1	1.00	Strongly congruence
11. Content was correct.	1	1	1	1	1	1.00	Strongly congruence
12. Time allocation in learning unit was appropriate for contents.	1	1	1	1	1	1.00	Strongly congruence

B.2 The Results of Evaluation of the Conceptual Understanding Test Items

TABLE 25 THE RESULTS OF EVALUATION ON IOC OF THE CONCEPTUAL UNDERSTANDING TEST ITEMS

No.	N = 3			IOC	Interpretation	No.	N = 3			IOC	Interpretation
	E ₁	E ₂	E ₃				E ₁	E ₂	E ₃		
1	0	1	1	0.67	Congruence	15	1	1	1	1.00	Strongly congruence
2	0	1	1	0.67	Congruence	16	1	1	1	1.00	Strongly congruence
3	1	1	1	1.00	Strongly congruence	17	1	1	1	1.00	Strongly congruence
4	1	1	1	1.00	Strongly congruence	18	1	1	1	1.00	Strongly congruence
5	0	1	0	0.33	Need modification	19	1	1	1	1.00	Strongly congruence
6	0	1	0	0.33	Need modification	20	1	1	1	1.00	Strongly congruence
7	1	1	1	1.00	Strongly congruence	21	1	0	1	0.67	Congruence
8	1	1	1	1.00	Strongly congruence	22	0	1	1	0.67	Congruence
9	1	1	1	1.00	Strongly congruence	23	0	1	1	0.67	Congruence
10	1	1	1	1.00	Strongly congruence	24	1	1	1	1.00	Strongly congruence
11	1	1	1	1.00	Strongly congruence	25	1	1	1	1.00	Strongly congruence
12	1	1	1	1.00	Strongly congruence	26	1	1	1	1.00	Strongly congruence
13	1	1	1	1.00	Strongly congruence	27	1	1	1	1.00	Strongly congruence
14	1	1	1	1.00	Strongly congruence	28	1	1	1	1.00	Strongly congruence

TABLE 25 (continued)

No.	N = 3			IOC	Interpretation	No.	N = 3			IOC	Interpretation
	E ₁	E ₂	E ₃				E ₁	E ₂	E ₃		
29	1	1	1	1.00	Strongly congruence	45	1	0	1	0.67	Congruence
30	1	-1	1	0.33	Need modification	46	1	0	1	0.67	Congruence
31	1	1	1	1.00	Strongly congruence	47	1	1	1	1.00	Strongly congruence
32	1	1	1	1.00	Strongly congruence	48	1	1	1	1.00	Strongly congruence
33	1	1	1	1.00	Strongly congruence	49	1	1	1	1.00	Strongly congruence
34	1	1	1	1.00	Strongly congruence	50	1	0	1	0.67	Congruence
35	1	1	1	1.00	Strongly congruence	51	1	1	1	1.00	Strongly congruence
36	1	1	1	1.00	Strongly congruence	52	1	1	1	1.00	Strongly congruence
37	1	1	1	1.00	Strongly congruence	53	1	1	1	1.00	strongly congruence
38	1	1	1	1.00	Strongly congruence	54	1	0	1	0.67	congruence
39	1	1	1	1.00	Strongly congruence	55	1	1	1	1.00	Strongly congruence
40	1	1	1	1.00	Strongly congruence	56	1	1	1	1.00	Strongly congruence
41	1	1	1	1.00	Strongly congruence	57	1	1	1	1.00	Strongly congruence
42	1	1	1	1.00	Strongly congruence	58	1	1	0	0.67	Congruence
43	1	1	1	1.00	Strongly congruence	59	1	1	1	1.00	Strongly congruence
44	0	0	1	0.33	Need modification	60	1	1	1	1.00	Strongly congruence

TABLE 26 THE RESULTS OF EVALUATION ON ITEM DIFFICULTY (p) AND ITEM DISCRIMINATION (r) OF THE CONCEPTUAL UNDERSTANDING TEST ITEMS

No.	p	r	Interpretation	Used for No.	No.	p	r	Interpretation	Used for No.
1	0.15	0.06	Can not be used		32	0.67	0.47	Can be used	17
2	0.23	0.20	Can be used		33	0.67	0.66	Can be used	18
3	0.47	0.47	Can be used	1	34	0.43	0.46	Can be used	
4	0.75	0.44	Can be used	2	35	0.68	0.54	Can be used	19
7	0.63	0.33	Can be used	3	36	0.30	0.23	Can be used	20
8	0.35	0.35	Can be used	4	37	0.29	0.15	Can not be used	
9	0.32	0.37	Can be used	5	38	0.13	0.02	Can not be used	
10	0.20	-0.01	Can not be used		39	0.25	0.28	Can be used	
11	0.23	0.30	Can be used	6	40	0.39	0.30	Can be used	
12	0.59	0.27	Can be used	7	41	0.17	0.02	Can not be used	
13	0.28	0.32	Can be used	8	42	0.75	0.25	Can be used	21
14	0.23	0.28	Can be used	9	43	0.62	0.44	Can be used	22
15	0.35	0.26	Can be used		45	0.03	-0.03	Can not be used	
16	0.37	0.21	Can be used		46	0.17	-0.07	Can not be used	
17	0.24	-0.06	Can not be used		47	0.24	0.32	Can be used	23
18	0.37	0.23	Can be used	10	48	0.27	0.57	Can be used	24
19	0.07	0.16	Can not be used		49	0.09	-0.02	Can not be used	
20	0.09	0.18	Can not be used		50	0.42	0.27	Can be used	25
21	0.67	0.44	Can be used	11	51	0.36	-0.10	Can not be used	
22	0.74	0.40	Can be used	12	52	0.25	0.23	Can be used	
23	0.35	-0.03	Can not be used		53	0.25	0.36	Can be used	26
24	0.19	0.08	Can not be used		54	0.23	0.36	Can be used	27
25	0.31	0.25	Can be used	13	55	0.17	-0.07	Can not be used	
26	0.41	-0.07	Can not be used		56	0.25	0.38	Can be used	28
27	0.41	0.26	Can be used	14	57	0.25	0.23	Can be used	29
28	0.51	0.46	Can be used	15	58	0.29	0.29	Can be used	
29	0.25	0.02	Can not be used		59	0.41	0.29	Can be used	30
31	0.54	0.52	Can be used	16	60	0.26	-0.01	Can not be used	

Note: Reliability (KR-20) = 0.78

B.3 The Results of Evaluation of the Analytical Thinking Test Items

TABLE 27 THE RESULTS OF EVALUATION ON IOC OF THE ANALYTICAL THINKING TEST ITEMS

No.	Analysis processes	N = 5					IOC	Interpretation
		E ₁	E ₂	E ₃	E ₄	E ₅		
1	Matching	1	1	1	1	1	1.00	Strongly congruence
2	Matching	1	1	1	0	1	0.80	Strongly congruence
3	Matching	1	1	1	1	1	1.00	Strongly congruence
4	Matching	1	1	0	1	1	0.80	Strongly congruence
5	Matching	1	0	1	1	1	0.80	Strongly congruence
6	Matching	1	0	1	1	1	0.80	Strongly congruence
7	Matching	1	0	1	1	1	0.80	Strongly congruence
8	Matching	1	1	1	1	1	1.00	Strongly congruence
9	Matching	1	0	1	1	1	0.80	Strongly congruence
10	Matching	1	0	1	1	1	0.80	Strongly congruence
11	Classifying	1	1	1	1	1	1.00	Strongly congruence
12	Classifying	1	1	1	1	1	1.00	Strongly congruence
13	Classifying	1	1	-1	1	1	0.60	Congruence
14	Classifying	1	1	1	1	1	1.00	Strongly congruence

TABLE 27 (continued)

No.	Analysis processes	N = 5					IOC	Interpretation
		E_1	E_1	E_1	E_1	E_1		
15	Classifying	1	0	1	1	1	0.80	Strongly congruence
16	Classifying	1	1	1	1	1	1.00	Strongly congruence
17	Classifying	1	1	1	1	1	1.00	Strongly congruence
18	Classifying	1	1	1	1	1	1.00	Strongly congruence
19	Classifying	1	0	1	1	1	0.80	Strongly congruence
20	Classifying	1	1	1	1	1	1.00	Strongly congruence
21	Error Analysis	1	1	1	1	1	1.00	Strongly congruence
22	Error Analysis	1	1	1	1	1	1.00	Strongly congruence
23	Error Analysis	1	1	1	1	1	1.00	Strongly congruence
24	Error Analysis	1	0	1	1	1	0.80	Strongly congruence
25	Error Analysis	1	1	0	0	1	0.60	Congruence
26	Error Analysis	1	1	1	1	1	1.00	Strongly congruence
27	Error Analysis	1	0	1	1	1	0.80	Strongly congruence
28	Error Analysis	1	1	1	1	1	1.00	Strongly congruence
29	Error Analysis	1	1	1	1	1	1.00	Strongly congruence

TABLE 27 (continued)

No.	Analysis processes	N = 5					IOC	Interpretation
		E ₁	E ₂	E ₃	E ₄	E ₅		
30	Error Analysis	1	1	1	1	1	1.00	Strongly congruence
31	Generalizing	1	1	0	1	1	0.80	Strongly congruence
32	Generalizing	1	1	0	1	1	0.80	Strongly congruence
33	Generalizing	1	1	-1	1	1	0.60	Congruence
34	Generalizing	1	1	1	1	1	1.00	Strongly congruence
35	Generalizing	1	1	1	1	1	1.00	Strongly congruence
36	Generalizing	1	1	1	1	1	1.00	Strongly congruence
37	Generalizing	1	1	1	1	1	1.00	Strongly congruence
38	Generalizing	1	1	1	1	1	1.00	Strongly congruence
39	Generalizing	1	1	1	1	1	1.00	Strongly congruence
40	Generalizing	1	1	1	1	1	1.00	Strongly congruence
41	Specifying	1	1	1	1	1	1.00	Strongly congruence
42	Specifying	1	1	1	1	1	1.00	Strongly congruence
43	Specifying	1	1	1	1	1	1.00	Strongly congruence
44	Specifying	1	1	1	1	1	1.00	Strongly congruence

TABLE 27 (continued)

No.	Analysis processes	N = 5					IOC	Interpretation
		E_1	E_2	E_3	E_4	E_5		
45	Specifying	1	1	1	1	1	1.00	Strongly congruence
46	Specifying	1	0	0	1	1	0.60	congruence
47	Specifying	1	1	-1	1	1	0.60	congruence
48	Specifying	1	1	1	1	1	1.00	Strongly congruence
49	Specifying	1	1	0	1	1	0.80	Strongly congruence
50	Specifying	1	0	1	1	1	0.80	Strongly congruence

TABLE 28 THE RESULTS OF EVALUATION ON ITEM DIFFICULTY (p) AND ITEM DISCRIMINATION (r) OF THE ANALYTICAL THINKING TEST ITEMS

No.	p	r	Interpretation	Used for No.	No.	p	r	Interpretation	Used for No.
1	0.64	0.63	Can be used	1	26	0.15	0.07	Can not be used	
2	0.90	0.09	Can not be used		27	0.56	0.63	Can be used	
3	0.40	0.07	Can not be used		28	0.26	0.33	Can be used	
4	0.82	0.39	Can not be used		29	0.64	0.52	Can be used	14
5	0.46	0.39	Can be used	2	30	0.28	0.35	Can be used	15
6	0.73	0.39	Can be used	3	31	0.58	0.59	Can be used	16
7	0.54	0.33	Can be used	4	32	0.56	0.57	Can be used	17
8	0.19	0.24	Can not be used		33	0.27	0.28	Can be used	
9	0.75	0.35	Can be used		34	0.34	0.22	Can be used	18
10	0.62	0.41	Can be used	5	35	0.51	0.65	Can be used	19
11	0.46	0.54	Can be used	6	36	0.19	0.11	Can not be used	
12	0.41	0.33	Can be used	7	37	0.48	0.63	Can be used	20
13	0.57	0.52	Can be used	8	38	0.62	0.63	Can be used	21
14	0.54	0.57	Can be used	9	39	0.32	0.20	Can be used	
15	0.56	0.61	Can be used		40	0.70	0.59	Can be used	
16	0.69	0.57	Can be used	10	41	0.26	0.17	Can not be used	
17	0.51	0.70	Can be used	11	42	0.67	0.50	Can be used	22
18	0.46	0.54	Can be used		43	0.30	0.24	Can be used	23
19	0.81	0.43	Can not be used		44	0.36	0.43	Can be used	
20	0.69	0.50	Can be used		45	0.36	0.48	Can be used	
21	0.73	0.50	Can be used		46	0.57	0.52	Can be used	
22	0.52	0.39	Can be used	12	47	0.56	0.50	Can be used	
23	0.30	0.11	Can not be used		48	0.64	0.35	Can be used	24
24	0.25	0.41	Can be used	13	49	0.49	0.33	Can be used	25
25	0.62	0.24	Can be used		50	0.38	0.09	Can not be used	

Note: Reliability (KR-20) = 0.79

B.4 The Results of Evaluation of the Application of Knowledge Test Items

TABLE 29 THE RESULTS OF EVALUATION OF IOC OF THE APPLICATION OF KNOWLEDGE TEST ITEMS

No.	N = 3			IOC	Interpretation	No.	N = 3			IOC	Interpretation
	E ₁	E ₂	E ₃				E ₁	E ₂	E ₃		
1	1	1	1	1.00	Strongly congruence	10	1	1	1	1.00	Strongly congruence
2	1	1	1	1.00	Strongly congruence	11	0	1	1	0.67	Congruence
3	1	1	1	1.00	Strongly congruence	12	1	1	1	1.00	Strongly congruence
4	1	1	1	1.00	Strongly congruence	13	1	1	1	1.00	Strongly congruence
5	1	1	1	1.00	Strongly congruence	14	0	1	1	0.67	Congruence
6	0	1	1	0.67	Congruence	15	1	1	1	1.00	Strongly congruence
7	1	1	1	1.00	Strongly congruence	16	1	1	1	1.00	Strongly congruence
8	1	1	1	1.00	Strongly congruence	17	0	1	1	0.67	Congruence
9	1	1	1	1.00	Strongly congruence	18	1	1	1	1.00	Strongly congruence

TABLE 30 THE RESULTS OF EVALUATION ON ITEM DIFFICULTY (p) AND ITEM DISCRIMINATION (r) OF THE APPLICATION OF KNOWLEDGE TEST ITEMS

No.	p	r	Interpretation	Used for No.	No.	p	r	Interpretation	Used for No.
1	0.42	0.26	Can be used		10	0.22	0.36	Can be used	
2	0.44	0.69	Can be used	1	11	0.43	0.26	Can be used	7
3	0.43	0.55	Can be used	2	12	0.28	0.32	Can be used	8
4	0.10	0.16	Can not be used		13	0.53	0.32	Can be used	9
5	0.28	0.29	Can be used	3	14	0.11	0.13	Can not be used	
6	0.41	0.25	Can be used	4	15	0.37	0.36	Can be used	10
7	0.49	0.28	Can be used		16	0.29	0.14	Can not be used	
8	0.70	0.38	Can be used	5	17	0.28	0.31	Can be used	11
9	0.77	0.32	Can be used	6	18	0.48	0.31	Can be used	12

Note: Reliability (Cronbach's coefficient alpha) = 0.76

B.5 The Results of Evaluation of the Opinions Questionnaire toward the FEACA Model Items

TABLE 31 THE RESULTS OF EVALUATION ON IOC OF THE OPINION QUESTIONNAIRE TOWARD THE FEACA MODEL ITEMS

No.	Opinion	N = 5					IOC	Interpretation
		E ₁	E ₂	E ₃	E ₄	E ₅		
1	Positive	1	1	1	1	1	1.00	Strongly congruence
2	Positive	1	1	1	1	1	1.00	Strongly congruence
3	Positive	1	1	1	1	1	1.00	Strongly congruence
4	Negative	1	1	1	1	1	1.00	Strongly congruence
5	Positive	1	1	1	1	1	1.00	Strongly congruence
6	Positive	1	1	1	1	1	1.00	Strongly congruence
7	Negative	1	1	1	1	1	1.00	Strongly congruence
8	Positive	1	1	1	1	1	1.00	Strongly congruence
9	Positive	1	1	1	1	1	1.00	Strongly congruence
10	Positive	1	1	1	1	1	1.00	Strongly congruence
11	Positive	1	0	1	1	1	0.80	Strongly congruence
12	Positive	1	0	1	1	1	0.80	Strongly congruence

TABLE 31 (continued)

No.	Opinion	N = 5					IOC	Interpretation
		E ₁	E ₂	E ₃	E ₄	E ₅		
13	Positive	1	1	1	1	1	1.00	Strongly congruence
14	Positive	1	1	1	1	1	1.00	Strongly congruence
15	Negative	1	1	1	1	1	1.00	Strongly congruence
16	Positive	1	1	1	1	1	1.00	Strongly congruence
17	Positive	1	0	1	1	1	0.80	Strongly congruence
18	Negative	1	1	1	1	1	1.00	Strongly congruence
19	Positive	1	0	1	1	1	0.80	Strongly congruence
20	Negative	1	1	1	1	1	1.00	Strongly congruence

TABLE 32 THE RESULTS OF EVALUATION ON ITEM DISCRIMINATION (r) OF THE
OPINIONS QUESTIONNAIRE TOWARD THE FEACA MODEL ITEMS

No.	r	Interpretation	Used for No.	No.	r	Interpretation	Used for No.
1	0.26	Can be used	1	11	0.47	Can be used	11
2	0.43	Can be used	2	12	0.45	Can be used	12
3	0.42	Can be used	3	13	0.61	Can be used	13
4	0.30	Can be used	4	14	0.53	Can be used	14
5	0.25	Can be used	5	15	0.38	Can be used	15
6	0.54	Can be used	6	16	0.30	Can be used	16
7	0.30	Can be used	7	17	0.66	Can be used	17
8	0.49	Can be used	8	18	0.54	Can be used	18
9	0.31	Can be used	9	19	0.62	Can be used	19
10	0.43	Can be used	10	20	0.33	Can be used	20

Note: Reliability (Cronbach's coefficient alpha) = 0.84

Appendix C
The Research Instruments

- C.1 The Example of Conceptual Understanding Test
- C.2 The Example of Analytical Thinking Test
- C.3 The Example of Application of Knowledge Test
- C.4 The Opinions Questionnaire toward the FEACA Model

C.1 The Example of Conceptual Understanding Test

**แบบทดสอบวัดความเข้าใจแนวคิดเรื่อง แรงและการเคลื่อนที่ในชีวิตประจำวัน
สำหรับนักเรียนระดับมัธยมศึกษาปีที่ 3**

คำชี้แจง

1. แบบทดสอบฉบับนี้ใช้เพื่อวัดความเข้าใจแนวคิดเรื่องแรงและการเคลื่อนที่ในชีวิตประจำวัน สำหรับนักเรียนระดับมัธยมศึกษาตอนต้น
2. ลักษณะข้อสอบเป็นปรนัยชนิดเลือกตอบจำนวน 30 ข้อ ให้เวลาทำ 50 นาที
3. ให้นักเรียนอ่านคำถามแต่ละข้อให้เข้าใจ แล้วเลือกคำตอบที่ถูกต้องที่สุดเพียงคำตอบเดียว จากข้อ ก. ข. ค. หรือ ง. โดยขีดเครื่องหมายกากบาท (X) ลงในช่องสี่เหลี่ยมตรงกับข้อที่เลือก ในกระดาษคำตอบ
4. โปรดอย่าขีดเขียนหรือทำเครื่องหมายใดๆ ลงในแบบทดสอบฉบับนี้

1. เมื่อปล่อยก้อนหินให้เคลื่อนที่ในแนวตั้งภายใต้แรงโน้มถ่วงของโลก ความเร่งเป็นอย่างไร
 - ก. ความเร่งเป็นศูนย์
 - ข. ความเร่งมีค่าคงที่ ในทิศเดียวกับทิศการเคลื่อนที่
 - ค. ความเร่งมีค่าเพิ่มขึ้น ในทิศเดียวกับทิศการเคลื่อนที่
 - ง. ความเร่งมีค่าเพิ่มขึ้น ในทิศตรงข้ามกับทิศการเคลื่อนที่

2. รถยนต์คันหนึ่งกำลังเคลื่อนที่เป็นเส้นตรงด้วยความเร็วคงที่ ความเร่งเป็นอย่างไร
 - ก. ความเร่งเป็นศูนย์
 - ข. ความเร่งมีค่าคงที่ ในทิศเดียวกับทิศการเคลื่อนที่
 - ค. ความเร่งมีค่าลดลง ในทิศเดียวกับทิศการเคลื่อนที่
 - ง. ความเร่งมีค่าเพิ่มขึ้น ในทิศเดียวกับทิศการเคลื่อนที่

3. วัตถุ A กำลังเคลื่อนที่ด้วยความเร็วคงที่ 10 เมตรต่อวินาที เมื่อมีแรงลัพธ์ที่เท่ากับศูนย์มากระทำ ความเร็วของวัตถุ A จะเป็นอย่างไร

ก. ความเร็วเพิ่มขึ้น	ข. ความเร็วลดลง
ค. ความเร็วเป็นศูนย์	ง. ความเร็วไม่เปลี่ยนแปลง

4. ในขณะที่รถยนต์กำลังเคลื่อนที่ด้วยความเร็วคงที่ 50 เมตรต่อวินาที แรงลัพธ์ที่กระทำต่อรถเป็นอย่างไร
 - ก. แรงลัพธ์ที่กระทำต่อรถเป็นศูนย์
 - ข. แรงลัพธ์ที่กระทำต่อรถมีขนาดเพิ่มขึ้น และมีทิศเดียวกับทิศการเคลื่อนที่
 - ค. แรงลัพธ์ที่กระทำต่อรถมีขนาดคงที่ค่าหนึ่ง และมีทิศเดียวกับทิศการเคลื่อนที่
 - ง. แรงลัพธ์ที่กระทำต่อรถมีขนาดคงที่ค่าหนึ่ง แต่มีทิศตรงข้ามกับทิศการเคลื่อนที่

5. รถยนต์คันหนึ่งกำลังเคลื่อนที่ด้วยความเร็วคงที่ 50 เมตรต่อวินาที เมื่อเห็นสุนัขวิ่งตัดหน้า คนขับจึงเบรกรถ แรงลัพธ์ที่กระทำต่อรถเมื่อลดความเร็วลงด้วยอัตราที่คงที่เป็นอย่างไร
 - ก. แรงลัพธ์ที่กระทำต่อรถเป็นศูนย์
 - ข. แรงลัพธ์ที่กระทำต่อรถมีขนาดลดลง และมีทิศตรงข้ามกับทิศการเคลื่อนที่
 - ค. แรงลัพธ์ที่กระทำต่อรถมีขนาดคงที่ค่าหนึ่ง และมีทิศเดียวกับทิศการเคลื่อนที่
 - ง. แรงลัพธ์ที่กระทำต่อรถมีขนาดคงที่ค่าหนึ่ง แต่มีทิศตรงข้ามกับทิศการเคลื่อนที่

C.2 The Example of Analytical Thinking Test

แบบทดสอบวัดการคิดวิเคราะห์
สำหรับนักเรียนระดับมัธยมศึกษาตอนต้น

คำชี้แจง

1. แบบทดสอบฉบับนี้ใช้เพื่อวัดการคิดวิเคราะห์ของนักเรียนระดับมัธยมศึกษาตอนต้น
2. ลักษณะข้อสอบเป็นปรนัยชนิดเลือกตอบจำนวน 25 ข้อ ให้เวลาทำ 30 นาที
3. ให้นักเรียนอ่านคำถามแต่ละข้อให้เข้าใจ แล้วเลือกคำตอบที่ถูกต้อง
ที่สุดเพียงคำตอบเดียว จากข้อ ก. ข. ค. หรือ ง. โดยขีดเครื่องหมายกากบาท (X) ลง
ในช่องสี่เหลี่ยมตรงกับข้อที่เลือก ในกระดาษคำตอบ
4. โปรดอย่าขีดเขียนหรือทำเครื่องหมายใดๆ ลงในแบบทดสอบฉบับนี้

1. ของแข็งและของเหลวมีคุณสมบัติข้อใดที่เหมือนกัน

ก. รูปร่างคงที่

ข. ปริมาตรคงที่

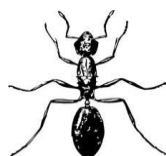
ค. ความสามารถในการไหล

ง. ระยะห่างระหว่างโมเลกุล

พิจารณาภาพต่อไปนี้ แล้วตอบคำถามข้อ 2



แมลง ก



แมลง ข

2. ข้อใดกล่าวถึงแมลงทั้งสองชนิดได้ถูกต้อง

ก. จำนวนขาไม่เท่ากัน

ข. ลักษณะปีกเหมือนกัน

ค. ลักษณะขาเหมือนกัน

ง. จำนวนข้อปล้องของลำตัวเท่ากัน

พิจารณาภาพต่อไปนี้ แล้วตอบคำถามข้อ 3



3. เซลล์พืชมีส่วนประกอบใดต่อไปนี้แตกต่างจากเซลล์สัตว์

ก. ผนังเซลล์และคลอโรพลาสต์

ข. แวกคิวโอลและเยื่อหุ้มเซลล์

ค. คลอโรพลาสต์และไรโบโซม

ง. รูปร่างเซลล์และไมโทคอนเดรีย

C.3 The Example of Application of Knowledge Test

แบบทดสอบวัดการนำความรู้ไปใช้
เรื่อง แรงและการเคลื่อนที่ในชีวิตประจำวัน

คำชี้แจง

1. แบบทดสอบฉบับนี้มีจำนวนทั้งหมด 12 ข้อ ให้เวลาทำ 50 นาที
2. ให้นักเรียนเขียนคำตอบลงในช่องว่าง พร้อมทั้งอธิบายเหตุผลโดยใช้ความรู้ทางวิทยาศาสตร์
3. ให้นักเรียนส่งคืนแบบทดสอบให้กรรมการควบคุมการสอบทันทีเมื่อหมดเวลา
4. ให้นักเรียนเขียนชื่อ-นามสกุล ชั้น เลขที่ ลงในแบบทดสอบให้เรียบร้อย

ชื่อ-นามสกุล.....
 ชั้น.....เลขที่.....
 โรงเรียน.....

1. รถจักรยานคันหนึ่งเริ่มเคลื่อนที่จากหยุดนิ่ง เมื่อเคลื่อนที่ไปได้ 10 วินาที รถมีความเร็ว 40 เมตรต่อวินาที รถคันนี้เคลื่อนที่ด้วยความเร่งเท่าใด เพราะเหตุใด

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2. รถไฟฟ้ากำลังเคลื่อนที่ด้วยความเร็วคงที่ค่าหนึ่ง เมื่อใกล้ถึงสถานีได้ลดความเร็วลงเพื่อจอด รถไฟฟ้ามีความเร่งหรือไม่ จงอธิบาย

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3. ขณะที่ขึ้นจากเรือพาย เรือจะมีการเคลื่อนที่อย่างไร เพราะเหตุใดเรือจึงมีการเคลื่อนที่เช่นนั้น และควรทำอย่างไรเพื่อไม่ให้เรือเคลื่อนที่

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4. ขณะที่นักว่ายน้ำกลับตัวในน้ำจะใช้เท้าดันผนังสระว่ายน้ำ เพราะเหตุใดจึงทำเช่นนั้น จงอธิบาย

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5. เหตุใดนักกีฬา เช่น นักเทนนิส จึงสวมรองเท้าพื้นยางลงแข่งขัน จงอธิบาย

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C.4 The Opinions Questionnaire toward the FEACA Model

แบบสอบถามความคิดเห็นของนักเรียน

ที่มีต่อรูปแบบการเรียนการสอนวิทยาศาสตร์ที่เน้นวิธีการสอนโดยใช้บริบท

ตอนที่ 1 ให้นักเรียนอ่านข้อความในแต่ละข้อแล้วพิจารณาว่านักเรียนเห็นด้วยกับข้อความดังกล่าว
 มากน้อยเพียงใด โดยทำเครื่องหมาย (✓) ลงในช่องขวามือของข้อความแต่ละข้อเพียงช่องเดียว

ข้อที่	รายการประเมิน	ระดับความคิดเห็น				
		มากที่สุด	มาก	ปานกลาง	น้อย	น้อยที่สุด
1	การจัดการเรียนรู้โดยใช้เหตุการณ์ในชีวิตประจำวันช่วยให้นักเรียนเข้าใจเนื้อหาวิทยาศาสตร์มากขึ้น					
2	การจัดการเรียนรู้โดยใช้เหตุการณ์ในชีวิตประจำวันทำให้นักเรียนเห็นว่าการเรียนวิทยาศาสตร์เป็นเรื่องง่าย					
3	การจัดการเรียนรู้โดยใช้เหตุการณ์ในชีวิตประจำวันทำให้นักเรียนเห็นว่าวิทยาศาสตร์เป็นเรื่องใกล้ตัว					
4	การจัดการเรียนรู้โดยใช้เหตุการณ์ในชีวิตประจำวันทำให้นักเรียนรู้สึกเบื่อหน่ายเพราะเป็นเรื่องที่รู้แล้ว					
5	การจัดการเรียนรู้โดยใช้เหตุการณ์ในชีวิตประจำวันทำให้นักเรียนสนใจวิทยาศาสตร์มากขึ้น					
6	การจัดการเรียนรู้โดยใช้เหตุการณ์ในชีวิตประจำวันทำให้นักเรียนอยากเรียนรู้วิทยาศาสตร์มากขึ้น					
7	การจัดการเรียนรู้ทำให้นักเรียนรู้สึกอัดอั้นเวลาถูกถามคำถาม					
8	การจัดการเรียนรู้ช่วยให้นักเรียนได้ฝึกการเปรียบเทียบความเหมือนและความแตกต่างของสิ่งต่าง ๆ					
9	การจัดการเรียนรู้ช่วยให้นักเรียนได้ฝึกการแบ่งกลุ่มโดยใช้เกณฑ์ที่เหมาะสม					
10	การจัดการเรียนรู้ช่วยให้นักเรียนได้ฝึกการวิเคราะห์ข้อมูลว่าถูกต้องหรือมีข้อผิดพลาด					
11	การจัดการเรียนรู้ช่วยให้นักเรียนได้ฝึกการสรุปผลการทดลองจากข้อมูลที่รวบรวมได้					

ข้อที่	รายการประเมิน	ระดับความคิดเห็น				
		มากที่สุด	มาก	ปานกลาง	น้อย	น้อยที่สุด
12	การจัดการเรียนรู้ช่วยให้นักเรียนได้ฝึกการประยุกต์ใช้ความรู้					
13	การจัดการเรียนรู้ช่วยให้นักเรียนสามารถนำความรู้ที่เรียนไปอธิบายเหตุการณ์ในชีวิตประจำวันได้					
14	กิจกรรมการเรียนรู้การสนทนา มีความสอดคล้องกับชีวิตประจำวัน					
15	นักเรียนรู้สึกเครียดเมื่อต้องออกมานำเสนอผลงานหน้าห้องเรียน					
16	นักเรียนมีโอกาสได้ร่วมแสดงความคิดเห็นอย่างเต็มที่					
17	การจัดการเรียนรู้มีความหลากหลายน่าสนใจ					
18	ระหว่างที่เรียน นักเรียนอยากใช้เวลาผ่านไปอย่างรวดเร็ว					
19	นักเรียนรู้สึกสนุกและมีความสุขเมื่อเรียนวิทยาศาสตร์					
20	นักเรียนรู้สึกเบื่อเมื่อต้องทำการทดลองทางวิทยาศาสตร์					

ตอนที่ 2 ให้นักเรียนแสดงความคิดเห็นเกี่ยวกับปัญหาหรือข้อเสนอแนะในการจัดการเรียนรู้

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Appendix D

The Learning Unit

D.1 The Teachers' Guideline

D.2 The Instructional Plans

D.1 The Teachers' Guideline

แนวทางการใช้
รูปแบบการเรียนการสอนวิทยาศาสตร์ที่เน้นวิธีการสอนโดยใช้บริบท



สภาพปัญหาและความสำคัญ

เป้าหมายของการจัดการเรียนการสอนวิทยาศาสตร์ในปัจจุบันมุ่งเน้นให้ผู้เรียนมีความรู้ความเข้าใจหลักการและทฤษฎีพื้นฐานทางวิทยาศาสตร์ มีความสามารถในการคิด มีทักษะกระบวนการทางวิทยาศาสตร์ มีเจตคติที่ดีต่อวิทยาศาสตร์ รวมทั้งสามารถนำความรู้ที่ได้รับไปประยุกต์ใช้ในชีวิตประจำวันได้ อย่างไรก็ตาม ผลการประเมินของหน่วยงานทางการศึกษาต่างๆ แสดงให้เห็นว่าการจัดการเรียนการสอนวิทยาศาสตร์ยังไม่สามารถทำให้ผู้เรียนบรรลุเป้าหมายที่ตั้งไว้ เช่น นักเรียนมีผลสัมฤทธิ์ทางการเรียนต่ำกว่าเกณฑ์ ความสามารถในการคิดต่ำกว่ามาตรฐาน โดยเฉพาะการคิดวิเคราะห์ นักเรียนมีเจตคติที่ไม่ดีต่อวิทยาศาสตร์ รวมทั้งไม่สามารถนำความรู้ที่ได้รับไปประยุกต์ใช้ในชีวิตประจำวันได้ ซึ่งเป็นผลเนื่องมาจากการจัดการเรียนการสอนวิทยาศาสตร์ในปัจจุบันผู้เรียนมักเรียนแบบท่องจำจากตำราหรือสิ่งที่ผู้สอนอธิบายในชั้นเรียน ทำให้ไม่เกิดความเข้าใจที่แท้จริงและไม่สามารถประยุกต์ใช้ความรู้ได้ ดังนั้นจึงควรปรับเปลี่ยนรูปแบบการเรียนการสอนวิทยาศาสตร์ โดยเน้นการจัดกิจกรรมการเรียนรู้ให้สอดคล้องกับเหตุการณ์ในชีวิตประจำวันหรือประสบการณ์เดิมของผู้เรียน เพื่อให้ผู้เรียนได้พัฒนาความรู้ความเข้าใจหลักการและทฤษฎีพื้นฐานทางวิทยาศาสตร์ด้วยตนเอง รวมทั้งเปิดโอกาสให้ผู้เรียนได้นำความรู้ที่ได้รับไปอธิบายเหตุการณ์อื่น ๆ ในชีวิตประจำวัน ควบคู่ไปกับการพัฒนาความสามารถในการคิดด้วย

แนวคิดพื้นฐาน

การเรียนรู้ที่มีประสิทธิภาพจะเกิดขึ้นเมื่อผู้เรียนมีความรู้พื้นฐานหรือประสบการณ์เดิมในเรื่องนั้นๆ มาบ้างแล้ว การจัดประสบการณ์ให้ผู้เรียนได้เรียนรู้เรื่องใหม่ต้องมีการเชื่อมโยงกับความรู้เดิมที่มีอยู่ ดังนั้นการจัดการเรียนรู้ให้กับผู้เรียนควรนำเหตุการณ์ในชีวิตประจำวัน หรือประสบการณ์เดิมของนักเรียนมาเป็นประเด็นเริ่มต้นในการเรียนรู้ เพื่อช่วยให้ผู้เรียนเกิดการเรียนรู้ได้ดีขึ้น รวมทั้งกระตุ้นความสนใจของผู้เรียนด้วย



จุดมุ่งหมายของการจัดการเรียนรู้

การจัดการเรียนรู้ตามรูปแบบ ฯ มีจุดมุ่งหมายหลักดังนี้

1. เพื่อให้นักเรียนมีความรู้ความเข้าใจในหลักการและทฤษฎีพื้นฐานทางวิทยาศาสตร์
2. เพื่อส่งเสริมให้นักเรียนพัฒนาการคิดวิเคราะห์ตามแนวคิดของมาร์ซาโน 5 ด้าน คือ การจับคู่ (Matching) การจัดหมวดหมู่ (Classifying) การวิเคราะห์ข้อผิดพลาด (Error Analysis) การสรุปหลักการทั่วไป (Generalizing) และการประยุกต์ (Specifying)
3. เพื่อส่งเสริมให้นักเรียนนำความรู้ความเข้าใจในหลักการและทฤษฎีพื้นฐานทางวิทยาศาสตร์ไปประยุกต์ใช้ในชีวิตประจำวัน
4. เพื่อส่งเสริมให้นักเรียนมีเจตคติที่ดีต่อวิทยาศาสตร์
5. เพื่อให้นักเรียนตระหนักถึงความสัมพันธ์ระหว่างวิทยาศาสตร์และชีวิตประจำวัน



รูปแบบการจัดการเรียนการสอนวิทยาศาสตร์ที่เน้นวิธีการสอนโดยใช้บริบท

รูปแบบ ฯ นี้เป็นการจัดการเรียนรู้ที่เชื่อมโยงความรู้ทางวิทยาศาสตร์เข้ากับเหตุการณ์ในชีวิตประจำวันหรือสถานการณ์ต่าง ๆ ที่สอดคล้องกับประสบการณ์เดิมของนักเรียน โดยในแต่ละขั้นตอนจะสอดแทรกกิจกรรมที่พัฒนาการคิดวิเคราะห์ของนักเรียนตามแนวคิดของมาร์ซาโน มุ่งเน้นที่จะส่งเสริมให้นักเรียนมีความเข้าใจในมิติทางวิทยาศาสตร์ มีทักษะในการคิดวิเคราะห์ และสามารถนำความรู้ความเข้าใจทางวิทยาศาสตร์ไปประยุกต์ใช้ในชีวิตประจำวันได้ ประกอบด้วย 5 ขั้นตอน ดังนี้

ขั้นที่ 1: มุ่งความสนใจ (Focusing)

ขั้นตอนนี้มีจุดมุ่งหมายเพื่อกระตุ้นความสนใจและตรวจสอบความรู้พื้นฐานของนักเรียน โดยครูนำเสนอเหตุการณ์ในชีวิตประจำวันหรือสถานการณ์ต่าง ๆ ที่สอดคล้องกับประสบการณ์เดิมของนักเรียน พร้อมทั้งตั้งประเด็นคำถามเพื่อกระตุ้นให้นักเรียนร่วมกันอภิปรายและแสดงความคิดเห็นเกี่ยวกับเหตุการณ์ดังกล่าว นักเรียนเปรียบเทียบพร้อมจัดกลุ่มคำตอบให้อยู่ในหมวดหมู่ที่มีความหมาย เมื่อจบขั้นตอนนี้คำตอบของนักเรียนจะไม่ถูกตัดสินว่าถูกหรือผิด แต่จะเป็นประเด็นเพื่อนำไปสู่การสำรวจตรวจสอบต่อไป

ขั้นที่ 2: สำรวจตรวจสอบ (Exploring)

ขั้นตอนนี้มีจุดมุ่งหมายเพื่อให้ นักเรียนได้มีโอกาสศึกษาค้นคว้าหรือลงมือปฏิบัติผ่านกิจกรรมที่มีความสอดคล้องกับเหตุการณ์ที่นำเสนอในขั้นตอนแรก นักเรียนจะแยกเป็นกลุ่มและทำกิจกรรมหรือการทดลองที่สอดคล้องกับเหตุการณ์ที่ครูนำเสนอ เพื่อหาคำตอบของประเด็นคำถามที่ร่วมกันอภิปราย โดยครูคอยแนะนำและอำนวยความสะดวกในระหว่างที่นักเรียนทำกิจกรรมพร้อมทั้งตรวจสอบว่านักเรียนได้ข้อมูลครบถ้วนสำหรับใช้ในขั้นตอนต่อไป

ขั้นที่ 3: วิเคราะห์ข้อมูล (Analyzing)

จุดมุ่งหมายของขั้นตอนนี้เน้นให้นักเรียนวิเคราะห์ข้อมูลและสร้างองค์ความรู้ด้วยตนเอง นักเรียนวิเคราะห์ข้อมูลและหาความสัมพันธ์ของข้อมูลที่ได้จากการทำกิจกรรมโดยการตอบคำถาม ทำกิจกรรมและสร้างองค์ความรู้โดยการสรุปผลของกิจกรรมที่ได้ทำ พร้อมทั้งนำเสนอแลกเปลี่ยนข้อค้นพบต่าง ๆ กับเพื่อนร่วมชั้น โดยครูคอยแนะนำและอำนวยความสะดวกในระหว่างที่นักเรียนทำกิจกรรม

ขั้นที่ 4: พัฒนาแนวความคิด (Conceptual Developing)

ขั้นตอนนี้มีจุดมุ่งหมายเพื่อสร้างความเข้าใจในมิติที่ถูกต้องเกี่ยวกับเนื้อหานั้น ๆ โดยครูนำอภิปรายข้อค้นพบต่าง ๆ ที่นักเรียนนำเสนอและร่วมกันสรุปเพื่อให้ได้แนวความคิดที่ถูกต้องพร้อมแก้ไขความเข้าใจที่คลาดเคลื่อนของนักเรียน นักเรียนศึกษาเพิ่มเติมจากใบความรู้หรือแหล่งเรียนรู้อื่น ๆ แล้วร่วมกันอภิปรายเหตุการณ์ในขั้นตอนแรกโดยใช้องค์ความรู้ที่ได้พัฒนาขึ้น

ขั้นที่ 5: ประยุกต์ใช้ (Applying)

ขั้นตอนนี้มีจุดมุ่งหมายเพื่อให้นักเรียนนำความรู้ที่ได้ไปอธิบายเหตุการณ์ใหม่ โดยครูนำอภิปรายการนำความรู้ที่ได้ไปใช้ในชีวิตประจำวัน จากนั้นนักเรียนแต่ละกลุ่มระดมความคิดเพื่อยกตัวอย่างเหตุการณ์อื่นพร้อมอธิบายเหตุการณ์เหล่านั้นโดยใช้ความรู้ที่ได้พัฒนาขึ้น แล้วนำเสนอหน้าชั้นเรียน โดยเพื่อนนักเรียนกลุ่มอื่นร่วมกันวิเคราะห์ความถูกต้องของเหตุการณ์และเหตุผลที่ใช้ในการอธิบาย



การคิดวิเคราะห์

การคิดวิเคราะห์ เป็นพื้นฐานที่สำคัญของการเรียนรู้และการดำรงชีวิต รวมทั้งเป็นพื้นฐานของการคิดประเภทอื่นเช่น การคิดแก้ปัญหา การคิดอย่างมีวิจารณญาณ ฯลฯ รูปแบบ ๔ นี้มุ่งเน้นที่จะพัฒนาการคิดวิเคราะห์ตามแนวคิดของมาร์ซาโน 5 ด้าน ดังนี้

1. **การจับคู่ (Matching)** หมายถึง การเปรียบเทียบหรือระบุความเหมือนความแตกต่างของข้อมูล ความรู้หรือเหตุการณ์ต่าง ๆ อย่างมีหลักเกณฑ์
2. **การจัดหมวดหมู่ (Classifying)** หมายถึง การประมวลความรู้ เพื่อจัดกลุ่ม หรือจัดลำดับชั้นของข้อมูล ความรู้หรือเหตุการณ์ต่าง ๆ ตามคุณสมบัติที่เหมือนกันอย่างมีความหมาย และมีหลักเกณฑ์ รวมทั้งระบุลำดับชั้นที่เหนือกว่าหรือต่ำกว่าของข้อมูล ความรู้หรือเหตุการณ์ต่าง ๆ ได้อย่างมีความหมาย
3. **การวิเคราะห์ข้อผิดพลาด (Error Analysis)** หมายถึง การประเมินความถูกต้อง และการตัดสินความน่าเชื่อถือของข้อมูล ความรู้หรือเหตุการณ์ต่าง ๆ รวมทั้งการระบุข้อผิดพลาดในการให้เหตุผลบนพื้นฐานของความถูกต้อง
4. **การสรุปหลักการทั่วไป (Generalizing)** หมายถึง การสร้างข้อสรุปจากข้อมูลหรือเหตุการณ์เฉพาะที่ได้จากการสังเกตและศึกษาค้นคว้า
5. **การประยুক্ত (Specifying)** หมายถึง การนำความรู้หรือหลักการที่สรุปไว้แล้วไปใช้อธิบายเหตุการณ์ใหม่ รวมทั้งทำนายสิ่งที่จะเกิดขึ้นจากสถานการณ์ที่กำหนดให้บนพื้นฐานของความรู้ความเข้าใจ

การเตรียมความพร้อม

การจัดการเรียนรู้ตามรูปแบบ ฯ นี้ประกอบด้วยหน่วยการเรียนรู้ที่ออกแบบสื่อและวัสดุอุปกรณ์ที่ใช้ในหน่วยการเรียนรู้ และเครื่องมือที่เกี่ยวข้องกับการวัดและประเมินผลไว้ให้ผู้สอนสามารถนำไปใช้ได้ทันที หรืออาจนำไปปรับปรุงและเพิ่มเติมได้ตามความเหมาะสม เพื่อเป็นประโยชน์ต่อการจัดการเรียนรู้มากที่สุด ผู้สอนควรเตรียมความพร้อมดังนี้

การเตรียมสื่อการเรียนรู้

การจัดการเรียนรู้ตามรูปแบบ ฯ นี้มุ่งเน้นให้ผู้เรียนได้เรียนรู้ และลงมือทำกิจกรรมต่าง ๆ ด้วยตนเอง โดยมีแผนการจัดการเรียนรู้เพื่อเป็นแนวทางสำหรับผู้สอน ดังนั้นผู้สอนจึงควรเตรียมสื่อและวัสดุอุปกรณ์ต่างๆ ให้พร้อมและมีจำนวนเพียงพอสำหรับผู้เรียนก่อนนำไปใช้ นอกจากนี้ผู้สอนควรทำความเข้าใจแผนการจัดการเรียนรู้อย่างละเอียดและชัดเจน พร้อมทั้งจัดเตรียมใบกิจกรรมและใบความรู้ให้พร้อมแจกกับผู้เรียน

การเตรียมเครื่องมือการวัดและประเมินผล

ผู้สอนต้องตระหนักว่าการจัดการเรียนรู้และการวัดและประเมินผลเป็นกระบวนการเดียวกัน จำเป็นต้องดำเนินการอย่างต่อเนื่อง และเพื่อให้การวัดและประเมินผลได้สะท้อนความสามารถของผู้เรียนอย่างแท้จริง ผลการประเมินควรได้มาจากแหล่งข้อมูลและวิธีการที่หลากหลาย เช่น การสังเกตแบบบันทึกการเรียนรู้ของผู้เรียน แบบทดสอบต่างๆ เป็นต้น

ดังนั้นผู้สอนควรเตรียมศึกษาวิธีการวัดและประเมินผลดังกล่าว เพื่อการเก็บข้อมูลอย่างตรงไปตรงมา และนำไปสู่การแปลผลและลงข้อสรุปที่สมเหตุสมผล

แนวปฏิบัติของการจัดการเรียนการสอน

การใช้รูปแบบ ๔ เพื่อส่งเสริมความเข้าใจในเนื้อหา การคิดวิเคราะห์ตามแนวคิดของมาร์ซาโน และการนำความรู้ไปใช้ มีแนวปฏิบัติดังนี้

1. ผู้ใช้รูปแบบ ๔: รูปแบบการเรียนการสอนวิทยาศาสตร์ที่พัฒนาขึ้นนี้ เป็นการจัดการเรียนรู้ที่เชื่อมโยงความรู้ทางวิทยาศาสตร์เข้ากับเหตุการณ์ต่างๆ ในชีวิตประจำวัน สถานการณ์ต่างๆ หรือประสบการณ์เดิมของนักเรียน เพื่อส่งเสริมให้ผู้เรียนมีความเข้าใจในเนื้อหาทางวิทยาศาสตร์ การคิดวิเคราะห์ และการนำความรู้ไปใช้ประโยชน์ในชีวิตประจำวัน ผู้สอนสามารถศึกษาทำความเข้าใจและปฏิบัติตามได้โดยง่ายจากคู่มือครูประกอบการสอน

2. กลุ่มเป้าหมาย: นักเรียนที่เป็นกลุ่มเป้าหมายของรูปแบบ ๔ นี้คือ นักเรียนชั้นมัธยมศึกษาปีที่ 3 ที่เรียนรู้เนื้อหาในหน่วยการเรียนรู้เรื่อง แรงและการเคลื่อนที่ในชีวิตประจำวัน แต่ผู้สอนสามารถนำไปประยุกต์ใช้กับนักเรียนในระดับชั้นอื่นได้ตามความเหมาะสม

3. ระยะเวลาในการจัดการเรียนรู้โดยใช้รูปแบบการเรียนการสอนนี้คือ 22 คาบ

4. รูปแบบ ๔ นี้ใช้ควบคู่กับคู่มือครูและคู่มือนักเรียนประกอบการเรียนรู้ หน่วยการเรียนรู้เรื่อง แรงและการเคลื่อนที่ในชีวิตประจำวัน พร้อมทั้งแนวทางการวัดและประเมินผล

5. เพื่อให้การใช้รูปแบบ ๔ นี้ประสบความสำเร็จสูงสุด ผู้สอนจำเป็นต้องศึกษากระบวนการจัดการเรียนรู้ตามรูปแบบ ๔ นี้ให้ละเอียดก่อนการดำเนินการ ดังนี้

- ศึกษาคู่มือครูว่ารูปแบบการเรียนการสอนนี้ประกอบด้วยเอกสารอะไรบ้าง
- ศึกษาเนื้อหาในเอกสารให้เข้าใจอย่างถ่องแท้ก่อนดำเนินการใช้
- จัดเตรียมอุปกรณ์ประกอบการเรียนการสอนที่เสนอแนะให้พร้อมก่อนการใช้

หมายเหตุ การจัดการเรียนรู้ตามรูปแบบ ๔ นี้ใช้แผนการจัดการเรียนรู้เป็นแนวทางในการจัดกิจกรรมการเรียนรู้วิทยาศาสตร์ ซึ่งในการนำไปใช้จริงนั้นอาจมีการปรับเปลี่ยนให้เกิดความเหมาะสมทั้งในเรื่องของเวลาและรายละเอียดของเนื้อหาสาระให้มีความสอดคล้องกับความต้องการและความสนใจของผู้เรียนได้

บทบาทผู้สอน

ผู้สอนในฐานะผู้อำนวยความสะดวกให้ผู้เรียนในระหว่างแสวงหาความรู้ ผู้สอนควรเข้าใจบทบาทของตนเอง โดยดำเนินการดังนี้

1. จัดกิจกรรมการเรียนรู้วิทยาศาสตร์ ที่ผสมผสานให้ผู้เรียนได้พัฒนาความรู้ควบคู่กับการปฏิบัติจริง โดยเน้นกระบวนการเรียนรู้ การคิด และกระบวนการกลุ่ม
2. ส่งเสริมให้ผู้เรียนเกิดการเรียนรู้ แลกเปลี่ยนความรู้หรือประสบการณ์ซึ่งกันและกัน ระดมสมอง อภิปรายกลุ่ม และสื่อสารร่วมกันอย่างมีประสิทธิภาพ โดยลดการถ่ายทอดความรู้จากผู้สอนให้น้อยลง
3. ใช้คำถามกระตุ้นให้ผู้เรียนเกิดการเรียนรู้และมีความเข้าใจในสิ่งที่กำลังเรียนรู้
4. รับฟังความคิดเห็นของผู้เรียนและให้ความสำคัญต่อการแสดงความคิดเห็นของผู้เรียน
5. สังเกตความสนใจและความถนัดของผู้เรียน เพื่อจะได้จัดกิจกรรมให้ตรงตามความสนใจและความถนัดนั้น
6. ใช้สื่อการสอนที่สนุก ไม่น่าเบื่อ และตอบสนองความสนใจใคร่รู้ของผู้เรียน
7. อธิบายการทำกิจกรรมให้ผู้เรียนเข้าใจอย่างชัดเจน ด้วยภาษาที่นุ่มนวล ชูใจ ให้กำลังใจ และเป็นไปในเชิงสร้างสรรค์
8. แนะนำการทำกิจกรรมของผู้เรียนให้ถูกต้องพร้อมทั้งอำนวยความสะดวกเพื่อให้เกิดการเรียนรู้จากการทำกิจกรรม
9. ช่วยผู้เรียนสรุปสาระสำคัญที่เรียนรู้เมื่อผู้เรียนทำกิจกรรมสิ้นสุดลง
10. แบ่งผู้เรียนให้ทำกิจกรรมเป็นกลุ่มย่อยไม่เกิน 5 คน โดยมีการคละความสามารรถและเพศ
11. กล่าวชมเชยหรือให้รางวัลเมื่อผู้เรียนตอบคำถามหรือร่วมทำกิจกรรมได้ถูกต้อง เพื่อเป็นการสร้างแรงจูงใจและเป็นกำลังใจในแก่ผู้เรียน

บทบาทผู้เรียน

ผู้เรียนในฐานะผู้แสวงหาความรู้ และพัฒนาตนเองนั้น ผู้สอนควรชี้แนะให้ผู้เรียนเข้าใจบทบาทของตน โดยควรส่งเสริมให้ผู้เรียนฝึกฝนและดำเนินการในเรื่องต่อไปนี้

1. ศึกษาค้นคว้าด้วยตนเองจากแหล่งเรียนรู้ต่างๆ เช่น การอ่านหนังสือ ดูโทรทัศน์ แหล่งความรู้ในชุมชน และอินเทอร์เน็ต เป็นต้น
2. ลงมือปฏิบัติจริง สรุปสิ่งที่ได้เรียนรู้ด้วยตนเอง ตอบคำถาม ทำการทดลอง ทำกิจกรรม ทำแบบฝึกหัด เป็นรายบุคคลและรายกลุ่ม รวมทั้งแลกเปลี่ยนความคิดเห็นกับเพื่อน ๆ





Learning Unit on Force and Motion in Daily Life

มาตรฐานการเรียนรู้และตัวชี้วัด

หน่วยการเรียนรู้เรื่อง แรงและการเคลื่อนที่ในชีวิตประจำวัน เป็นหน่วยการเรียนรู้ที่มีเนื้อหาอยู่ในสาระที่ 4: แรงและการเคลื่อนที่ ซึ่งเป็นส่วนหนึ่งของกลุ่มสาระการเรียนรู้วิทยาศาสตร์ในระดับมัธยมศึกษาปีที่ 3 ตามหลักสูตรแกนกลางการศึกษาขั้นพื้นฐาน พุทธศักราช 2551 ประกอบด้วย มาตรฐานการเรียนรู้และตัวชี้วัด ดังนี้

มาตรฐาน ว 4.1 เข้าใจธรรมชาติของแรงแม่เหล็กไฟฟ้า แรงโน้มถ่วง และแรงนิวเคลียร์ มีกระบวนการสืบเสาะหาความรู้ สื่อสารสิ่งที่เรียนรู้และนำความรู้ไปใช้ประโยชน์อย่างถูกต้องและมีคุณธรรม

ตัวชี้วัด

- ว 4.1 ม. 3/1 อธิบายความเร่งและผลของแรงลัพธ์ที่ทำต่อวัตถุ
- ว 4.1 ม. 3/2 ทดลองและอธิบายแรงกิริยาและแรงปฏิกิริยาระหว่างวัตถุและนำความรู้ไปใช้ประโยชน์
- ว 4.1 ม. 3/3 ทดลองและอธิบายแรงพยุงของของเหลวที่กระทำต่อวัตถุ

มาตรฐาน ว 4.2: เข้าใจลักษณะการเคลื่อนที่แบบต่าง ๆ ของวัตถุในธรรมชาติ มีกระบวนการสืบเสาะหาความรู้และจิตวิทยาศาสตร์ สื่อสารสิ่งที่เรียนรู้และนำความรู้ไปใช้ประโยชน์

ตัวชี้วัด

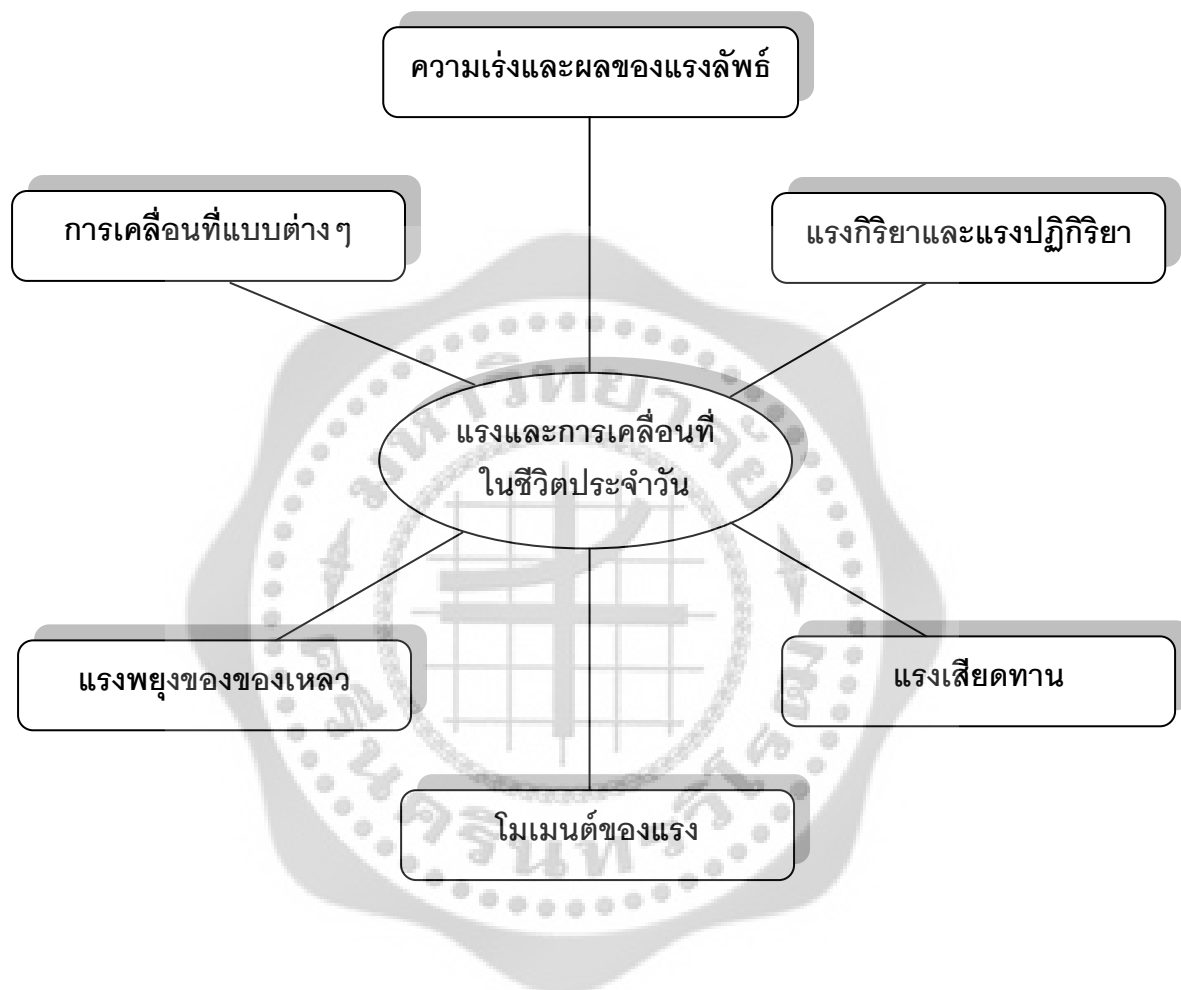
- ว 4.2 ม. 3/1 ทดลองและอธิบายความแตกต่างระหว่างแรงเสียดทานสถิตกับแรงเสียดทานจลน์ และนำความรู้ไปใช้ประโยชน์
- ว 4.2 ม. 3/2 ทดลองและวิเคราะห์โมเมนต์ของแรง และนำความรู้ไปใช้ประโยชน์
- ว 4.2 ม. 3/3 สังเกตและอธิบายการเคลื่อนที่ของวัตถุที่เป็นแนวตรงและแนวโค้ง

เป้าหมายของการจัดการเรียนรู้ หน่วยการเรียนรู้เรื่อง แรงและการเคลื่อนที่ในชีวิตประจำวัน

การจัดการเรียนรู้ตามรูปแบบ ฯ หน่วยการเรียนรู้เรื่อง แรงและการเคลื่อนที่ในชีวิตประจำวัน มีเป้าหมายสำคัญดังนี้

1. เพื่อให้นักเรียนมีความรู้ความเข้าใจในหลักการและทฤษฎีพื้นฐานเรื่อง ความเร่งและผลของแรงลัพธ์ แรงกิริยาและแรงปฏิกิริยา แรงเสียดทาน โมเมนต์ของแรง แรงพยางของของเหลว และการเคลื่อนที่แบบต่าง ๆ
2. เพื่อส่งเสริมให้นักเรียนพัฒนาการคิดวิเคราะห์ 5 ด้าน คือ การจับคู่ (Matching) การจัดหมวดหมู่ (Classifying) การวิเคราะห์ข้อผิดพลาด (Error Analysis) การสรุปหลักการทั่วไป (Generalizing) และการระบุจุด (Specifying)
3. เพื่อส่งเสริมให้นักเรียนพัฒนาการนำความรู้เรื่อง ความเร่ง ผลของแรงลัพธ์ที่กระทำต่อวัตถุ แรงกิริยาและแรงปฏิกิริยา แรงเสียดทาน โมเมนต์ของแรง แรงพยางของของเหลว และการเคลื่อนที่แบบต่าง ๆ ไปใช้ประโยชน์ในชีวิตประจำวัน
4. เพื่อส่งเสริมให้นักเรียนมีเจตคติที่ดีต่อวิทยาศาสตร์
5. เพื่อให้นักเรียนตระหนักถึงความสัมพันธ์ระหว่างวิทยาศาสตร์และชีวิตประจำวัน

ผังมโนคติ
หน่วยการเรียนรู้เรื่อง แรงและการเคลื่อนที่ในชีวิตประจำวัน



ผลการเรียนรู้ที่คาดหวัง

1. สืบตรวจสอบ อธิบายและคำนวณหาความเร่งของวัตถุได้
2. อธิบายและสรุปความสัมพันธ์ของความเร่งและแรงลัพธ์ที่กระทำต่อวัตถุได้
3. นำความรู้เรื่องความเร่งและผลของแรงลัพธ์ไปใช้ในชีวิตประจำวันได้
4. วิเคราะห์ อธิบายและสรุปความสัมพันธ์ของแรงกิริยาและแรงปฏิกิริยาได้
5. นำความรู้เรื่องแรงกิริยาและแรงปฏิกิริยาไปอธิบายเหตุการณ์ในชีวิตประจำวันได้
6. อธิบายและเปรียบเทียบความแตกต่างของแรงเสียดทานสถิตและแรงเสียดทานจลน์ได้
7. ทดลองและสรุปปัจจัยที่มีผลต่อแรงเสียดทานได้
8. นำความรู้เรื่องแรงเสียดทานไปใช้ประโยชน์ในชีวิตประจำวันได้
9. ทดลองและสรุปหลักการของโมเมนต์ของแรงได้
10. วิเคราะห์และคำนวณหาโมเมนต์ของแรงจากสถานการณ์ต่าง ๆ ได้
11. อธิบายและยกตัวอย่างการนำหลักการของโมเมนต์ไปใช้ประโยชน์ในชีวิตประจำวันได้
12. จำแนกและจัดหมวดหมู่อุปกรณ์ที่นำความรู้เรื่องโมเมนต์ไปใช้ประโยชน์ได้
13. สรุปความสัมพันธ์ระหว่างแรงพยุกับน้ำหนักที่หายไปของวัตถุและคำนวณหาแรงพยุได้
14. จำแนกและจัดหมวดหมู่ลักษณะการจมในของเหลวของวัตถุได้
15. นำความรู้เรื่องแรงพยุไปใช้ในชีวิตประจำวันได้
16. สืบตรวจสอบ อธิบาย จำแนกและจัดหมวดหมู่การเคลื่อนที่แบบต่าง ๆ ในชีวิตประจำวันได้
17. นำความรู้เรื่องการเคลื่อนที่แบบต่าง ๆ ไปใช้ประโยชน์ในชีวิตประจำวันได้
18. ประเมินเหตุการณ์ที่เพื่อนยกตัวอย่างได้อย่างถูกต้องและมีเหตุผล

แผนการดำเนินการจัดการเรียนรู้

กลุ่มสาระการเรียนรู้วิทยาศาสตร์

ชั้นมัธยมศึกษาปีที่ 3

หน่วยการเรียนรู้เรื่อง แรงและการเคลื่อนที่ในชีวิตประจำวัน

ภาคเรียนที่ 1/2554

สัปดาห์ที่	เนื้อหา	จำนวนคาบ	งานที่มอบหมาย
1	ปฐมนิเทศและทำการทดสอบก่อนเรียน	2	- แบบทดสอบวัดความเข้าใจในมโนคติ - แบบทดสอบวัดการคิดวิเคราะห์ - แบบทดสอบวัดการนำความรู้ไปใช้
2	แผนการจัดการเรียนรู้ที่ 1 เรื่อง ความเร่งและผลของแรงลัพธ์	2	- กิจกรรมที่ 1.1 “เล่นเร็วหรือเล่นช้า” - กิจกรรมที่ 1.2 “การเปลี่ยนแปลงความเร็ว” - กิจกรรมที่ 1.3 “แบบฝึกหัด”
3	แผนการจัดการเรียนรู้ที่ 2 เรื่อง แรงกิริยาและแรงปฏิกิริยา	3	- กิจกรรมที่ 2.1 “เก้าอี้ล้อเลื่อน” - กิจกรรมที่ 2.2 “เครื่องชั่งสปริง” - กิจกรรมที่ 2.3 “รถลูกโป่ง” - กิจกรรมที่ 2.4 “แบบฝึกหัด”
4	แผนการจัดการเรียนรู้ที่ 3 เรื่อง แรงเสียดทาน	3	- กิจกรรมที่ 3.1 “ชนิดของแรงเสียดทาน” - กิจกรรมที่ 3.2 “ปัจจัยที่มีผลต่อแรงเสียดทาน” - กิจกรรมที่ 3.3 “แบบฝึกหัด”
5	แผนการจัดการเรียนรู้ที่ 4 เรื่อง โมเมนต์ของแรง	3	- กิจกรรมที่ 4.1 “การเคลื่อนที่ของหนังสือ” - กิจกรรมที่ 4.2 “สมดุลของคน” - กิจกรรมที่ 4.3 “อุปกรณ์ในชีวิตประจำวัน” - กิจกรรมที่ 4.3 “แบบฝึกหัด”
6	แผนการจัดการเรียนรู้ที่ 5 เรื่อง แรงพยางของของเหลว	3	- กิจกรรมที่ 5.1 “แรงพยางของของเหลว” - กิจกรรมที่ 5.2 “จมหรือลอย” - กิจกรรมที่ 5.3 “แบบฝึกหัด”
7	แผนการจัดการเรียนรู้ที่ 6 เรื่อง การเคลื่อนที่แบบต่างๆ	2	- กิจกรรมที่ 6.1 “การเคลื่อนที่ในชีวิตประจำวัน” - กิจกรรมที่ 6.2 “การเคลื่อนที่แบบต่าง ๆ” - กิจกรรมที่ 6.3 “แบบฝึกหัด”
8	ทำการทดสอบหลังเรียน	3	- แบบทดสอบวัดความเข้าใจในมโนคติ - แบบทดสอบวัดการคิดวิเคราะห์ - แบบทดสอบวัดการนำความรู้ไปใช้ - แบบสอบถามความคิดเห็นของนักเรียนที่มีต่อรูปแบบ ฯ
	รวม	21	

D.2 The Instructional Plans



แผนการจัดการเรียนรู้ที่ 1

กลุ่มสาระการเรียนรู้วิทยาศาสตร์

ชั้นมัธยมศึกษาปีที่ 3

หน่วยการเรียนรู้เรื่อง แรงและการเคลื่อนที่ในชีวิตประจำวัน

ภาคเรียนที่ 1/2554

เรื่อง ความเร่งและผลของแรงลัพธ์

เวลา 2 ชั่วโมง

มาตรฐานการเรียนรู้

มาตรฐาน ว 4.1: เข้าใจธรรมชาติของแรงแม่เหล็กไฟฟ้า แรงโน้มถ่วง และแรงนิวเคลียร์ มีกระบวนการสืบเสาะหาความรู้ สื่อสารสิ่งที่เรียนรู้และนำความรู้ไปใช้ประโยชน์อย่างถูกต้องและมีคุณธรรม

ตัวชี้วัด

ว 4.1 ม.3/1 อธิบายความเร่งและผลของแรงลัพธ์ที่ทำต่อวัตถุ

สาระสำคัญ

เมื่อวัตถุเคลื่อนที่ด้วยความเร็วที่เปลี่ยนแปลงไปในหนึ่งหน่วยเวลาแสดงว่าวัตถุมีการเคลื่อนที่ด้วยความเร่ง โดยการเปลี่ยนความเร็วอาจเปลี่ยนขนาด เปลี่ยนทิศทาง หรือเปลี่ยนทั้งขนาดและทิศทาง วัตถุจะเคลื่อนที่ด้วยความเร่งเมื่อมีแรงลัพธ์ที่ไม่เท่ากับศูนย์มากระทำ แต่ถ้ามีแรงลัพธ์ที่เท่ากับศูนย์มากระทำต่อวัตถุ วัตถุจะหยุดนิ่งหรือเคลื่อนที่ด้วยความเร็วคงที่

การศึกษาเกี่ยวกับความเร่งและผลของแรงลัพธ์ที่กระทำกับวัตถุสามารถนำไปอธิบายลักษณะการเคลื่อนที่ของวัตถุในชีวิตประจำวันได้

จุดประสงค์การเรียนรู้

หลังจากเรียนจบเรื่องนี้แล้ว นักเรียนสามารถ

1. คำนวณหาความเร่งของวัตถุเมื่อกำหนดความเร็วของวัตถุที่เวลาต่างๆ ได้
2. นำความรู้เรื่องความเร่งและผลของแรงลัพธ์ไปใช้ในชีวิตประจำวันได้
3. ประเมินเหตุการณ์ที่เพื่อนยกตัวอย่างได้ถูกต้องและมีเหตุผล

สาระการเรียนรู้

1. ความเร่ง
2. แรงลัพธ์
3. ผลของแรงลัพธ์

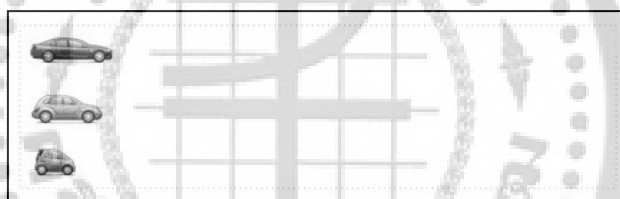
กิจกรรมการเรียนรู้

ขั้นที่ 1: มุ่งความสนใจ (Focusing)

1. ครูกล่าวทักทายนักเรียนและใช้สถานการณ์ในการนำเข้าสู่บทเรียน โดยให้นักเรียนดูวิดีโอทัศน์การแข่งขันรถ และสังเกตสิ่งที่เกิดขึ้น พร้อมทั้งใช้คำถามกระตุ้นให้นักเรียนสังเกตและแสดงความคิดเห็น ในประเด็นต่อไปนี้ เช่น

- รถแต่ละคันเคลื่อนที่ด้วยระยะทางเท่ากันหรือไม่
- รถแต่ละคันใช้เวลาในการเคลื่อนที่เท่ากันหรือไม่
- รถแต่ละคันเคลื่อนที่ด้วยความเร็วเท่ากันหรือไม่
- รถคันไหนเคลื่อนที่เร็วที่สุดและคันไหนเคลื่อนที่ช้าที่สุด

2. ครูให้นักเรียนดูวิดีโอทัศน์การแข่งขันของรถสามคัน (คันแรกมีความเร็วลดลง คันที่สองมีความเร็วคงที่ และคันที่สามมีความเร็วเพิ่มขึ้น) แล้วใช้คำถามกระตุ้นให้นักเรียนร่วมกันอภิปรายและแสดงความคิดเห็นเกี่ยวกับสิ่งที่สังเกตได้ พร้อมทั้งเปรียบเทียบความเหมือนและความแตกต่างของการเคลื่อนที่ของรถแต่ละคันในประเด็นต่างๆ เช่น ระยะทาง เวลา ความเร็ว เป็นต้น



3. นักเรียนเปรียบเทียบคำตอบของตนเองกับของเพื่อน แล้วร่วมกันสรุปและจัดกลุ่มคำตอบทั้งหมดบนกระดานดำ ก่อนทำการสำรวจตรวจสอบต่อไป

ขั้นที่ 2: สำรวจตรวจสอบ (Exploring)

1. นักเรียนแบ่งกลุ่ม ๆ ละ 3-5 คน
2. นักเรียนทำกิจกรรมที่ 1.1 “การเปลี่ยนแปลงความเร็ว” พร้อมทั้งบันทึกผลการสังเกตในตาราง

กิจกรรมที่ 1.1
การเปลี่ยนแปลงความเร็ว

กลุ่มที่ ชั้น

1. เลขที่ 4. เลขที่

2. เลขที่ 5. เลขที่

3. เลขที่

ให้นักเรียนศึกษาข้อมูลแสดงการเคลื่อนที่ของรถสามคันที่เวลาต่างๆ

รถคันที่ 1

ขั้นที่ 3: วิเคราะห์ข้อมูล (Analyzing)

1. นักเรียนแต่ละกลุ่มวิเคราะห์ข้อมูลโดยตอบคำถามและสรุปผลของกิจกรรมที่ 1.1

2. ตัวแทนนักเรียนแต่ละกลุ่มนำเสนอผลของกิจกรรมหน้าชั้นเรียน

ขั้นที่ 4: พัฒนาแนวความคิด (Conceptual Developing)

1. ครูและนักเรียนร่วมกันอภิปรายเกี่ยวกับข้อสรุปของกิจกรรมที่ 1.1 เพื่อให้ได้ข้อสรุปว่า “รถคันที่ 1 และคันที่ 3 มีการเปลี่ยนแปลงความเร็ว โดยคันที่ 1 มีความเร็วลดลงและคันที่ 3 มีความเร็วเพิ่มขึ้น ส่วนคันที่ 2 มีความเร็วคงที่”

2. นักเรียนศึกษาใบความรู้ที่ 1.1 “ความเร่ง” และใบความรู้ที่ 1.2 “ผลของแรงลัพธ์”

ใบความรู้ที่ 1.1
ความเร่ง

ความเร่ง

ความเร่ง (Acceleration) คือ การเปลี่ยนแปลงความเร็วของวัตถุในหนึ่งหน่วยเวลา มีหน่วยเป็นเมตรต่อวินาที² (m/s²) ความเร่งเป็นปริมาณเวกเตอร์ ดังนั้นวัตถุจะมีความเร่งเมื่อความเร็วเปลี่ยนไป โดยอาจเปลี่ยนขนาด เปลี่ยนทิศทาง หรือเปลี่ยนทั้งขนาดและทิศทาง ถ้าวัตถุใดมีความเร่ง 1 เมตรต่อวินาที² แสดงว่าวัตถุนั้นจะเคลื่อนที่ด้วยความเร็วที่เปลี่ยนไป 1 เมตรต่อวินาที ทุก ๆ วินาที หากได้จากสมการ

$$\text{ความเร่ง} = \frac{\text{ความเร็วปลาย} - \text{ความเร็วต้น}}{\text{เวลาที่ใช้}}$$

ใบความรู้ที่ 1.2
แรงลัพธ์และผลของแรงลัพธ์

แรงลัพธ์

แรงลัพธ์ คือ การรวมแรงมากกว่า 1 แรงที่กระทำต่อวัตถุ ซึ่งในการรวมแรงต้องพิจารณาทั้งขนาดและทิศทางของแรง เนื่องจากแรงเป็นปริมาณเวกเตอร์ แรงอาจมีทิศทางเดียวกันหรือทิศทางตรงกันข้ามได้ โดยเราอาจกำหนดว่า วัตถุเคลื่อนที่ไปทางขวาเป็นบวก (+) และวัตถุเคลื่อนที่ไปทางซ้ายเป็นลบ (-) เช่น

3. ครูและนักเรียนร่วมกันอภิปรายการเคลื่อนที่ของรถทั้งสามคันจากขั้นที่ 1 เพื่อให้ได้ข้อสรุปว่ารถคันที่ 1 มีความหน่วง รถคันที่ 2 มีความเร็วคงที่ และรถคันที่ 3 มีความเร่ง

ขั้นที่ 5: ประยุกต์ใช้ (Applying)

- ครูนำอภิปรายการนำความรู้เรื่องความเร่งและผลของแรงลัพธ์ไปใช้ในชีวิตประจำวัน เช่น การกระโดดร่ม การเหยียบคันเร่งเพื่อเพิ่มความเร็วของรถ การเหยียบเบรกเพื่อลดความเร็วของรถ
- นักเรียนแต่ละกลุ่มยกตัวอย่างเหตุการณ์ในชีวิตประจำวันที่น่าความรู้เรื่องความเร่งไปใช้ พร้อมอธิบาย โดยเพื่อนกลุ่มอื่นร่วมกันประเมินความถูกต้อง
- นักเรียนทำกิจกรรมที่ 1.2 “แบบฝึกหัด”

กิจกรรมที่ 1.2
แบบฝึกหัด

ชื่อ..... ชั้น..... เลขที่.....

จงตอบคำถามต่อไปนี้

- รถจักรยานยนต์คันหนึ่งเคลื่อนที่เป็นเส้นตรง ขณะที่สังเกตมีความเร็ว 30 เมตรต่อวินาที หลังจากนั้น 10 วินาทีต่อมา ความเร็วเพิ่มขึ้นเป็น 80 เมตรต่อวินาที จงหาความเร่งของรถคันนี้
- รถยนต์คันหนึ่งเคลื่อนที่เป็นเส้นตรง ขณะที่สังเกตมีความเร็ว 50 เมตรต่อวินาที หลังจากนั้น 5 วินาทีต่อมา ความเร็วลดลงเป็น 10 เมตรต่อวินาที จงหาความเร่งของรถคันนี้

4. นักเรียนทำแบบประเมินตนเองของผู้เรียน

ตารางสรุปทักษะการคิดวิเคราะห์ที่พัฒนาในแต่ละขั้นของกิจกรรมการเรียนรู้

กิจกรรมการเรียนรู้	การคิดวิเคราะห์
ขั้นที่ 1: มุ่งความสนใจ	การจับคู่ การจัดหมวดหมู่ และการสรุปหลักการทั่วไป
ขั้นที่ 2: สำรวจตรวจสอบ	-
ขั้นที่ 3: วิเคราะห์ข้อมูล	การสรุปหลักการทั่วไป
ขั้นที่ 4: พัฒนาแนวความคิด	การสรุปหลักการทั่วไป
ขั้นที่ 5: ประยุกต์ใช้	การประยุกต์ และการวิเคราะห์ข้อผิดพลาด

สื่อการเรียนรู้

1. วีดิทัศน์การแข่งขันรถ
2. วีดิทัศน์การเคลื่อนที่ของรถสามคัน
3. ใบกิจกรรมที่ 1.1 “การเปลี่ยนแปลงความเร็ว”
4. ใบกิจกรรมที่ 1.2 “แบบฝึกหัด”
5. ใบความรู้ที่ 1.1 “ความเร่ง”
6. ใบความรู้ที่ 1.2 “ผลของแรงลัพธ์”
7. แบบประเมินตนเองของผู้เรียน

การวัดและประเมินผลการเรียนรู้

ตัวบ่งชี้/ พฤติกรรม	วิธีการวัดและประเมินผล	เครื่องมือวัดและประเมินผล	เกณฑ์การวัดและประเมินผล
คำนวณหาความเร่งของวัตถุเมื่อกำหนดความเร็วของวัตถุที่เวลาต่างๆ ได้	ตรวจผลงานจากกิจกรรมที่ 1.2	แบบประเมินกิจกรรมที่ 1.2	ร้อยละ 80
นำความรู้เรื่องความเร่งและผลของแรงลัพธ์ไปใช้ในชีวิตประจำวันได้	สังเกตพฤติกรรม	แบบสังเกต	นักเรียนสามารถยกตัวอย่างและอธิบายเหตุการณ์ในชีวิตประจำวันได้ถูกต้อง
ประเมินเหตุการณ์ที่เพื่อนยกตัวอย่างได้ถูกต้องและมีเหตุผล	สังเกตพฤติกรรม	แบบสังเกต	นักเรียนสามารถประเมินเหตุการณ์ที่เพื่อนยกตัวอย่างได้ถูกต้อง

บันทึกหลังการจัดการเรียนรู้

แผนการจัดการเรียนรู้ที่.....เรื่อง.....

ชั้นมัธยมศึกษาปีที่.....โรงเรียน.....

1. ผลการสอน

1.1 ^{ขั้น}มุ่งความสนใจ

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1.2 ^{ขั้น}สำรวจตรวจสอบ

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1.3 ^{ขั้น}วิเคราะห์ข้อมูล

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1.4 ^{ขั้น}พัฒนาแนวความคิด

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1.5 ^{ขั้น}ประยุกต์ใช้

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2. ปัญหา หรือ อุปสรรค

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3. ข้อเสนอแนะ / แนวทางแก้ไข

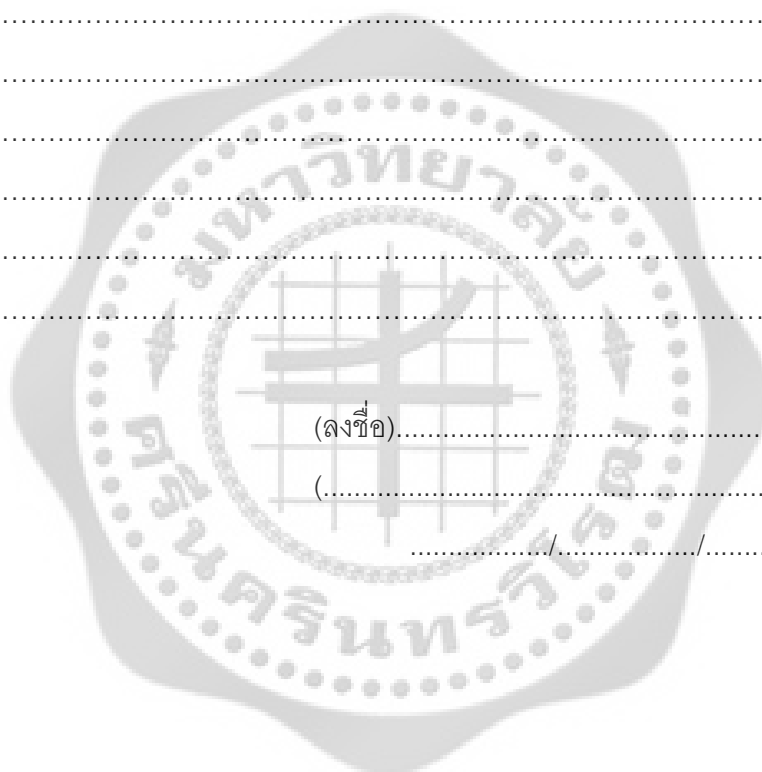
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(ลงชื่อ).....ผู้สอน

(.....)

...../...../.....

แบบประเมินตนเองของผู้เรียน

ชื่อ-นามสกุล.....ชั้น.....เลขที่.....
เรื่อง.....วันที่.....เดือน.....พ.ศ.....

คำชี้แจง จงตอบคำถามต่อไปนี้

1. นักเรียนได้เรียนรู้เรื่องอะไรบ้างจากการเรียนในครั้งนี้

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2. นักเรียนคิดว่านักเรียนจะสามารถนำความรู้ไปใช้ในชีวิตประจำวันได้อย่างไร

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3. นักเรียนได้มีส่วนร่วมในการทำกิจกรรมในการเรียนอะไรบ้าง อย่างไร

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4. นักเรียนชอบกิจกรรมการเรียนการสอนนี้หรือไม่ เพราะเหตุใด

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5. นักเรียนพบปัญหา หรือ อุปสรรคอะไรบ้างในการเรียนและในการทำกิจกรรมการเรียนรู้ในครั้งนี้

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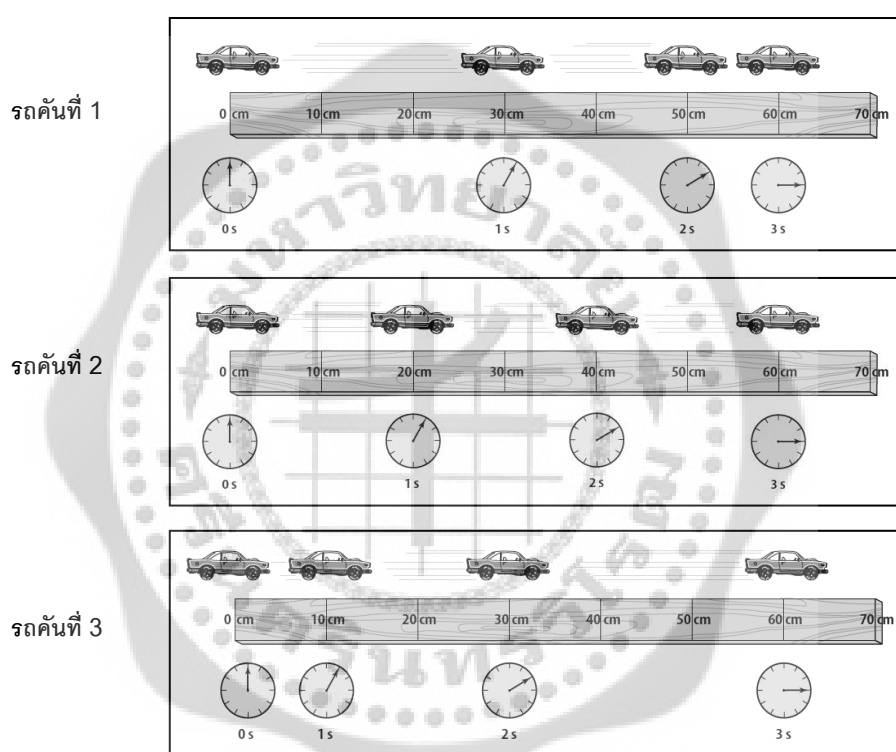
.....

กิจกรรมที่ 1.1
การเปลี่ยนแปลงความเร็ว

กลุ่มที่..... ชั้น.....

1.....เลขที่..... 4.....เลขที่.....
2.....เลขที่..... 5.....เลขที่.....
3.....เลขที่.....

ให้นักเรียนศึกษาข้อมูลแสดงการเคลื่อนที่ของรถสามคันที่เวลาต่างๆ



ภาพที่ 1 แสดงการเคลื่อนที่ของรถสามคัน

ตารางบันทึกผลการสังเกต

วินาทีที่	รถคันที่ 1		รถคันที่ 2		รถคันที่ 3	
	ระยะทาง (cm)	ความเร็ว (cm/s)	ระยะทาง (cm)	ความเร็ว (cm/s)	ระยะทาง (cm)	ความเร็ว (cm/s)
1						
2						
3						

จงตอบคำถามต่อไปนี้

1. รถทั้งสามคันเคลื่อนที่ได้ระยะทางเท่ากันหรือไม่ อย่างไร

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2. รถทั้งสามคันใช้เวลาในการเคลื่อนที่เท่ากันหรือไม่ อย่างไร

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3. ในแต่ละวินาทีรถแต่ละคันมีความเร็วเท่ากันหรือไม่ อย่างไร

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4. ให้นักเรียนคำนวณหาความเร็วที่เปลี่ยนแปลงในแต่ละช่วงเวลาของรถทั้งสามคัน

ช่วงวินาทีที่	ความเร็วที่เปลี่ยนแปลงในหนึ่งหน่วยเวลา (cm/s^2)		
	รถคันที่ 1	รถคันที่ 2	รถคันที่ 3
0 - 1			
1 - 2			
2 - 3			

5. รถทั้งสามคันมีการเปลี่ยนแปลงความเร็วเป็นอย่างไร

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กิจกรรมที่ 1.2
แบบฝึกหัด

ชื่อ.....ชั้น.....เลขที่.....

จงตอบคำถามต่อไปนี้

1. รถจักรยานยนต์คันหนึ่งเคลื่อนที่เป็นเส้นตรง ขณะที่สังเกตมีความเร็ว 30 เมตรต่อวินาที หลังจากนั้น 10 วินาทีต่อมา ความเร็วเพิ่มขึ้นเป็น 80 เมตรต่อวินาที จงหาความเร่งของรถคันนี้

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2. รถยนต์คันหนึ่งเคลื่อนที่เป็นเส้นตรง ขณะที่สังเกตมีความเร็ว 50 เมตรต่อวินาที หลังจากนั้น 5 วินาทีต่อมา ความเร็วลดลงเป็น 10 เมตรต่อวินาที จงหาความเร่งของรถคันนี้

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3. รถยนต์คันหนึ่งเคลื่อนที่เป็นเส้นตรงจากจุดเริ่มต้นจนถึงที่หมาย ได้ข้อมูลดังตาราง

ระยะทาง (m)	0	10	20	30	40	50
เวลา (s)	0	1	2	3	4	5
ความเร็ว (m/s)						

- 3.1 รถยนต์คันนี้เคลื่อนที่ด้วยความเร็วคงที่หรือไม่ อย่างไร

.....

- 3.2 รถยนต์คันนี้เคลื่อนที่ด้วยความเร่งเท่าไร

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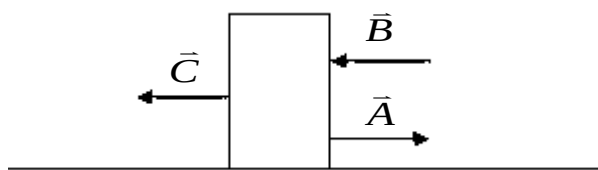
4. เด็กคนหนึ่งเดินไปทางทิศเหนือ 15 เมตร จากนั้นเดินกลับมาทางทิศใต้ 10 เมตร แล้วเดินต่อไปในทิศเดิมอีก 7 เมตร จงหาการกระจัดลัพธ์จากการเดินทางครั้งนี้

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5. ออกแรง $\vec{A}$, $\vec{B}$ และ $\vec{C}$ กระทำกับวัตถุตั้งรูป แรงลัพธ์ที่กระทำกับวัตถุเป็นเท่าใด

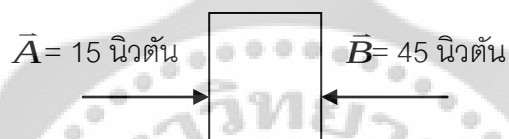


กำหนดให้ $\vec{A} = 35$ นิวตัน

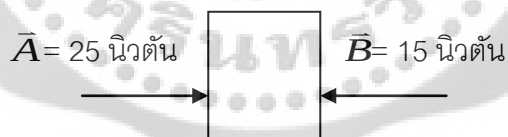
$\vec{B} = 10$ นิวตัน

$\vec{C} = 20$ นิวตัน

6. ออกแรง $\vec{A}$ และ $\vec{B}$ กระทำกับวัตถุมวล 5 กิโลกรัม ทำให้วัตถุเคลื่อนที่ด้วยความเร่งเท่าใด



7. ออกแรง $\vec{A}$ และ $\vec{B}$ กระทำกับวัตถุมวล 2 กิโลกรัม ทำให้วัตถุเคลื่อนที่ด้วยความเร่งเท่าใด



ใบความรู้ที่ 1.1 ความเร่ง

ความเร่ง

ความเร่ง (Acceleration) คือ การเปลี่ยนแปลงความเร็วของวัตถุในหนึ่งหน่วยเวลา มีหน่วยเป็นเมตรต่อวินาที² (m/s²) ความเร่งเป็นปริมาณเวกเตอร์ ดังนั้นวัตถุจะมีความเร่งเมื่อความเร็วเปลี่ยนไป โดยอาจเปลี่ยนขนาด เปลี่ยนทิศทาง หรือเปลี่ยนทั้งขนาดและทิศทาง ถ้าวัตถุใดมีความเร่ง 1 เมตรต่อวินาที² แสดงว่าวัตถุนั้นจะเคลื่อนที่ด้วยความเร็วที่เปลี่ยนไป 1 เมตรต่อวินาที ทุก ๆ วินาที หาได้จากสมการ

$$\text{ความเร่ง} = \frac{\text{ความเร็วปลาย} - \text{ความเร็วต้น}}{\text{เวลาที่ใช้}}$$

เช่น รถคันหนึ่งกำลังเคลื่อนที่เป็นเส้นตรง ในแต่ละวินาทีที่มีความเร็วเป็น 30 m/s, 35 m/s, 40 m/s, 45 m/s ตามลำดับ จะเห็นได้ว่ารถมีความเร็วเปลี่ยนไป 5 m/s ทุก ๆ วินาที แสดงว่ารถคันนี้มี ความเร่ง 5 m/s²

ตัวอย่าง รถคันหนึ่งเคลื่อนที่เป็นเส้นตรงจากเดิมอยู่นิ่งจนมีความเร็ว 20 เมตรต่อวินาที ในช่วงเวลา 10 วินาที จงหาความเร่งของรถคันนี้

วิธีทำ จาก
$$\text{ความเร่ง} = \frac{\text{ความเร็วปลาย} - \text{ความเร็วต้น}}{\text{เวลาที่ใช้}}$$

$$= \frac{20 - 0}{10 - 0}$$

$$= 2 \text{ m/s}^2$$

ตอบ รถมีความเร่ง 2 เมตรต่อวินาที²

การเปลี่ยนแปลงความเร็ว สามารถเกิดขึ้นได้ทั้งกรณีความเร็วเพิ่มขึ้นหรือความเร็วลดลง โดยเรียกการลดลงของความเร็วในหนึ่งหน่วยเวลาว่า **ความหน่วง (Deceleration)** ถ้าวัตถุมีความหน่วง 1 เมตรต่อวินาที² แสดงว่าวัตถุนั้นเคลื่อนที่ด้วยความเร็วลดลง 1 เมตรต่อวินาที ทุก ๆ วินาที ถ้าเป็นการเคลื่อนที่แนวตรงเมื่อเกิดความหน่วงจะทำให้วัตถุเคลื่อนที่ช้าลงจนหยุดในที่สุด

ตัวอย่าง รถคันหนึ่งเคลื่อนที่เป็นเส้นตรงด้วยความเร็วต้น 20 เมตรต่อวินาที แล้วเบรกจนหยุดนิ่งในช่วงเวลา 5 วินาที จงหาความเร่งของรถคันนี้

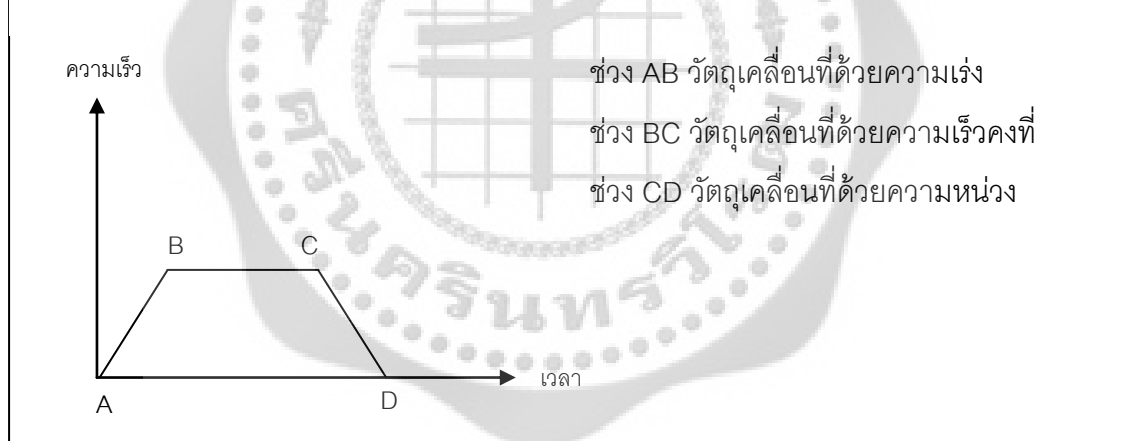
วิธีทำ

$$\begin{aligned}\text{จาก ความเร่ง} &= \frac{\text{ความเร็วปลาย} - \text{ความเร็วต้น}}{\text{เวลาที่ใช้}} \\ &= \frac{0 - 20}{5 - 0} \\ &= -4 \text{ m/s}^2\end{aligned}$$

ตอบ รถมีความหน่วง 4 เมตรต่อวินาที²

ถ้าความเร็วของวัตถุไม่เปลี่ยนแปลงทั้งขนาดและทิศทาง หรือวัตถุมีความเร็วคงที่ แสดงว่าวัตถุมีความเร่งเป็นศูนย์ เช่น รถยนต์ที่เคลื่อนที่ด้วยความเร็วคงที่ 50 เมตรต่อวินาที ในทิศทางเดิม ความเร่งของรถจะเป็นศูนย์เพราะไม่มีการเปลี่ยนแปลงขนาดและทิศทางของความเร็ว

ภาพที่ 2 กราฟแสดงความสัมพันธ์ระหว่างความเร็วกับเวลา



วัตถุที่เคลื่อนที่อย่างอิสระภายใต้แรงโน้มถ่วงของโลก จะเคลื่อนที่ด้วยความเร่ง ซึ่งความเร่งนี้จะมีค่าคงที่เท่ากับ 9.8 เมตรต่อวินาที²



ภาพที่ 3 การกระโดดร่มดิ่งพสุธา

เกร็ดความรู้

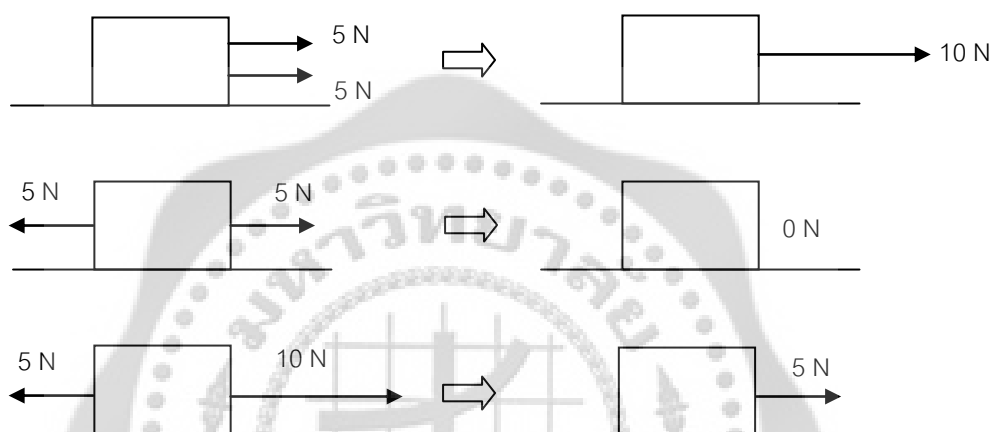
การกระโดดร่มของนักดิ่งพสุธา ขณะที่นักดิ่งพสุธากระโดดออกจากเครื่องบิน แรงโน้มถ่วงของโลกจะทำให้พวกเขามีความเร่ง 9.8 เมตรต่อวินาที² แต่เมื่อพวกเขากางร่มชูชีพ พวกเขาจะมีความหน่วงทันที

ใบความรู้ที่ 1.2

แรงลัพธ์และผลของแรงลัพธ์

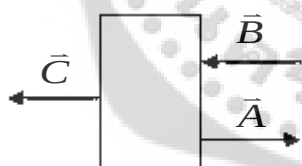
แรงลัพธ์

ผลของแรงทั้งหมดที่กระทำต่อวัตถุ เรียกว่า แรงลัพธ์ เป็นการรวมแรงทั้งหมดที่กระทำต่อวัตถุ ซึ่งในการรวมแรงนั้น ต้องพิจารณาทั้งขนาดและทิศทางของแรง เนื่องจากแรงเป็นปริมาณเวกเตอร์ แรงอาจมีทิศเดียวกันหรือทิศต่างกันก็ได้ โดยเราอาจจะกำหนดให้ เวกเตอร์ที่มีทิศไปทางขวาเป็นบวก (+) และเวกเตอร์ที่มีทิศไปทางซ้ายเป็นลบ (-) เช่น



ภาพที่ 4 การหาแรงลัพธ์ของวัตถุ

ตัวอย่าง มีแรง 3 แรงกระทำต่อวัตถุ ดังรูป จงหาแรงลัพธ์ที่กระทำต่อวัตถุ



กำหนดให้ $\vec{A} = 20$ นิวตัน

$\vec{B} = 15$ นิวตัน

$\vec{C} = 20$ นิวตัน

$$\text{ผลรวมของแรงลัพธ์} = 20 + (-15) + (-20)$$

$$= -15 \text{ นิวตัน}$$

ตอบ แรงลัพธ์ที่กระทำต่อวัตถุมีขนาด 15 นิวตัน ในทิศไปทางซ้าย

ผลของแรงลัพธ์

แรงลัพธ์ที่กระทำต่อวัตถุมีผลต่อการเคลื่อนที่ของวัตถุ โดยอาจทำให้วัตถุหยุดนิ่งหรือเคลื่อนที่โดยจำแนกได้ดังนี้

1. แรงลัพธ์เท่ากับศูนย์

เมื่อมีแรงลัพธ์ที่เท่ากับศูนย์มากระทำต่อวัตถุ จะทำให้วัตถุหยุดนิ่งหรือเคลื่อนที่ด้วยความเร็วคงที่ ซึ่งเป็นไปตามกฎการเคลื่อนที่ข้อที่หนึ่งของนิวตัน

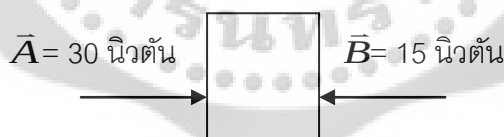
$$\text{แรงลัพธ์} = 0$$

2. แรงลัพธ์ไม่เท่ากับศูนย์

เมื่อมีแรงลัพธ์ที่ไม่เท่ากับศูนย์มากระทำกับวัตถุ จะทำให้วัตถุเคลื่อนที่ด้วยความเร่ง ซึ่งเป็นไปตามกฎการเคลื่อนที่ข้อที่สองของนิวตัน โดยสามารถหาแรงลัพธ์ได้จาก ผลคูณระหว่างมวลกับความเร่ง

$$\text{แรงลัพธ์} = \text{มวล} \times \text{ความเร่ง}$$

ตัวอย่าง มีแรง $\vec{A}$ และ $\vec{B}$ กระทำต่อวัตถุมวล 3 กิโลกรัมดังรูป จงหาความเร่งของวัตถุ



$$\begin{aligned}\text{แรงลัพธ์ที่กระทำต่อวัตถุ} &= 30 + (-15) \\ &= 15 \text{ N}\end{aligned}$$

$$\begin{aligned}\text{จาก } \text{แรงลัพธ์} &= \text{มวล} \times \text{ความเร่ง} \\ 15 \text{ (kg-m/s}^2\text{)} &= 3 \text{ (kg)} \times \text{ความเร่ง} \\ \text{ความเร่ง} &= 5 \text{ (m/s}^2\text{)}\end{aligned}$$

ตอบ วัตถุมีความเร่ง 5 เมตรต่อวินาที² ในทิศไปทางขวา



VITAE

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