

**THE DEVELOPMENT OF AN INNOVATIVE INTEGRATED APPROACH
TO ICT-MEDIATED LEARNING IN SCIENCE**

A DISSERTATION

BY

SIRINOOT TEANRUNGROJ

Presented in partial fulfillment of the requirements for the

Doctor of Education degree in Science Education

at Srinakharinwirot University

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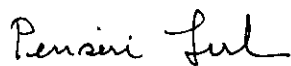
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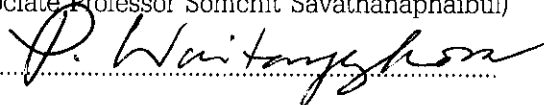
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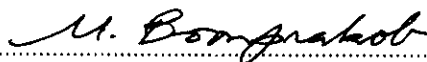
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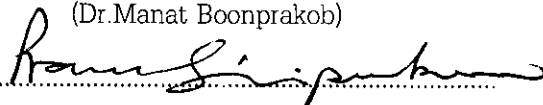
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CHAPTER 1

INTRODUCTION

Background

1. Education and Science Education

Education is an important process in human development and is the learning process for social development through the “imparting of knowledge, practice, training, transmission of culture, enhancement of academic progress, building a body of knowledge by creating a learning environment and learning society, and the availability of factors conducive to continuous lifelong learning” (MOE. 1999). Kaewdang (Chadtrakup. 1999: abstract; citing Kaewdang. 2000) also makes a similar list of the outcomes of the importance of education in human and social development.

Indeed, human and social development through education is an aim of the public understanding of science as Walton (1999: 153) points out that “in reality, the public understanding of science should be viewed as encompassing the public understanding, awareness or appreciation of science, engineering technology and mathematics”. On the same point UNESCO also states the importance of education in particular of science and technology:

... in a world where every aspect of life is increasingly dependent upon scientific & technological progress, promoting capacity-building and education in science and technology is indispensable for all nations not only to achieve sustainable development but also to create a scientifically and technologically literate citizenry in the interests of ensuring true democracy.

Consequently, the increasing disaffection of children and youth for science and technology worldwide is a cause of major concern as the children of today will be the citizens and decision makers of tomorrow.

(Hall-Rose. 2003: 1)

However, the basic systematic method in helping children use scientific ideas as tools for meeting the challenge of the rapidly changing environment around them is from the learning process in formal education through teachers or science educators who are involved as facilitators. Turner and Dimarco (1998: 23) point out that “one aim of science education is to

produce a society that understands the relation of scientific knowledge". This means an everyday knowledge or beliefs that can evaluate the difference between beliefs and scientific knowledge. According to Linn and His (2000), the education system can help children develop their powerful understandings of scientific ideas and useful pragmatic scientific principles to investigate personally relevant problems and to revisit their science ideas regularly which will turn them into people who are committed to lifelong learning.

2. Science Education in Thailand

Over the past decades, many countries around the world have realized that the success of national development results from science and science education. In Thailand, it has also been realized that the development of education is a vital national development strategy especially in human resources and economic development, and is a major product of science and technology, and science education contributes to the improvement of quality of life enabling people to keep pace with rapid changes in the global society (MOE. 1999). NSTDA-The National Science & Technology Development Agency (2000), Kaewdang (2001), Boonklurb (n.d.), and Khaemanee (2002) makes the same point. This problem is also reflected in the study of Downer and Rana (1999) which states that "In Thailand, the country's science and technology education program is not adequately preparing young people for the demands of working in a technological society".

From the review of the impact of inflation on the world economic system, reported by IMD-the International Institute for Management Development, Thailand is ranked 49th out of 49 countries in competency in science and technology. According to Kaewdaeng (2001), this disappointing result is due to the failure of the Thai education system. This result also reflects similar unsatisfactory achievement levels in TIMSS-The Third International Mathematics and Science Study, and TIMSS-R-The Third International Mathematics and Science Study-Repeat. Indeed, this is a critical problem in the Thai education system. The Ministry of Education (1996) points out that the problem comes from the teaching-learning system which is still focused on transferring academic knowledge to learners through rote-learning rather than on enhancing students' capabilities in acquiring knowledge, creativity, and problem-solving. Additionally, The Ministry of Education (1996) reports that overall curriculum objectives have not been reflected by measurement, evaluation, and entrance examination at all levels of education. Therefore, "to focus its efforts, the Ministry of Education has set a target of

educational excellence by the year 2007 by means of an education reform, involving schools, teachers, curriculum and management" (MOE. 1996). The Ministry of Education has specified as high priorities learning and teaching methodology. Particularly, science and technology can be improved by using educational technology (MOE. 1999).

In looking at the problems of secondary science education in Thailand, Downer and Rana (1999: 1) specifically report on the situation of the secondary science education program in which the problems are due to an inappropriate curriculum and the paucity of qualified teachers. Similarly, Poshyananda (2000) has identified three problems within education; 1) poor quality of mathematics, science and technology education, 2) problems in science and technology curricula, and 3) quality of teachers.

3. How to Improve Science Education

Alongside the importance of the quality of science and technology education in Thailand is the problem of the low level of science education. The concerns of educators have been directed toward finding various strategies for improvement because the problems have resulted from a wide range of factors. To improve the performance of students, the approach to teaching and learning should be changed. Boonklurb (n.d.) suggests that "...In order to achieve the science and technology literacy goal, the whole system needs to be changed, namely the science curriculum, the teaching/learning process, the assessment of students' outcomes and the training of science teachers." (Boonklurb. n.d.: 69). Walton (1999: 160) also states that "We should not simply assume that the learning of science is only a matter of pedagogy ..."

To help students understand science and prepare themselves for a new global society, Pouranachot (2002: 32) suggests that learning and teaching science should make students more curious through the use of active learning to understand the world and the use of scientific processes, to ask questions and to make decisions which they can apply to social solutions. Therefore, one of the aims of science education reform should focus on the characteristics of the learners as identified by Downer and Rana (1999: 170), they are:

- 1) An understanding of the principles and basic theories of science.
- 2) An understanding of the characteristics, scope, and limitations of science.
- 3) Skills in scientific and technological studies, discoveries, and inventions.

- 4) Rational thinking, open-mindedness, accepting others' opinions, belief in and making use of the scientific method in problem solving.
- 5) Love, interest, and eagerness to learn about science and technology.
- 6) A realization of the relationship among science, technology, human beings, and the environment concerning their mutual influences and impacts.
- 7) A knowledge of the application of scientific and technological and understanding to society and in daily life.

To improve science learning, teachers should use a variety of teaching strategies and encourage different learning strategies. The aims are to help students discover and understand their world. Another main aim is that students learn actively and autonomously. The following domains are the focused area for this study.

3.1. The Constructivist Approach

The constructivist approach is an important approach that refers to the idea that students construct knowledge for themselves. This approach is employed for education reform, especially in science education. This is supported by Bartlett, Burton and Peim (2001: 138) who state that "it is in the science subject area that constructivist ideas have been most influential". Similarly, Mathews (2002: 125) reflecting upon Bentley (1998) points out that constructivism is "indeed as an epistemology, constructivism speaks to the nature of science". When teachers design a science-learning package using a constructivist approach, they have to acknowledge that each student has his or her own preferred learning style. The learning environment management has become an interesting area for designing a learning package. This means that teachers have to manage their class by integrating a variety of teaching and learning strategies, an atmosphere encouraging students to seek out an experiment with new things or ideas, and provide students with the opportunity to develop their own style of learning.

Overall and Sangster (2003: 24) state that "to be active learners, they need to be able to: forecast how well they will do on various tasks; know what they already understand about the tasks; and know what aspects of the tasks they can do". The active classroom learning environment is currently considered to be an important methodology for education reform worldwide. Various active learning strategies can be employed in the classroom. The student-centered approach has been adopted in the National Education Acts of many countries worldwide of which one is Thailand. The work of Downer and Rana in 1999 points out that active learning is the good method for classroom instruction. Similarly, Koul and Fisher (2002)

also recommend in their study that the classroom learning environment dimensions are good indicators of the teaching and learning process. The considerations of these indicators are more benefits to improve students' outcomes. However, "this approach is fundamentally incompatible with the traditional classroom role of the Thai teacher" (Downer & Rana. 1999: 174).

Moreover, important teaching and learning techniques that should be employed in active classroom learning environment is how students can apply their knowledge to solve the problems that they meet in daily life. Various active learning techniques are applied in the constructivist classroom. They are; questioning technique, encouraging creativity, encouraging collaborative learning, motivating student, and self-evaluation. These techniques are recommended by various educators and researchers because they can support students' learning and constructing knowledge by themselves. Looking at the problem-solving technique, Brophy (1998: 1) reflecting upon Kluhr; et al. (1993), Adams; et al. (1988), Sherwood; et al. (1987) says, "In the domain of science, problem solving is a necessary activity to develop the understanding of the inquiry process". Gagnon and Collay (2001: 12) also reflecting upon Gagne' (1985) state that instruction should be structured to involve problem solving in order to ensure a higher level of understanding. Similarly, Johnsey (1986: 8) makes the same point "Teaching a general strategy with the problem-solving technique makes more sense than teaching children how to solve specific problems because the same strategy can be applied to a wide variety of situations not only in the classroom but also in the world at large". The study of Brophy supports this as well. His report shows that "problem-solving activities provide powerful opportunities for students to acquire and apply new information" (Brophy. 1998: 2).

3.2. The Integration of Information and Communication Technology into Classroom Practice

Educational reform in almost all countries focuses on curriculum, teaching strategies, learning strategies and assessment methods by integrating Information and Communication Technology. According to the study of SITES - The Second Information Technology in Education Study, Kozma (n.d.) reports that both developed and developing countries are beginning to invest ICT in education reform. Mooij and Smeets (2001: 265) reflecting upon Sinko; et al. (1999), and Smeets; et al. (1999) posit, "In many countries, ICT is becoming more and more important in education". Similarly, Pelgrum (2001: 163) states that "ICT is not only the backbone of the Information Society, but also an important catalyst and tool for inducing

educational reforms that change our students into productive knowledge workers”.

According to Shahrinin and Butterworth (2002: 204), the rapidly growing use of computers in business, at homes and in schools is apparently the reason for introducing computers to children in primary and secondary education levels. Furthermore, many educators contend that “computers can be used to promote learning and development in early childhood education if they are used appropriately”. The keys to raising student achievement are to promote students with a solid foundation of basic skills and to motivate them to learn (ACOT. 2002). This technology becomes an important factor in accomplishing this goal and designing the learning environment. Reflecting upon the idea of renowned educators like John Dewey, Maria Montessori, Paulo Freire, Eleanor Duckworth, TheodoreSizer, and Maxine Greene (Gagnon and Collay. 2001: 11) say that educators worldwide are challenging themselves to change their old view from designing for teaching to designing for learning. Unfortunately, few educational reforms have succeeded because the efforts to redesign a new classroom learning strategy has taken place only because of grassroots efforts by classroom teachers to change their science practice (Gagnon & Collay. 2001; citing Lambert; et al. 1997). Similarly, Reid (2002: 3) also reports from his research that “there were only teachers who try to integrate a new technology into their teaching”.

However, various educators are concerned with the impact of integrating information technology into the teaching process because it will change forever the way in which teachers teach and students learn by changing classroom learning environments and society (Harwell; et al. 2001). Salomon; et al. (1991) agree that new technology will “enable teachers to create learning environments to meet different students’ needs and to make teaching and learning more efficient and more applicable to the real world problems” (Krajcik. 2002: 411; citing Salomon; et al. 1991). This is supported by Harrison who points out that “the world is an open door, accessible through information technology” (Harrison editor. 1992: 73). According to Salomon; et al. (Krajcik. 2002: 411; citing Salomon; et al. 1991; Krajcik. 2002: 1), new computer-based technology can change what students do in the science classroom because this technology has a great potential for supporting students in learning science. Pickersgill (Kelleher. 2000: 1; citing Pickersgill. 2000), Haddad and Jurich (2001: 1) are also in agreement.

3.3. How to Improve Learning in Physics in Thailand

Physics is the learning about phenomena or explaining how the physical world works.

Students who learn physics will develop an appreciation of the world by their experience. But Haddad (2001: 5) points out that "... school conditions in most cases have reduced the wonderful, dynamic and multidimensional world of science into flat texts, scripted demonstrations and occasional cookbook experiments". McDermott (Jimoyiannis & Komis. 2001: 184; citing McDermott. 1993) similarly points out that "... transforming ideas and correcting defects of students' knowledge in physics is beyond the reach of the traditional teaching approaches because they tend to ignore the possibility that the perception of students is possibly different from that of the teacher".

In discussing learning in physics, Jimoyiannis and Komis (2001) draw upon the ideas of Halloun (1985), Whitaker (1983), Driver; et al. (1985), Duit; et al. (1991) that students normally possess a system of beliefs and intuitions about physical phenomena derived mainly from their everyday experiences but that conventional instruction is ineffective in that children develop more misconceptions about scientific theories. Therefore, teachers and students consider physics to be a difficult pursuit and abstract study.

To improve learning in physics, the constructivist teaching approach is considered to be an appropriate approach which can be used to engage students with more activities in the learning process. Furthermore, this approach should enable students to apply physical concepts and principles to novel situations.

On the one hand, it is ICT integration and the role of ICT that could develop a better understanding of Physics and encourage more active learning. Many researches have been done to investigate using ICT to help children understand physics; for example, computer simulation programs are chosen, students used as tools to help overcome the cognitive constraints originating from various misconceptions. According to the research of Jimoyiannis and Komis (2001), computer simulation programs of special interest to physics teaching could support learning in physics concepts and processes. Similarly, Lingard (2003) investigates using spreadsheets to teach terminal velocity for high school students. The results show that this technique works with a wide variety of abilities in Year-10 classes, and enhances students' understanding of a difficult topic.

Scaife and Wellington (1993: 61-62), in reflecting upon Barton and Rogers (1991), say that using data-logging will change the routine process of logging and give students more time to practice the interpretation skills that enhance scientific thinking, creativity and problem-

solving ability. Gipps (2001) also found from his observations on the subject of data-logging and computer control that data-logging is well suited to inquiry learning in science.

In Thailand, there have been many attempts to use ICT to improve learning in science with regards to the aims of The Institute for the Promotion of Teaching Science and Technology (IPST) on using ICT in science education (Boonklub. n.d.).

From the above, it is clear that the questions of how to integrate new technology in the learning process in the science classroom are worth studying. The integration of new technology into the science classroom is difficult to manage. This integration poses many challenging problems to educators worldwide. Some of these questions are centered on how to find appropriate new strategies for future science education such as 1) what is the learning pedagogy in the new science classroom learning environment? 2) which model is appropriate for new technologies in science classroom? and 3) what is the appropriate technique for measuring science learning outcomes? Therefore, with the appropriate strategies and techniques, ICT can support children's understanding of science, even in abstract concepts of Physics, and develop a new learning environment for the future science classroom. The important questions for this study are how to integrate the challenges and their solutions into the curriculum, to the learning process and to the science classroom. This study, therefore, develops an innovative style of teaching and learning empowered by the use of ICT. In addition, this study will also investigate learning environments, which are influenced by information technologies, and how ICT can encourage more effective learning in science.

Purpose of the Study

The main idea behind this study is to investigate how the achievement of students can be improved by the use of ICT, a wide range of information and communication technologies with the active learning methodologies being integrated into the curriculum and classroom. The purposes of this study are summarized as follows:

- 1) To develop an integrated approach to ICT-mediated learning in Science for the science curriculum entitled Force and Motion Module, which was designed based on active learning pedagogy for students in Year-10 (aged 14-15) at Key Stage 4 (Mathayom Suksa 4).

- 2) To investigate how the achievement of students can be improved.

- 3) To explore how ICT can change the learning style of students.
- 4) To investigate how the creativity in scientific communication of students can be improved.
- 5) To examine how ICT can change the classroom learning environment.

Scope of the Study

This study aims to investigate the students' understanding of science. A new science classroom learning environment is introduced integrating a wide range of ICT and active learning methodologies. 'Force and Motion', one of the abstract concepts in physics, data-logging and handheld technology, computer simulation program, generic software, and Sub-strand 4 of science and technology curriculum for Key Stage 4 are the focused areas in this study.

Research Questions

Specifically, the research questions are broken down into 4 main questions. They are as follows:

- 1) Can the achievements of students be improved by the use of ICT?
- 2) Are the learning styles of students changed by the use of ICT?
- 3) Can creativity in the scientific communication of students be improved by the use of ICT?
- 4) Can the learning environment be improved by the use of ICT?

Significance of the Study

This study attempts to acquire additional information concerning the integration of ICT into the science classroom learning environment. The findings of this study should assist science educators in general and science teachers in particular, in the design and implementation of ICT in their classroom.

Limitations of the Study

This study is limited by the characteristics of the population. The selected populations are students in secondary science schools who are equipped with microcomputers, handheld equipment and a networking environment. The ICT skills of the population and the availability of ICT are the main limiting factors for this study.

Population

The population of this study consists of students in the science program in Year-10 (aged 14-15) at Key Stage 4 (Mathayom Suksa 4).

Sample

The subjects are 82 students in the science program in Year-10 at Key Stage 4 who are studying in the first semester of the academic year 2004 at Triam Udom Suksa Pattanakarn School in Bangkok Thailand.

Variables of the Study

The integrated approach to ICT-mediated learning in Science is the only independent variable. The dependent variables, on the other hand are composed of the following factors.

- 1) Achievement; knowledge, comprehension and application (according to three main areas of cognitive domain of Bloom's taxonomy).
- 2) Learning style; divergent learning style, assimilative learning style, convergent learning style and accommodative learning style (according to Kolb's experiential learning styles).
- 3) Creativity in scientific communication; in terms of posters.
- 4) Learning environment; in terms of classroom interactions.

Definition of the terms

The terms used in this study are defined as follows:

1. Innovation means the learning cycle which is developed in 4 stages: 1) look and listen; 2) investigate; 3) share and 4) test. This learning cycle name '**LisT**' learning model. The uses of ICT are integrated into this learning cycle, which aims to improve the achievements of

students, creativity in scientific communication of students and active learning atmosphere. This innovation is also a new model, which has not been used in sample school environments.

2. ICT stands for Information and Communication Technology. It is the term used to describe the tools and processes to access, retrieve, store, organize, manipulate, produce, present and exchange information by electronic and other automated means (UNESCO. 2003).

3. Active Learning Methodology means the learning methodology that teachers foster in their classroom learning environment in which students construct their new knowledge by active and autonomous hands-on activity and fun in a collaborative environment with peers. Students get the opportunity to use ICT as a tool for their learning.

4. The Integrated Approach to ICT-Mediated Learning in Science means the proposed approach which utilizes a variety of ICT for learning in science. The ICT will be used by teacher and student as research tools, discovery processes, communication tool, a shared ideas tool, a presentation tool, a modeling tool, a collaborative learning tool, and so on. Teachers and students use the Internet as a gateway for learning. The 'Force and Motion' module, data-logging, handheld technology, computer simulation programs, web technology, the essential generic software and the curriculum Sub-strand 4 at Key Stage 4 are utilized in this approach.

5. Computer Simulation Program means a computer program, which is designed to solve problems using the same information processing techniques that a human would (McGilly. 1994: 8). The philosophy of this program is a constructivist philosophy that is controlled by the student and helps the student in construction of new knowledge or concepts.

6. Handheld Technology means the ICT equipment that is used for collecting data during the investigation process and during a practical science activity. This study means probes, sensors and data logger in the data collecting processes.

7. Data-logging means computer software that is used as a microcomputer-based laboratory (MBL) for collecting and manipulating experimental data in terms of tabulating, graphing and modeling from handheld technology.

8. Achievement means students' understanding of science within a new science classroom learning environment that integrates ICT and active learning methodologies as delineated in Cognitive Domain of Bloom's Taxonomy- Taxonomy of Educational Objectives (Bloom editor. 1956):

- 1) Knowledge: Knowing facts and describing what is observed.
- 2) Comprehension: Using ideas in familiar contexts, explaining how and why something happens.
- 3) Application: Using knowledge and understanding in a new context.

9. Learning Style means ways of learning in which students show their particular characteristic strengths and preferences. The ways they learn means the processing of information, and dealing with ideas. This study uses the four styles of learning as classified according to Kolb's experiential learning style inventory updated in 1985. They are:

- 1) Convergent Learning Style refers to persons who like to learn using abstract conceptualization and active experimentation. Their characteristics are that they mostly prefer to deal with things or narrow technical interests (Clark. 2000).

- 2) Divergent Learning Style refers to persons who like to learn using reflective observation and concrete experience. Their characteristics are that they mostly prefer to think about the subject imaginatively (Clark. 2000).

- 3) Assimilative Learning Style refers to persons who like to learn using abstract conceptualization and reflective observation. Their characteristics are that they mostly prefer to ask questions and attempt to create theoretical models. They are often more concerned with abstract concepts (Clark. 2000).

- 4) Accommodative Learning Style refers to persons who like to learn using concrete experience and active experimentation. Their strengths lie in doing things and involving themselves in new experiences. They tend to solve problems intuitively, relying on others for information (Clark. 2000).

10. Creativity in Scientific Communication means the ability of students to make a scientific issue from their understanding of scientific knowledge by using their higher order thinking skills: analysis; synthesis and evaluation. This issue will be demonstrated through ICT communication media in the form of posters, essays, slides or web publishing.

11. Active Learning Environment means learning environment in the classroom in which the teacher manages the classroom with active learning methodology. The learning environment of this study focuses on classroom interactions. This interaction is observed when the classroom atmosphere is changed from a traditional classroom to an ICT-mediated classroom learning environment. The classroom interactions mean teacher-student interactions,

student-student interactions and student-ICT interactions.

Conceptual Framework

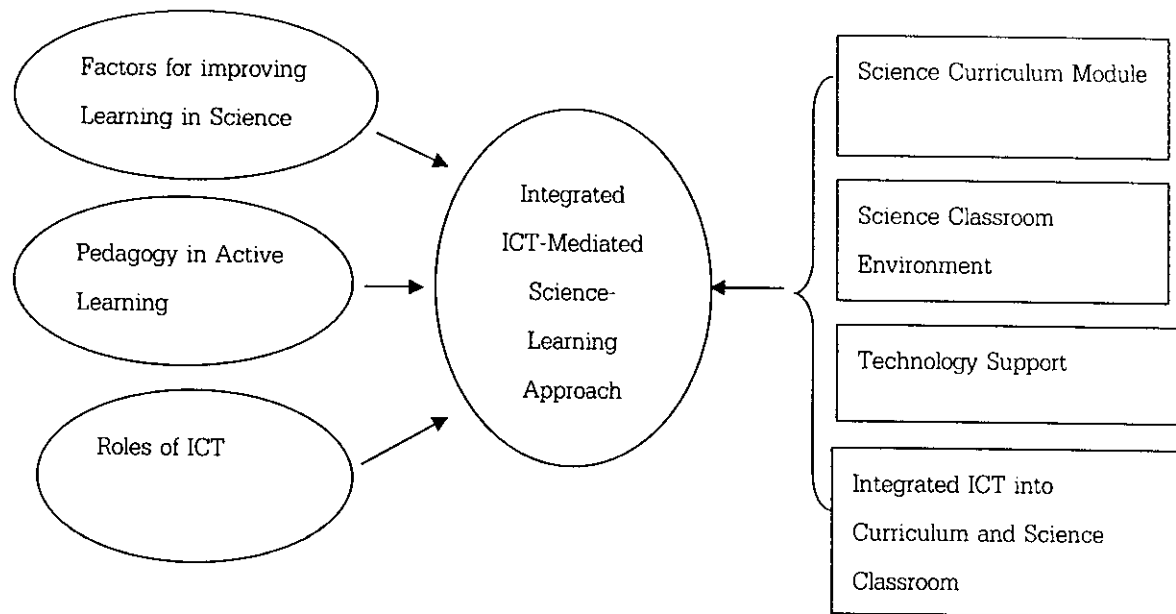


FIGURE 1 The Conceptual Framework

The conceptual framework for this study is provided as shown in Figure 1. The outcome of this study is an integrated approach to ICT-mediated learning in Science. This study focuses on two main areas of research study as follows:

1) The supporting information, ideas and researches about the improving science education. The main topics are as follows:

- Factors for improving learning in Science
- Pedagogy in active learning
- Roles of ICT.

2) The real situation in science education and ICT. The main topics are as follows:

- Science curriculum module
- Science classroom learning environment
- Technology support
- Integrated ICT into the science curriculum and science classroom.

Hypotheses

- 1) The performance of the integrated approach to ICT-mediated learning in Science is 80/80¹.
- 2) The achievement of students on the post-test would be higher than that of the pre-test.
- 3) The learning style of students is changed.
- 4) The creativity in scientific communication of students would be improved by the use of ICT.
- 5) The learning environment becomes an active learning environment enhanced by classroom interactions.

¹ 80/80 is the method for evaluating the performance of the approach. The first 80 means the average percentage scores of learning units and the last 80 means the percentage of tests scores.

CHAPTER 2

REVIEW OF THE LITERATURE

This chapter provides a review of the relevant literature upon which this dissertation is built. The purpose is to construct a framework for the body of knowledge related to improving science learning using ICT (Information and Communication Technology) in three broad sections. The first section deals with the active learning pedagogy, ICT enabled, in science education that is reviewed to understand and design the learning process for improving children's understanding of science. The second section, the ICT in science education, is a discussion and understanding of how to integrate the following ICT, computer simulation programs, data-logging, generic software and web technology to the outcomes from the first section in building up the innovative model for improving science learning using ICT. The third section deals with the practical work and assessment methods used in this study.

SECTION 1 The Active Learning Pedagogy in Science Education

1.1 Active Learning Approach

- 1.1.1 Constructivist learning theory
- 1.1.2 Constructionism learning theory
- 1.1.3 Constructivist classroom learning environment

1.2 Elements in Pedagogy of Active Learning

- 1.2.1 Active learning strategy
- 1.2.2 Collaborative work
- 1.2.3 Grouping techniques
- 1.2.4 Problem solving
- 1.2.5 Investigation
- 1.2.6 Creativity
- 1.2.7 Learning style

SECTION 2 ICT-Mediated in Science Education

- 2.1 ICT and a paradigm shift in education
- 2.2 How ICT can be related to science education
- 2.3 ICT elements for learning in science

- 2.4 Computer simulation program
- 2.5 Data-logging and its components
- 2.6 Generic software

SECTION 3 Practical Works and Assessment Techniques

- 3.1 Practical work
- 3.2 Assessment Techniques
 - 3.2.1 SOLO-taxonomy
 - 3.2.2 Bloom's taxonomy of educational objective
 - 3.2.3 Systematic classroom observation

SECTION 4 Conclusions

- 4.1 **LisT**, the integrated ICT-mediated learning in Science model

SECTION 1 The Active Learning Pedagogy in Science Education

This section provides information regarding the factors found in theories and research upon active learning approaches that relate to science learning. Many educators have defined the meaning of 'learning'. Bruner (1960, 1977: 17) states that "Learning should not only take us somewhere, it allows us later to go further more easily". Khaemanee, Dechakrup and Pornkul (2002: 1-3) give its meaning as 'the integration of learning process, knowledge, and the learning outcome'. Drillcoll (1994: 3) says that 'learning is lifelong activity'. Gagnon and Collay (2001: xvii; 2001: xx) also describe "learning as a process of constructing knowledge or changing what an individual knows by constructing a pattern of action to solve the problem of meaning".

In looking at learning, persons normally have their own strengths in one or more terms of intelligences, perception or process (Sarasin. 1999: 3-4). Howard, Gardner¹ (1983) has defined terms of intelligences as the following seven intelligences:

¹ Howard Gardner's work initially formulated a list of seven intelligences. The first two are ones that have been typically valued in schools, the next three are usually associated with the arts, and the final two are what he called 'personal intelligences' (Gardner. 1999: 52). His work stands in a direct line from the work of John Dewey. Since he originates a listing of the intelligences in *Frames of Mind* (1983) there has been a great deal of discussion and he adds an eighth intelligence - Naturalist Intelligence - to his list (Gardner. 1999: 52).

1) Logical/mathematical: This refers to scientific and mathematical thinking in analyzing problems logically, calculation, considering propositions and hypotheses, and doing complex mathematical operations. Children with this kind of intelligence are interested in patterns, categories and relationships.

2) Verbal Linguistic: This refers to ability to think in words and to use language to express and appreciate complex meanings. Children with this kind of intelligence enjoy writing, reading, or telling stories.

3) Musical: This refers to sensitivity to pitch, rhythm, and tone. Children with this kind of intelligence are singing or humming to themselves. They are usually quite aware of sounds others may miss. These kids are often discriminating listeners.

4) Spatial: This refers to a capacity to think in three-dimensional ways: to perceive imagery; to modify images, to move oneself or objects through space; and to understand how objects are related and how they fit together in an ordered manner. Children with this kind of intelligence think in images and pictures.

5) Bodily/ kinetic: This refers to ability to use one's whole body or parts of the body to solve problems, to manipulate objects and fine-tune physical skills. Children with this kind of intelligence process knowledge through bodily sensations. They are often athletic, dancers or good at crafts such as sewing or woodwork.

6) Interpersonal: This refers to a capacity to work effectively with others, to understand an accurate perception of oneself, and to use such knowledge in planning and directing one's life. Children with this kind of intelligence will be leaders among their peers, be good at communicating and seem to understand others' feelings.

7) Intrapersonal: This refers to an effective working model of oneself, a capacity to understand oneself, to appreciate one's feelings, fears and motivations. Children with this kind of intelligence are very aware of their own feelings.

Therefore, the term 'learning' could be defined as the systematic methodology which integrates content or knowledge, and methods or tools for learning to help individuals reach learning outcomes in their own perspective.

Consequently, the question is 'how to manage a good learning process to achieve the aims of learning'. Khaemane, Dechakrup and Pornkul (2002: 13-14) describe the learning process as a complicated process in that:

- 1) Learning is a cognitive process
- 2) Learning is personal experience
- 3) Learning is a social process
- 4) Learning is a thinking process and/or researching process
- 5) Learning is an active and enjoyable process
- 6) Learning depends on nurturing environment
- 7) Learning happens at anytime and in anyplace
- 8) Learning is a process of change;
- 9) Learning is a lifelong learning process.

Having said all that, it could be concluded that many factors are involved in 'learning processes' such as learning environment, people, society, knowledge, learning methodology, and so on. Vosniadou; et al. (2001: 382) agree that learning is an activity that happens in a social and cultural context by students who put their efforts, mindful process to construct their own knowledge and skills through active processing, rather than being passive listeners.

It is the 'learning environment that supports active learning and guides the student towards the acquisition of self-process' (Vosniadou; et al. 2001: 382). It is, therefore, important to present the styles of learning management in this section. Khaemane, Dechakrup and Pornkul (2002: 29-30) have classified three styles of learning management as summarized below:

1) Teacher-centred: The learning management method in which teacher manages almost all learning. The teacher is the important actor or the teacher is more active than students.

2) Student-centred: The learning management method in which the students direct almost all learning. The teacher is the facilitator or students are more active actors than the teacher.

3) Technology-centred: The learning management method in which students use information and communication technology or learning media for their learning.

In looking at the problems and rationale of science education as mentioned in chapter 1, improving children's performance in science learning should manage the classroom learning environment by the natural integration of a student-centered style with technology-centered style. The following sessions describe related ideas and theories that are relevant to this study.

1.1 Active Learning Approach

Many educators promote the implementation of the active learning approach in their research and also in their classroom management. Harwell; et al. (2001: 261) refer to John Dewey, Jean Piaget, Lev Vygotsky, Howard Gardner and others, Brooks and Brooks (1993; 1999) in the teachers' role and the students' role in classroom that students are in the pivotal role of constructing mental schemes of one's own understanding of the world. Teachers should focus attention on the learners by seeking and valuing students' points of view, by structuring learning activities which challenge students' beliefs, by recognizing that students need to experience personal relevance in the curriculum, by planning learning experiences around big ideas and interdisciplinary themes, and by evaluating student learning in the context of the classroom learning activities. It is the active learning approach that will bring together the role of both teacher and students. Dodge (1996: 1) states that active learning is a natural process. It involves putting the students in situations that compel them to read, speak, listen, think deeply, and to write. Harrison (editor 1992: 8-9) defines active learning as a learning methodology in which students are active learners with opportunities to manipulate small group discussions, problem-solving, debating, brain-storming, surveys, reports, creative writing, posters, formal presentations, and doing case studies.

In this respect, active learning means the learning methodology the teachers foster in their classroom learning environment in which students construct their new knowledge by active and autonomous hands-on activity and fun in a collaborative environment with their peers. Moreover, students get the opportunity to use ICT as tools for their learning. Particularly in science learning, a hands-on activity provides students with an experience in which they will gain a greater insight into scientific ideas and concepts. Barton (1997: 65) also supports this argument.

The following sub-session will review some theories and research for supporting the active learning methodology that will be used to design the integrated approach to ICT-mediated learning in Science of this study.

1.1.1 Constructivist Learning Theory

The active learning approach results from constructivist learning theory. This theory is considered as a paradigm shift in education (Braker & Hanson. 2003). It is an important learning theory for understanding the active learning process. The theory is based upon theories

considered as a paradigm shift in education (Braker & Hanson. 2003). It is an important learning theory for understanding the active learning process. The theory is based upon theories of cognitive psychology that were developed by educational thinkers such as John Dewey, Jean Piaget, Lev Vygotsky and Jerome Bruner. They believe that this theory can improve a student's understanding because it focuses on cognitive learning theory and a constructivist epistemology, rather than behaviorist learning theory (Gagnon (n.d.). Neo and Neo (n.d.), Gagnon and Collay (n.d.) argue that this approach helps students construct their own knowledge on the basis of interaction with their environment. Similarly, Conway (1997), in reflecting upon Roblyer, Edwards and Havriluk says that the model of constructivism emphasizes the students' ability to solve real-life and practical problems. Therefore, it can be said that constructivism is a way of building models for learning, teaching and curriculum design (Tobin editor. 1993). Therefore, the roles of the teacher in this learning approach have to change to facilitate and to arrange for required resources while students teach themselves (Conway. 1997).

According to the educational thinkers, John Dewey, Jean Piaget, Lev Vygotsky, Jerome Bruner, it is vital for this research design to review the ideas and theories in the following paragraphs:

Piaget talks of the natural development of children's cognitive structures and the solid framework for understanding children's ways of doing and thinking at different stages of development. He classifies four stages of child development by age structure as shown in Table 1.

TABLE 1 PIAGET'S STAGES OF CHILD DEVELOPMENT

Stage	Period of development	Age structure
I	The Sensory-Motor Period	Infancy
II	The Pre-operational Period	Pre-school and infant school
III	The Concrete Operative Period	Junior schools
IV	The Formal Operations Period	Secondary schooling

Source: Galloway & Edwards. 1992: 64

From the four stages of child development, Piaget summarizes that it is the mechanisms and processes by which the infant, and then the child, develops into an individual who can reason and think using hypotheses. He believes that when children experience discrepancies between what they already know and what they discover in their environment, they can construct an understanding of the world around them. It happens in the three processes of transition (Galloway & Edwards. 1992: 64):

1) Assimilation: The organism (mind) deals with new events by making them fit into its existing structures. The organism does not adapt itself to the new information. This needs to be balanced by some form of next stage, accommodation.

2) Accommodation: The organism (mind) adapts to the new events such as new concepts being formed or existing ones extended to incorporate and make sense of the new information.

3) Equilibration: In addition to emphasizing the importance of careful sequencing of experience to ensure accommodation, this model places the students actively at the centre of their own learning.

Driscoll (2000) refers to Piaget's suggestions that it is the teaching process that can support these developmental processes for children as active learners who construct a model of the world, by:

- 1) Providing support for the spontaneous research of the child.
- 2) Using active methods that require rediscovering or reconstructing "truths".
- 3) Using collaborative as well as individual activities.
- 4) Devising situations that present useful problems, and create disequilibrium in the child.

Vygotsky talks of the teacher and child in terms of a process of jointly constructing an understanding of the world through language and communication, through the social and cultural context. In line with Piaget's ideas, he maintains a broad view of development. He suggests that good instruction should provide learners with authentic situations in which they must resolve dilemmas. However, the child has not yet learned to operate at an entirely abstract level, so the instruction should focus on tasks and goals that are relevant to the child. That is socially meaningful activity (Driscoll. 2000, 1994)

In the social context, Vygotsky recommends collaborative learning in which group

members can help each other. He suggests two developments of child's intellectual capacity. They are actual developmental level and the level of potential development. He explains that normally individuals have different levels of ability. Therefore, more advanced peers can help less advanced members operate within their ZPD-the zone of proximal development. This zone is defined as the distance between a child's actual developmental levels as determined by independent problem solving and the higher level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers (Vygotsky. 1978: 86; Driscoll. 2000, 1994: 225).

Bruner begins his study with the cognitive growth by looking at the environmental and experiential factors, and then argues for the building of a cultural psychology. He believes that the outcome of cognitive development is 'thinking'. Humans use their capability to interact with culturally invented technology to build up their cognitive framework. The culturally invented technologies include not only concrete things such as computers and televisions, but also more abstract notions such as the way a culture categorizes phenomena, and language itself (Driscoll. 2000).

In the classroom domain, this educational approach of Bruner is defined in terms of 'Discovery Learning' which takes place through 'inductive reasoning' by using specific examples to formulate a general principle. Bruner(1960, 1977: 11-16) points out that learning is an active process in which learners construct new ideas or concepts based upon their current/past knowledge, therefore the teacher should provide and encourage students to discover new knowledge by themselves using intuition, imagination, and creativity. The idea is that students are more likely to remember concepts they discover on their own. He suggests four themes of the Process of Education that describe the process of instruction rather than learning. They are 1) the role of structure in learning and how it may be made central in teaching, 2) readiness for learning, 3) The nature of intuitive and analytical thinking, and 4) The desire to learn and how it may be stimulated. It is a motive for learning. He is also interested in material to be learned which is the best stimulus for learning.

Comparing discovery learning with cognitive development, Bruner suggests three stages of cognitive growth in children's learning: enactive stage, iconic stage and symbolic stage. He points out that when children learn, they will move from the 'Enactive' stage to the 'Iconic' stage, and then move to the 'Symbolic' stage. In the Enactive Stage, children understand or represent their world through actions. Examples of the actions are manipulation,

tasting, throwing, or breaking things. This stage can be applied in teaching by providing an opportunity for practice or learning by doing (Burton. 2001). In the Iconic Stage, children represent the world through concrete images. In the last stage, the Symbolic Stage, children are able to use abstract ideas, symbolic, and logic to understand and represent the world.

How can we apply discovery learning to support children's understanding of the world? Bruner (1960) points out that a teacher can design his/her teaching environment by following these steps:

- 1) Through actions-Enactive: The students manipulate and act on materials.
- 2) Through images-Iconic: The students imagine their understanding in form of note and making observations.
- 3) Through the use of symbol-Symbolic: the students abstract general ideas and principles from these experiences and observations.

These key ideas of Bruner are more powerful in science learning. Bruner believes that knowing is a process rather than the accumulated wisdom of science. Moreover, he suggests that the science curriculum should foster the development of problem-solving skills through inquiry and discovery process (Bruner. 1960, 1977).

However, discovery learning is impractical because students identify what they need to know, then find out and apply it. Therefore, teachers should carefully prepare their teaching and learning environment and learn how to apply this approach to their classroom.

As discussed above: Piaget's; Vygotsky's and Bruner's theories of learning, these ideas provide very useful models that support the design of a science-learning model for this study. In addition, Bartlett, Burton and Peim (2001: 138) agree, "It is in the science subject area that constructivist ideas have been most influential". Similarly, Good; et al. (1993) support the view that the memorization of scientific facts is an ineffective way of teaching and learning about science because the 'facts' are not the heart of science teaching. Their reasons are that 1) rote learning is less useful, 2) scientific facts change and may even contradict previously learned knowledge, 3) scientific facts are relatively much less useful than scientific knowledge, 4) teaching is not about transmitting knowledge, but catalyzing knowledge construction and meaning-making, 5) facts, by their nature, are potentially isolated, disconnected and misleading, and 6) facts alone do not empower the learners to learn science on their own.

When applying the constructivist approach to science learning, educators should

consider the following three main impacts:

1) Curriculum: When using constructivism, curriculum should be customized to the students' prior knowledge¹ and emphasize hands-on problem solving.

2) Instruction: Constructivism focuses upon making the connections between facts and fostering new understanding in students. Therefore, instructors should tailor teaching strategies that encourage problem-solving and promote open-ended questions and dialogue among students.

3) Assessment: Constructivism focuses upon becoming part of the learning process, therefore the assessment process should encourage students to evaluate their own progress.

1.1.2 Constructionism Learning Theory

Constructionism is a theory of learning and a strategy for education that was originated by Seymour Papert in 1991 (Willis & Tucker. 2001: 5). Papert suggests that this educational approach is based on the work of educational thinkers such as John Dewey, Jean Piaget, and Maria Montessori. This approach is built on the assumption that children will perform best by finding for themselves the specific knowledge they need. The kind of knowledge children most need is the knowledge that will help them get more knowledge (Papert. 1993: 139).

Papert also spells out in educational ideas that "people learn by actively constructing knowledge rather than by having information poured into their heads" and "people learn with particular effectiveness when they are engaged in constructing personally meaningful artifacts such as computer programs, animation, or robot" (Thurmond. 1999).

The works of Papert (1980; 1993) invoke the dual concepts of exploratory learning with the aid of computer software and of learners being aware of their personal learning preferences (Jones, A. 2002). He also considers the construction of new knowledge rather than overall cognitive potential, and focuses on the study of how learners engage in a conversation with artifacts and

¹ Gagne' (1965) and Ausubel (1963; 1968) stress the crucial role of prior knowledge in new learning. Ausubel claims that prior knowledge is essentially positive and vital for meaningful acquisition of new facts. Gagne' claims that prior knowledge is positive, and proposes that new algorithmic skills could not be learned unless specific prerequisites are possessed. However, researchers have found that earlier learning can have a negative influence on the understanding of scientific principles (White. 1988: 18; citing Gagne'. 1965; Ausubel. 1963; 1968).

how learners construct new knowledge from that environment, termed 'self-directed learning'. He also retains the essential idea of externalization in terms of support and mediation to expand the potential of humans at any level of their development. However, Ackermann (2001: 5), on reflecting upon the work of Piaget, says, "Papert's Constructionism is both more situated and more problematic than Piaget's Constructivism or Vygotsky's socio-constructivism".

1.1.3 Constructivist Classroom Learning Environment

Various researchers and educators invest what in the area of classroom learning environment. This area is originated by Lewin in 1936 who pointed out that "the environment and the interaction of the individual were powerful determinants of behaviour" (Koul & Fisher, 2002: 3; citing Lewin, 1936). In terms of a constructivist classroom learning environment, this study looks at a model of classroom management that refers not only to learning resources, use of space and time, and Information and communication technology but also to how this will influence pedagogical practice (Galloway & Edwards, 1992). Particularly in a constructivist classroom context, it is not easy to adapt constructivist learning theory to classroom teaching (Gagnon, 2001). It is vital for students to acquire an opportunity to learn in an atmosphere that encourages them to discover or construct their new knowledge and share their ideas with their peers. In order for this to happen, teachers should use the classroom not only for transmitting knowledge but also to construct new knowledge based on students' prior knowledge. They should start by managing their classroom with a constructivist atmosphere to promote a constructivist learning process.

When considering 'knowledge' in a constructivist approach, students construct their personal knowledge through a learning process. Gagnon and Collay (n.d.) classify this term in four ways:

- 1) Knowledge is physically constructed by learners who are involved in active learning.
- 2) Knowledge is symbolically constructed by learners who are making their own representations of action.
- 3) Knowledge is socially constructed by learners who convey their meaning-making to others.
- 4) Knowledge is theoretically constructed by learners who try to explain things they

do not completely understand.

A number of researchers agree that learning environments should support active learning and guide the students towards the acquisition of knowledge as a self-regulated process (Vosniadou; et al. 2001: 382). Similarly, Khaemane, Dechakrupa and Pornkul (2002: 19), in reflecting upon Rogers' theory of learning, state that humans can develop well when they learn in a relaxing and independent atmosphere, termed 'supportive atmosphere'. But, it is considered to be difficult for teachers or science educators to integrate a theory of constructivism and learning environment when designing a new learning environment. Therefore, a well-designed learning environment using constructivist ideas or techniques will help learners construct new knowledge and reformulate their existing knowledge framework based on new experiences and understanding (Braker & Hanson. 2003: 1). Similarly, Neo and Neo (n.d.: 4), in reflecting upon Vygotsky's idea (1978), say "in the constructivist perspective, social interaction enables students to learn with and from one another and this can lead to increased development of cognitive and intellectual skills, knowledge and understanding".

When designing a constructivist classroom learning environment, teachers should bear in mind the factors that influence to students' learning outcomes. Murphy (1997), in reflecting upon many educators: Vygotsky (1978); Jonassen (1994); Wilson and Cole (1991); Ernest (1995) and Honebein (1996), defines the characteristics of Constructivist learning and teaching. For instance, Vygotsky (Murphy: 3; citing Vygotsky. 1978) emphasizes the importance of 'scaffolding' in supporting students to perform tasks that would be slightly beyond their ability without assistance and guidance from teachers. Also, Jonassen (1994) argues that learners can construct their own knowledge. Therefore, the learning environment is an important factor that can support learners by providing an active learning process with real experience-based activity. Jonassen also suggests eight characteristics of an active learning environment that differentiate constructivist learning environments as shown in Figure 2 on Page 27:

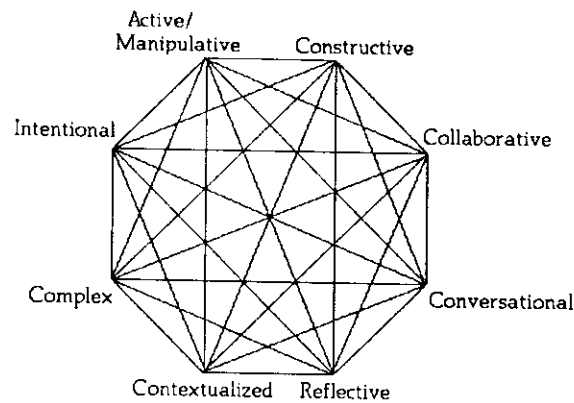


FIGURE 2 Learning environments

Sources: <http://tiger.coe.missouri.edu/~jonassen/courses/CLE/>

- 1) Constructivist learning environments provide multiple representations of reality.
- 2) Multiple representations avoid oversimplification and represent the complexity of the real world.
- 3) Constructivist learning environments emphasize knowledge construction and knowledge reproduction.
- 4) Constructivist learning environments emphasize authentic tasks in a meaningful context rather than abstract instruction out of context.
- 5) Constructivist learning environments provide learning environments such as real-world settings or case-based learning instead of predetermined sequences of instruction.
- 6) Constructivist learning environments encourage thoughtful reflection on experience.
- 7) Constructivist learning environments enable context and content dependent knowledge construction.
- 8) Constructivist learning environments support collaborative construction of knowledge through social negotiation, not competition among learners for recognition.

From an understanding of how learning environments affect the constructivist learning approach, the following paragraphs of this study review some learning processes or learning models developed under the ideas of constructivism.

In designing a science-learning model, Turner and Dimarco (1998: 60-62) suggest the following criteria to which teachers should pay attention in carefully planned teaching in order to help students' learning:

1) Prior knowledge which is the knowledge or experience that students have already learned or known. The teacher has to find out before teaching them.

2) Understanding in which teachers have to plan to know what are the common features of students' understanding and misconception of the topic that they are going to teach.

3) Linking the topic to previous work, teachers have to link with the work taught previously to help students' understanding.

4) Considering personal scientific understanding, teachers must be sure about the science of their lesson, the ideas and concepts of the lesson unit, and all equipment.

5) Considering the difficulty of the concepts which are more difficult for students to understand. This depends on a number of factors such as the relevance of topic, prior knowledge, intellectual demands which are significant for learning abstract concepts, and the mathematical demands of the concept. The teacher has to find ways to help them.

6) Ways to encourage and teach thinking, teachers have to give students' opportunities to practice thinking to their full potential, to encourage them to persist, and reward them by praising and recognizing their achievement.

There are many methods for applying the learning process to a constructivist classroom. Sarasin (1999) suggests that instructors should encourage students to verbalize their learning process and encourage them to think critically and challenge them to take risks in using information and skills in new learning situations. Furthermore, Gagnon and Collay (2001: x, 6) suggest constructivist learning design with the main assumption that "humans are developed by engaging in the personal and social construction of knowledge". They also believe in personality that:

1) Learners think individually to make personal meaning of learning events.

2) Learners think collaboratively to make shared meaning of learning events.

3) Learners connect their prior knowledge and previous experience to learning events.

4) Learners pose questions and respond to questions about learning events.

5) Learners present their thinking about learning events to others.

6) Learners reflect on their collective and individual thinking during learning events.

From these assumptions and beliefs, a CLD- constructivist learning design is developed that emphasizes six distinct elements: situation; grouping; bridge; questions; exhibit and reflection as shown in Figure 3 on Page 29. These elements are designed to provoke teacher

planning and reflection about the process of students' learning (Gagnon & Collay, 2001).

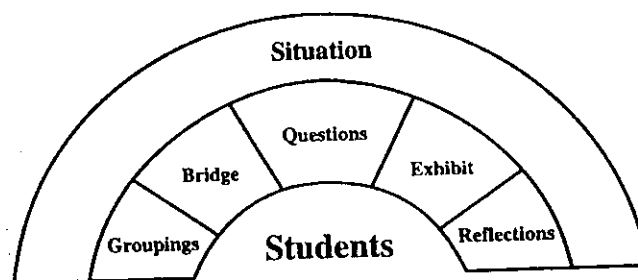


FIGURE 3 the relationship among CLD elements: Constructivist Learning Design (CLD)

Source: Gagnon & Collay, 2001: 9

1) Situation¹: This element is related to organizing learning episodes. Teachers frame their agenda and outline goals, lesson format, concentrating on how students will be engaged in the activities such as a process of solving problems, answering questions, creating metaphors, making decisions, and drawing conclusions.

2) Grouping: This element relates to grouping activity and students will interact with each other. The grouping technique depends on the constraints of students and materials.

- By student constraints: It could be as a whole class grouping, as individuals, or in collaborative thinking teams of two, three, four, or more. Teachers should decide how to group students such as by counting off, choosing a colour or piece of fruit, or grouping by clothing. This depends upon the designed situation and the available materials.

- By material constraints: It depends on the situation and how many sets of materials that students will use to explain about their collective experience.

¹ The situated cognitive model was coined by Jean Lave. This model describes learning in terms of situations specific to the mind at work and the world in which it works (Lave, 1988: 1) and suggests that the transfer of knowledge between one situation and another is restricted. Learners can act as legitimate peripheral participants, an analytical viewpoint of learning, a way of understanding learning (Lave, Jean and Warger, Etienne, 1991) as they gain increasing knowledge.

This study concentrates upon the classroom situation so that the application of a situated cognition model is less relevant in this case but may be a useful approach for learning that takes place outside the classroom.

3) Bridge: This element is a central piece of constructivist learning design that focuses on building a learner-centred context from which new knowledge is created between what students already know and what they want them to learn. This might involve such things as giving them a simple problem to solve, having a whole class discussion, playing a game, or making lists.

4) Question: This element could take place during each part/stage of the learning design. It is related to the formulating types and content of questions which encourage them to explain their thinking and to support them in continuing to think for themselves.

5) Exhibition: This element is related to ways for students to share the collective knowledge they have acquired and to exhibit a record of their thinking to others. This could include writing a description on cards and giving a verbal presentation, making a graph, or chart.

6) Reflection: This element is a way for students and instructors to articulate personal and collective learning, and solicit students' reflections about their learning. They would include what students remember from their thought process about feelings, images in their imagination, and language in their internal dialogue.

Whatever learning process takes place in an active learning atmosphere or a constructivist classroom learning environment, there is similarity in that students are helped to construct their own new knowledge. An interesting question is how to integrate all components of active learning into the constructivist classroom, particularly a science classroom, which is not only a place for transferring knowledge but also a place for constructing new knowledge and performing practical work in itself.

In this respect, evidence from a variety of research which is reflected by the literature review of Koul and Fisher (2002) who point out that classroom learning environment dimensions are good indicators of the teaching and learning process. They reflect a variety of research, for instance: 1) the study of the constructivist classroom environment by Taylor, Fraser and Fisher in 1997; 2) the study of the cross-national constructivist classroom environment by Aldridge and Fraser in 1999 and Fisher, Rickards, Goh and Wong in 1997, 3) the study of science laboratory classroom environment by McRobbie and Fraser in 1993, 4) the study of computer laboratory classroom environment by Newby and Fisher in 1997, 5) the study of computer-assisted instruction by Stolarchuk and Fisher in 1999 and The & Fraser in 1995, and 6) the study of

classroom environment and the teacher's cultural background by Khine and Fisher in 2001. The studies conclude that when a changing classroom learning environment is considered, a number of learning outcomes and the possibility of improving student outcomes can be predicted (ibid: 3).

Koul and Fisher (2002) studied the science classroom learning environment in India. Their study explore factors associated with students' perceptions of the classroom learning environment in India and investigated the associations between students' perceptions of their classroom learning environment and their attitudes to science using the WHIC-what is happening in this class- questionnaire. A variety of research has used this questionnaire to measure the psychosocial aspects of the classroom-learning environment in various contexts: student cohesiveness; teacher support; involvement; investigation; task orientation; cooperation; and equity. The observation and the interview are added to this study for supporting in-depth findings. The subjects are 1,021 students from 32 science classrooms. This research finding concluded that 1) the ultimate aim of education namely that of producing healthy-minded productive citizens can be achieved through positive attitudes towards learning by creating an enjoyable and productive learning environment, and 2) the existing learning environment can be reinforced by incorporating more positive practices. They will give an atmosphere to thriving students and teachers specifically and ultimately leading us towards a much healthier society.

1.2 Elements in Pedagogy of Active Learning

When looking at the constructivist-based paradigm, it is the active learning technique that can help students become active learners and pace their own learning process (Neo and Neo. n.d.). Kolb states that students need to engage in a wide variety of new experiences and opportunities to reflect upon new information, consideration of how the information affects and consideration of how they understand a new concept (Sarasin. 1999). Similarly, Turner (2001: 250) in reflecting upon Vygotsky (1986) says that 'the teacher cannot do the learning for the student and that in order for understanding to occur, the student has to be active in the learning processes'. Therefore, the following paragraphs will focus on the elements of active learning techniques that are involved in the constructivist classroom learning environment.

1.2.1 Active Learning Strategy

Turner (2001) strongly supports that active learning strategy is the key to a successful learning process because in the active learning strategy, students have some responsibility for

the development of activity which gives them a sense of ownership. Therefore, it can be claimed that the active learning is learning how to learn. It is contrasted with rote learning but is the same as discovery learning which motivates students by helping them to learn things by themselves.

Dennison and Kirk (1990) suggest a learning cycle as shown in Figure 4. Later, Watkins (1998) develops this learning cycle as an active learning strategy model, which is composed of four stages as presented in the same Figure 4 (Turner. 2001: 256; citing Watkins. 1998).

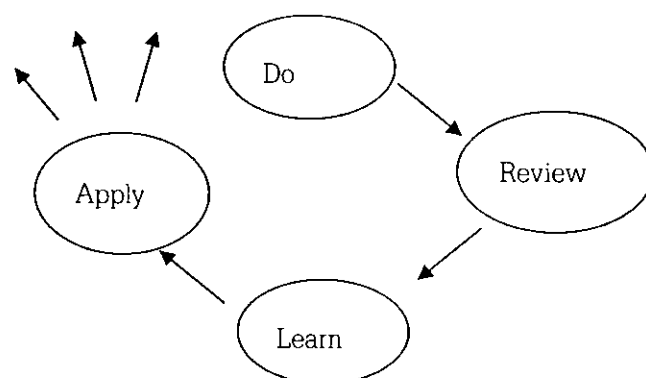


FIGURE 4 An Active learning Model

Source: Dennison and Kirk (1990: 4); Original Watkins (1998: 6); original Kirk (1987)

1) Do: This stage is the first stage in which teachers plan and teach the lesson to define the objectives of lesson. In this stage teachers can organize an experience, and an opportunity of doing something for their students (Dennison & Kirk. 1990: 3-4; Turner. 2001).

2) Review: This stage is to identify where learning takes place and what contributes to successful learning. Which ideas or processes gave difficulties? Teachers should try to identify factors contributing to success and to difficulties. In particular, teachers initiate discussion, offer insight about features of the experience, and give guidance to students who appear unable to review their experience (Dennison & Kirk. 1990: 3-4; Turner. 2001).

3) Learn: This stage involves clarifying what has been learned about teachers' teaching and what questions remain. Students should seek help about difficulties, from mentors, tutors, books, and colleagues. Students can identify problems, and solve those that are more deep-rooted (Turner. 2001).

4) Apply: This is the final stage, several arrows are meant to imply the numerous

situations in which students should learn how they can use new knowledge to improve their future lessons, planning, and further action (Dennison & Kirk. 1990: 3-4; Turner. 2001).

When the teachers plan to provide their classroom learning environment with a student-centered atmosphere, various active learning strategies are considered. On this subject, Harrison (1991: 7) defines the active classroom learning environment into various characters:

- 1) Group work
- 2) Accent on cooperation
- 3) Resource-based learning
- 4) Student responsibility for learning
- 5) Teacher as a guide / facilitator
- 6) Student ownership of ideas and work
- 7) Process skills and self-discipline
- 8) Students involvement in curriculum planning

9) Active students' involvement in learning, a wide range of learning styles employed

Besides this, Harrison (editor 1991: 9) suggests 12 active teaching strategies for teachers to integrate into their classroom. They are: 1) Group Discussion including Talking and Listening, 2) Active Reading, 3) Active Writing, 4) Presentation, 5) Role play and Drama, 6) Using Information Technology, 7) Visits, Visitors and Field Trips, 8) Data Handling, 9) Problem-Solving, 10) Video and audio tape recordings, 11) Games and Simulations, and 12) Assessment.

Sarasin (1999: 23) and Turner (2001: 267) make the same points and also add more teaching strategies such as using a small group discussion, surveys, teacher demonstration, case study, debates, and civil disagreements. These are strategies, they claim that represent diverse perspectives and problem solving in situations where there might be several solutions.

Turner (2001: 265) claims that the active learning mentioned above will be acquired by the advantage of setting up an active learning environment by teachers. He suggests 12 methods for use in an active learning environment. They are:

- 1) Students' skills in co-operating with other learners.
- 2) Group work is often used.
- 3) Curriculum development involves the learner.
- 4) The teacher uses a variety of teaching methods.

- 5) The learner 'owns' the ideas and the product.
- 6) The learner contributes ideas and the product.
- 7) The learners are active in their own learning.
- 8) The responsibility for learning is shifted to the learner.
- 9) Self-discipline is needed by the learner.
- 10) Process skills become important learning goals.
- 11) Resources-based learning methods are used frequently.
- 12) The teacher is a guide, not a provider.

In the domain of science education, it is an active learning strategy that allows students to develop their abilities to design and carry out investigations, and to draw inferences from exploratory tasks. As claimed by Harrison (editor 1992: 6), Gagnon and Collay (2001), the active learning strategy enables students to understand the use of scientific ideas more than traditional passive learning approaches. Also, this model leads students to a higher level of understanding in more general terms of their development.

1.2.2 Collaborative Work

Gokhale (1995) defined collaboration as the instruction method in which students at various performance levels work together in small groups toward a common goal. However, in terms of working together, Vygotsky (1978: 90) believes that in the social and cultural context, it can help children in constructing an understanding of the world in which they live. He also states "...learning awakens a variety of internal development processes that are able to operate only when the child is interacting with people in his environment and in cooperation with his peers. Once these processes are internalized, they become part of the child's independent development".

Vygotsky has influenced research in collaboration among children. His perspective requires data generating, planning and management, which can help children construct a common set of assumptions, procedures, and information, particularly in problem-solving roles (Forman & Cazden. 1998). Although learning is an individual mental process, it also takes place on a social level. The interactions between people and collaboration in exchanging information are considered very important as it helps the individual gain a much wider perspective (Khaemanee; Dechakrup & Pornkul. 2002: 12). Haslam (n.d.: 1) also agrees. In reflecting upon the work of Schauble; et al. (1995), he says 'If learning takes place in classes that are

collaborative, supportive and inclusive, more students can contribute to and participate in their own learning'.

Sarasin (1999: 27), reflecting upon Kolb, states that "once students have participated in such experiences involving reflection and application in the classroom or group setting, they should then also have extensive opportunities to create new concepts from the new information. This phase provides them with opportunities to synthesize, evaluate, and apply information that they have learned, which makes learning real for them and extends the processes'.

In research conducted by George and Bruce, the results show that successful performance levels in dyadic interactions are more significant than in individual work (Forman & Cazden. 1998). Similarly, Underwood (Monteith editor. 1998: 4; citing Underwood. 1998) who conducted a study by investigating a variety of tasks including reading interactive books, concludes that 'even in tasks with limited cognitive load, working together can have beneficial effects'. Moreover, Underwood (Monteith editor. 1998: 30; citing Underwood. 1998) in reflecting upon the study of Kruger (1993) says that when pairs of children solve a problem together, they think more effectively than when they work alone.

When working in groups, Slavin, and Johnson and Johnson have classified students' relationships into three styles: competitive, individual and cooperative learning (Khaemane. 2002). As far as the cooperative or collaborative learning styles are concerned, Khaemane, Dechakrup and Pornkul (2002: 24-25) would classify the characteristics of these interactions into 5 categories: 1) Positive Interdependence, 2) Face-to-face-promotive Interaction, 3) Individual Accountability, 4) Interpersonal and Small-group skills, and 5) Group Processing.

Consequently, this technique is beneficial to the design of the teaching and learning processes. Khaemane (2002: 105), reflecting upon Davidson (1994), also suggests that there are six teaching and learning styles found in the cooperative learning or collaborative learning classroom context. They are:

- 1) Student Team Learning
- 2) Learning Together
- 3) Group Investigation
- 4) The Structural Approach
- 5) Complex Instruction
- 6) The Collaborative Approach

This study defines the meaning of 'Collaborative Learning' as a learning method in which students work and learn together in groups to finish their goal by exchanging, investigation, discussion, and so on. In addition, students can use ICT to enhance their work.

Holubec, Johnson and Johnson (Khaemane. 2002: 101; citing Holubec; Johnson & Johnson. 1994) summarize, from more than 100 studies, the advantages of collaborative learning for students in these criteria: 1) greater efforts to achieve; 2) more positive relationships among students and 3) greater psychological health.

Linn and Burbules (1993: 92) summarize three benefits for students who learn in a collaborative environment which are important factors in helping students learn more about the world in which they live. These are listed as follows:

- 1) Fostering cognitive skills which include the ability to solve complex problems, to communicate experimental results, or to understand difficult material (Johnsons & Johnsons. 1979; Pea in press; Phelps & Damon. 1989; Webb. 1989).

- 2) Promoting social skills which include referred to respect for others, reliance on others for assistance, and sensitivity to group experience (Cohen. 1986; Sharan & Sharan. 1976).

- 3) Imparting work place skills which include working in a team, considering the student's role in different situations, learning the norms and practice of a group (Cohen. 1986; Lave & Wenger. 1991; Schoenfeld. 1989; Salvin. 1983).

Looking at collaborative learning in the ICT classroom learning environment, children can work more actively and more collaboratively with their peers. Underwood and Underwood agree that group work at the computer should be organized in cooperative work (Newton & Rogers. 2001: 24). These ideas are supported by a number of researchers such as:

Wegerif and Dawes (1998), reflecting upon the work of Howe; et al. (1996), Hoyles; et al. (1994), Light (1993), Littleton (1995) say that, "computers can provide a good focus for collaborative learning and communications".

Underwood (1998: 32), in reflecting upon the work of Clements; et al. (1985), Hawkins; et al. (1982), Underwood; et al. (1990), reports that children are more likely to work cooperatively and often achieve collaboration, when working on computer tasks rather than on standard classroom tasks.

Johnson; et al. (Newton & Rogers. 2001: 24; citing Johnson; et al. 1985), in a study of students working on a computer simulation program in a different group, report that students

organized in cooperative working groups perform better than groups organized in other ways.

1.2.3 Grouping Techniques

Grouping is an organizational strategy. It is an important element in the rationale for interactive group work. It provides situations in which students can test and try ideas and therefore start to engage in processes of evaluating their own work. This situation is called collaborative group work in which students work for group presentation. They learn about themselves in interaction with others in the ways of personal and social education (Galloway & Edwards, 1992).

In collaborative learning, the number of members in a group is one of the factors which determines success. It also depends on the task and learning process to which a student is assigned. Therefore, there is no fixed number of members in a group. For instance, Johnson and Holubec (Khaemane, 2002: 103; citing Johnson & Holubec, 1994) say that the number of students in group is from 3 to 6 but the best is 4 by mix of gender, competence and skills. Gagnon and Collay (2001) claim that grouping is dependent on objective of the task, the number of students, learning process and the number of materials that are available for the task. They recommend that a small group is necessary for students to move from personal meaning to share meaning in the social construction of knowledge.

Therefore, the organization of groupings is dependent on the following characteristics (Gagnon & Collay, 2001: 35-50):

- 1) Group configuration varies. The size and membership of groups are arranged according to the purpose of learning episode, the material available, and the length of time involved. The most effective communication takes place in small groups of two to six students.
- 2) Group accommodation difference. Using the role of observer, recorder and reporter for the students who initiate and monitor the group process and who record and report group thinking.
- 3) Groups solicit thinking from all members.
- 4) Groups account for individual learning.
- 5) Groups are organized deliberately by teachers.
- 6) Groups are assigned specific sets of material

However, a number of studies support group work such as Webb (1982), Skon; Johnson and Johnson (1981), and Laughlin (1978) have found that small-group learning procedures are

useful for training in intellectual skills, cognitive reasoning skills, and in concept learning skills (Andre. 1986: 195; citing Webb. 1982; Skon; Johnson & Johnson. 1981; Laughlin. 1978). Especially in practical science work, which is a social process that requires collaboration, Wellington (1998) reports that small group work, which inevitably goes on in practical science, can develop such skills as communication, interaction and co-operation. Underwood and Underwood (Newton & Rogers. 2001: 24; citing Underwood & Underwood. 1990), make the same point. They suggest that a small-group technique is better for students to share ideas during their activity. Similarly, Kennedy (Solomon. 2002; citing Kennedy. 1984) reports from his research of learning in Physics about electricity in a group of 11-year-olds that students' progress towards the accepted view of electricity and they make more progress by exchanging ideas, and speaking together about the experiment. Therefore, this is not an exact grouping technique. Teacher should consider the constraints of each learning environment in which grouping takes place.

1.2.4 Problem Solving

John Dewey is a well-known American philosopher and educator who believes in the importance of 'learning by doing' to foster the development of creativity and cooperation process among students. He believes that "men have to do something to the things when they wish to find out something; they have to alter conditions" (Dewey. 1916, 1966). He also insists that the true function of philosophy is to solve human problems and he/she will demonstrate that it can be made to do so (Buckman. 2001).

Beginning with the meaning of a 'problem', its meaning can be defined by reflecting upon Sternberg (1985: 229); see also Newell and Simon (1972), Gagne' (1970: 63), Good (1973: 518). They say that 'Problem' means a situation in which an individual wants to do something but s/he does not know the course of action and s/he needs to get what s/he wants and must find a means for getting there (Andre. 1986: 170). Therefore, it would be more useful if the problems that instructors pose to students are relevant and interesting to the learners.

Reflecting upon Brophy (1998: 3), Andre (1986: 171; 1989: 61), Candela (1997), Neo and Neo. (n.d.), Jones; et al. (1994: 1), Tsaparlis and Angelopoulos (2000: 131), 'Problem Solving' can be defined as a method or a process in which the learner discovers new knowledge and skills which they learned or engaged in a different context or a new situation by using a problem-solving process.

The problem-solving process is claimed to be a valuable strategy for developing some of the highest cognitive functions. Those functions are analyzing, generalizing, and synthesizing (Dundis. 2003; Jones; et al. 1994). The problem-solving process requires the solver to be able to use higher order cognitive skills, mental and behavioral activities. The aim is to discover a combination of previously learned rules with a number of steps. This will help the solver apply to achieve a solution in a new situation and explain the phenomenon or experimental activity (Sternberg. 1985; Brophy. 1998; Andre. 1989; Candela. 1997; Neo & Neo. n.d.; Jones; et al. 1994; Tsapalis & Angelopoulos. 2000).

The process of solving a problem also requires collaborative or cooperative work. Evidence from a number of studies points out that the verbalization of thought processes during problem-solving can facilitate problem solution and learning (Andre. 1986). Sharan (Marlowe & Page. 1998: 19; citing Sharan. 1985) reports that students learn best through problem solving, particularly in the process of investigation in which the student organizes and assimilates the experience. This process helps students develop logical thought and higher-order thinking skills. Tan (Neo & Neo. n.d.: 2; citing Tan. 2000) makes the same point saying that problem-solving activities will activate students in active learning and solving a problem will enhance creative and critical thinking skills and problem-solving skills.

Looking at learning in science, one goal of science instruction is to familiarize students with scientific knowledge that consists of laws, principles and theories (Carey; et al. 1993). But CTGV-Cognition and Technology Group at Vanderbilt (Brophy. 1998: 3; citing CTGV. 1992) argues that, "students should understand that science is more than memorizing those laws, principles and theories". Similarly, Johnsey (1986) points out that students normally use various abilities in learning science such as using language, drawings, diagrams, writing, talking, listening, mathematical skills and tools. Students get the experience in the well constructed problem, particularly in the real things, they will be highly developed in inventiveness and thought. Also, Brophy (1998), in reflecting upon Carey; et al. (1993), CTGV (1992), Johnsey (1986), claims that problem-solving is an appropriate teaching and learning method in science.

Many educators suggest a number of steps in the problem-solving process. They are:

Wallas (Andre. 1989: 63; 1986: 173; citing Wallas. 1926) describes four stages in the problem-solving process:

- 1) The preparation stage. The problem-solver analyses the problem, tries to define

it clearly, and gathers relevant facts and information.

2) The incubation stage. The problem is considered subconsciously while the problem solver is relaxing or considering something else.

3) The inspiration stage. The solution to the problem comes to the learner unexpectedly in the sort of 'light bulb lights' experience illustrated in cartoons. This corresponds to the insight experience of the Gestalt psychologists.

4) The verification stage. The solution involves checking and working out the details.

John Dewey introduces a basic five-step model for inquiry and problem-solving. These steps are known as the scientific method (Dewey. 1933; Jones; et al. 1994: 1; Atlas. n.d.: 1):

- 1) Preparation: to define the problem
- 2) Analysis: to formulate tentative hypotheses
- 3) Production: to collect, evaluate, organize, and interpret data
- 4) Verification: to reach conclusions
- 5) Reapplication: to test those conclusions.

GRASP: The Comino Approach suggests the key elements of getting results and solving problems as presented below:

- 1) Purpose: Identify purpose, focusing clearly on the desired result.
- 2) Criteria: Choose criteria for the successful achievement of the result.
- 3) Alternatives: Generate alternative ways of achieving that result.
- 4) Selection: Select the most promising course of action that will satisfy the criteria.
- 5) Put the chosen plan into action.
- 6) Monitor and control the process of reaching the desired outcome against the criteria.
- 7) Continuously review the purpose, criteria and progress.
- 8) Review the outcome

Gipps (2001: 1-2) suggests seven steps of problem-solving in scientific inquiry method:

- 1) Select a question to investigate
- 2) Define the problem.
 - What are you actually looking for?

- How will you know when you have found it?
- 3) Design an experiment
 - Use only what is available
 - What are the time parameters?
 - How many data points do you need?
 - How are you going to analyse the data?
- 4) Trial the experiment
 - Did the result improve your ability to answer the question?
 - Can a "good" result be repeated?
- 5) Redesign the experiment
 - If the first experiment gave a "bad" result, how should it be modified?
- 6) Trial the redesigned experiment
 - Are further modifications required?
- 7) Final interpretation of results:
 - Do the results open up possibilities for further experiments?

The Thai Ministry of Education suggests five steps in the problem-solving process (Khaemane. 2002: 310-311):

- 1) Observation: The student states the problem by getting information until she/he understands and know how to solve the problem.
- 2) Analysis: the problem will be started from the status of problem, cause and effect of the problem and the ordering of each problem.
- 3) Selection of problem-solving method.
- 4) Exploration of the solution following the method in Stage 3.
- 5) Conclusion. Students analyse the output from Stage 4. Then, they write a report of their solution.

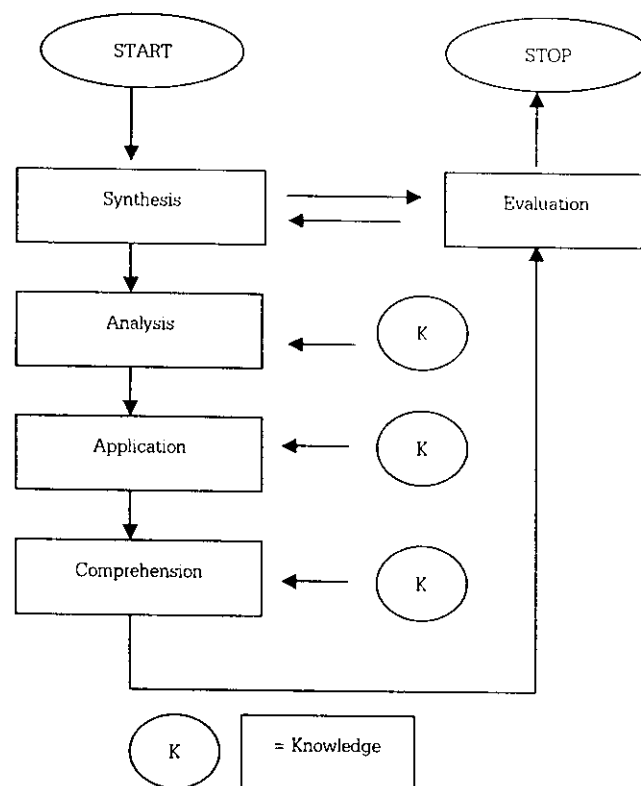


FIGURE 5 Bloom's six problem-solving skills

Source: OEP. 2003

Figure 5 shows this process of problem-solving which proposed by Bloom; et al. in 1979. They point out that when learners face a problem, they will use six problem-solving skills. These skills are summarized below (Jones; et al. 1994: 1; Bloom; et al. 1979: 201-207; unnamed. 2003; Clark. 2000):

- 1) Knowledge: This level solves the type of problems such as recalling data.
- 2) Comprehension: This level is the first level of understanding such as recalling the appropriate information and using it in conjunction with manipulation, translation, interpretation, or extrapolation of the equation or scientific principle.
- 3) Application: The next higher level of understanding is recognizing which set of principle ideas, rules, equations, or method should be applied.
- 4) Analysis: This is the process of breaking the problem into parts such that a hierarchy of sub-problems or ideas is made clear and the relationships between these ideas are

made explicit. Once the analysis of a problem is completed, the various sub-problems are then reduced to problems requiring the use of skills in level 3 (application). An example of an analysis question is "*What conclusions* did you come to after reviewing the experimental data?".

5) Synthesis: This is the putting together of parts to form a new whole. A synthesis problem would be one requiring the type, size, and arrangement of equipment necessary to make styrene. Given a fuzzy situation, synthesis is the ability to formulate (synthesize) a problem statement and/or the ability to propose a method of testing hypotheses. Once the various parts are synthesized, each part of the problem now uses the intellectual skills described in level 4 (analysis) to continue toward the complete solution. An example of synthesis level questions is "*Find a way* to explain the unexpected results of your experiment".

6) Evaluation: Once the solution to the problem has been synthesized, the solution must be evaluated. Qualitative and quantitative judgments about the extent to which the materials and methods satisfy the external and internal criteria should be made. An example of an evaluation question is "*Is the author justified* in concluding that the reaction rate is the slowest step in the mechanism".

All mentioned problem-solving processes above can be summarized into the 4 steps below:

- 1) Identifying the problem
- 2) Setting the hypothesis
- 3) Exploration
- 4) Evaluation and Application

Jones; et al. (1994) described the advantages of the problem-solving process as follows:

- 1) Students are actively engaged in comprehension and retention.
- 2) Students can apply this method to future problems.
- 3) Students will be trained in collaborative learning through which they can develop responsibility to the group, and listen to others' opinion.
- 4) Problem-solving involves cognitive (including higher levels) and affective learning (Jones; et al. 1994).
- 5) Students utilize materials and resources other than a single textbook.
- 6) Problem-solving provides an opportunity for students to learn from failure without

severe hardships.

Unfortunately, there are some drawbacks associated with the use of problem-solving. Jones; et al (1994: 1-2) point out some of its disadvantages as follows:

- 1) Unavailable materials and resources
- 2) Time consuming
- 3) Negative in outlook in thinking that the only worthwhile area of study is a "problem"
- 4) Requiring a lot of preparation and better discipline
- 5) Difficulty in evaluation

Therefore, to apply the problem-solving method in the classroom context, teachers should take in to consideration the following guidelines while they are preparing their lessons (Jones; et al. 1994).

- 1) Expose the students to a number of similar problems.
- 2) The problems presented must fit the maturity and skills' levels of the students.
- 3) The students must see the problem as being important.
- 4) Assist students in defining and delimiting the problem to be studied.
- 5) Check for sufficient resources and materials to be available for students' use.
- 6) Provide guidance and direction when necessary, taking care not to overdo it.
- 7) Help students establish criteria with which to make appropriate evaluations.

Moreover, a number of studies show that ICT can be used in the problem-solving process. Neo and Neo's (n.d.) research on using ICT supports a problem-solving method applied to a constructivist approach in Malaysia. In this study, students were divided into groups of five by self-selection and collaborate to complete their task with a variety of ICT multimedia software such as dream weaver or flash in order to exhibit their work on the web site. After the activity, the students were assessed in three constructs: teamwork, problem-solving and critical thinking skills, and personal attitude to their project. The results show that collaborative work with ICT can inculcate higher-order thinking skills such as problem-solving, and analytical and critical thinking skills. Moreover, this study also reports other students' opinions. In general students like problem-based projected and perform critical thinking and creating their solutions to enhance the site.

Brophy (1998) studies the effects of sequencing problem-solving, hands-on activities and laboratory activity on students' understanding of contents, student's engagement in the activity and student's self-regulation during the activity. This study uses two instructional methods: creating challenges with laboratory activity using inquiry method with the actual laboratory equipment to help students explore the concept of density of solid matter; and beginning instruction with a problem-oriented activity supported by a computer environment specifically designed to support students' inquiry during their problem-solving. Participants come from two magnet classrooms containing fifth and sixth grades. The results show that the combination of guided problem-solving and discovery-based laboratory experiments provide a strong instructional sequence for learning about volume and density and how to use them in problem-solving situations can improve the students' ability to sustain their own inquiry. All the students show a significant increase in their understanding of density. The experience with the problem-oriented activity and the simulated tools better prepared students to enter the hands-on activity and confidently work on the experiment with little teacher assistance. The active process of seeking information motivated students to continue their search. Hands-on activities often explore an isolated concept; therefore, these experiences often result in a low level of student engagement over time. This study gave some suggestions such as that science instruction should make problem-solving an integral portion of its instruction, and demonstrations and laboratory experiments have been vital tools for engaging students in authentic practices of inquiry. Further, computer technology has the potential to provide sufficient scaffolding without making instruction more difficult for the teachers.

1.2.5 Investigation

In science lessons, investigation is regarded as an important step in practical work (Woolnough. 1985; Gott & Foulds. 1989; Frost. 1995: 30) because pupils apply all the processes of measuring, graphical representation, prediction, controlling variables, interpretation, and observation along with their conceptual understanding and they carry out the investigation. Therefore, it can be claimed that investigation is an important strategy in science.

During practical work, especially at the investigation stage, students are involved in drawing conclusions and reporting through the processes of identifying a problem, deciding what to do and how to do it, allocating roles and responsibilities, carrying out the task, collecting data, analyzing and interpreting data and evaluating their investigations (Newton and

Rogers. 2001). Watson; Goldsworthy & Wood-Robinson (2002) define six kinds of complications of investigating tasks:

- 1) Classifying: a process of arranging a large range of phenomena, either objects or events, into manageable sets, and Identifying a process of recognizing objects and events as members of particular sets, possibly new and unique sets.
- 2) Fair testing: observing and exploring relations between variables, one independent to be manipulated independently of other factors.
- 3) Pattern seeking: involving observing and recording natural events as they occur.
- 4) Exploring: carrying out observations, making decisions about exactly what to observe, and the number and frequency of observations.
- 5) Investigating model: exploring a model or theory of the natural and physical world which is developed by scientists.
- 6) Making things or developing systems: a technological investigation in which students design an artifact or system to meet human needs.

The process of each kind of investigation can be summarized by the investigation process of APU-The Assessment of Performance Unit in the United Kingdom- in Figure 6 on Page 47. The process is interpreted in a cycle of 8 events: problem perception; problem reformulation; planning; carrying out the experiment; recording the data; interpreting data and drawing conclusion; evaluation of result; and evaluation of the method (Frost. 1995: 68-69).

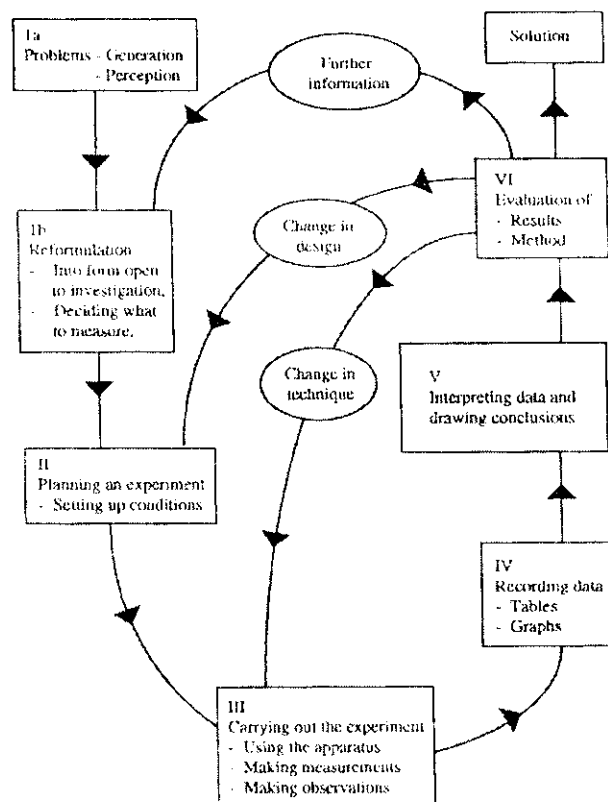


FIGURE 6 Investigations: Cycle of events, APU

Source Frost.1995: 68

1.2.6 Creativity

Many educators, artists, writers, psychologists have warned that the lack of creativity in the curriculum will affect children's and young peoples' creative potential (Loveless. 2002). It is creativity that is recognized as an essential element in participating in and contributing to the life and culture of society. This can be done at the level of individual, peer-groups or the wider society. Therefore, creativity is considered to be the quality that is essential for people to develop their potential to use their imagination to express themselves and to interact with people in communities and in wider social contexts (ibid.). Pothisuk (Kongsong. 2000: 25-26; citing Pothisuk. 1994: 89-92) suggests that an individual's creativity can be promoted through the learning process. It can promote a student's thinking skills; evaluate a student's work; provide method to access a variety of information; assign creative assignment; manage freedom or classroom atmosphere to promote using their imagination; promote self-confidence; promote a questioning atmosphere; use a variety of assessments; integrate with other subjects; promote

inquiry activity.

In the domain of science, Manzelli (1998: 1) states, "In our current scientific paradigm of understanding reality, there is no scientific definition of creativity". However, he explained that scientific knowledge has a strong impact on the development of our society and that creativity is the basic principle for improving personal intelligence for the progress of society. It is one of the fundamental strategies of the natural evolution' (ibid.). He also pointed out that 'Individual creativity will innovate new things by diverging from familiar patterns, namely divergent thinking, and then converging on new solutions, namely convergent thinking'. The outcome of this process, creative product, may be shown in the artistic products or self improvement (ibid.). Similarly, Young (Bonk. 1998: 1; citing Young. 1985) defines that "Creativity is individual skills or strategy in bringing out something new and valuable".

It is precisely that science is changing our society from the traditional world to a global society. On the one hand, personal intelligence causes a progression of our society that results from the learning process. Therefore, it is very significant for preparing students in a world which is rapidly changing.

As discussed above, the meaning of creativity can be defined in terms of divergent thinking, convergent thinking, artistic assessment and self-assessment (Dow. 2003: 1):

1) Creative Divergent Thinking is the ability to consciously generate new ideas that branch out to many possible solutions for a given problem.

2) Creative Convergent Thinking is the ability to correctly hone on the single correct solution to a problem. It often requires taking a novel approach to the problem, seeing the problem from a different perspective or making a unique association between parts of the problem.

3) Artistic assessment is the outcome that can be shown by the artistic product, for example a painting, story, poem, musical composition, collage, drawing.

4) Self Assessment is a person's responses to the amount of creativity that person feels they exhibit.

The following process describes when people are in a new situation in which they need to know and solve problem (Bonk. 1998; Dow. 2003; citing Torrance. 1988).

1) Sensing difficulties, problems, gaps in information, missing elements, something askew

- 2) Making guesses and formulating hypotheses about these deficiencies
- 3) Evaluating and testing these guesses and hypotheses
- 4) Possibly revising and re-testing them
- 5) Communicating the results

The processes showed above are the same as in the problem-solving process. Therefore, in the classroom problem-solving context, it is very important for teachers to know that students use creative thinking in improving themselves particularly in scientific ways. Dow (2003: 1) suggests four main components of "creativity tests" for teachers to monitor students' creativity in solving problems when they are in a new situation:

1) For Divergent Thinking: The solutions or responses are scored on four components:

- 1.1) Originality: using statistical infrequency of their response.
- 1.2) Fluency: using a number of their responses.
- 1.3) Flexibility: looking at the degree of difference of the responses, from a single domain or multiple domains.
- 1.4) Elaboration: using the amount of detail in their response.

2) For Convergent Thinking: These solutions are scored either correct or incorrect.

3) For Artistic Assessments: Evaluations are typically conducted by two or more judgments. Those must be in near agreement to the creativity of the product.

4) For Self-Assessment: A person's response to the amount of creativity a person feels they exhibit.

Creativity tests aim to assess the qualities and abilities that constitute creativity (Wieder. n.d.). There are many schools of thought regarding generating the standard tests that can be used for evaluating students' creativity. They are: 1) Teresa Amabile, a well-known researcher in the field of creativity; 2) TTCT-Torrance Test of Creative Thinking; 3) Meeker Test; 4) APR-Aptitude Research Project; 5) The creativity assessment package; 6) Creativity check list (ibid).

Sherief (Kongsong. 2000: 34; citing Sherief. 1979) examines the effects of classroom atmosphere on students' creative thinking. The study uses individual thinking for their activity and arranged activity by teachers. The subjects are Key Stage 1 students. The results show that

the mean score of creativity of students in an individual thinking group is higher than the mean score of creativity of students in an arranged activity group.

Kongsong (2000) investigates the creative thinking of gifted children by using about thinking module. The one group pretest-post-test is designed for 25 subjects from Key Stage 1. The results show that the creative thinking abilities of gifted children by using thinking module have increased significantly.

In the domain of a digital technologies-based society, Loveless (2002: 3) states "Creativity can be promoted and extended with the use of new technologies where there is understanding of, and opportunities for, the variety of creative processes in which learners can engage". Therefore, the creativity for this study is classified in terms of scientific communication. This refers to the ability of students to use both higher-order thinking skills: analysis; synthesis; and evaluation, and their understanding of science to make a scientific issue. This means that students can express their understanding of science to explain situations in their daily life. They may produce the issues in terms of posters or any electronic form.

1.2.7 Learning Style

Learning style is an approach to learning that emphasizes the fact that individuals perceive and process information in very different ways (Clark. 2000). Dunn; Beaudry; and Klavas (David & Franklin. 2004: 1; citing Dunn; Beaudry & Klavas. 1989) give the meaning of learning style as a "biologically and developmentally imposed set of personal characteristics that make the same teaching (and learning) methods more effective for some and less effective for others". Karp (2003) gives the meaning of the learning style as the way people learn best. Similarly, Fardouly (1998) confirms that various educational researches show that people have different learning styles or preferences. Filbeck (n.d.) reports on the studies of previous researchers that the learning style is most effective when the learner is able to use life experience to better understand principles (Dewey. 1938), or actively engage in the learning process (Lewin. 1951), or match with his or her psychological learning type (Piaget. 1971). This is of great importance not only in inform-teaching practices but also in bringing to the surface issues that help faculties and administrators think more deeply about their roles and the organizational culture in which they carry out their responsibilities (Claxton & Murrell. n.d.: 1). Some studies show that identifying a student's learning style and then providing instruction

consistent with that style contributes to more effective learning (ibid. n.d.). Brown (2003: 1) reports on studies by Miller (2000) and Stitt-Gohdes (2003) that when students' learning preferences match their instructor's teaching style, student's motivation and achievement usually improves. Moreover, Dunn; Griggs; Olsen and Gorman (Lefkowitz. 2002; citing Dunn and others. 1995) report from their study that students whose learning styles are accommodated through compatible instructional interventions can be expected to achieve 75% of a standard deviation higher than those who had not had their learning style considered.

The concept of learning styles is rooted in the classification of psychological types. Some educators describe many reasons for differences in individual learning style. For instance, Kozma (1994) describes two main reasons, behavioral approach and cognitive approach. Dunn (Taweelap. 2003: 12; citing Dunn. 1983) describes five reasons: 1) environmental condition; 2) emotional condition; 3) sociological condition; 4) physical condition; and 5) psychological condition.

Learning styles come from many schools of thought. They are 1) personality patterns (Clark. 2000: 16; Claxtin & Murrell. n.d.), 2) information processing, 3) perceptual modality, 4) social interaction (Claxtin & Murrell. n.d.), and 5) instructional methods (Claxtin & Murrell. n.d.). A variety of learning style inventories exist in order to test alternative hypothesis of learning style effectiveness, including Kolb's learning style inventory, Dunn's learning style inventory, the 4 MAT, and the Myers-Briggs type indicator (Filbeck. n.d.). The information-processing approach distinguishes between the ways learners think, solve problems, and remember information. David Kolb, who is credited with initiating the learning styles movement, states that "it is more effective to design curriculum so that there is some way for learners of every learning style to engage with the topic, material, and then begin to stretch his or her learning capability in other learning modes" (Brown. 2003: 1; citing Delahoussaye. 2002: 31).

Kolb's learning style inventory (KLSI) is a model of an information-processing approach which is based on three educators: John Dewey who emphasizes the need for learning to be grounded in experience; Kurt Lewin who stresses the importance of a person being active in learning; and Jean Piaget who originates the theory of intelligence as the result of the interaction of the person and the environment (Clark. 2000). Originated in 1979 and modified in 1985, Kolb's learning style is classified into four stages of learning, which are based on a model with two dimensions as shown in Figure 7 on Page 52 (ibid.).

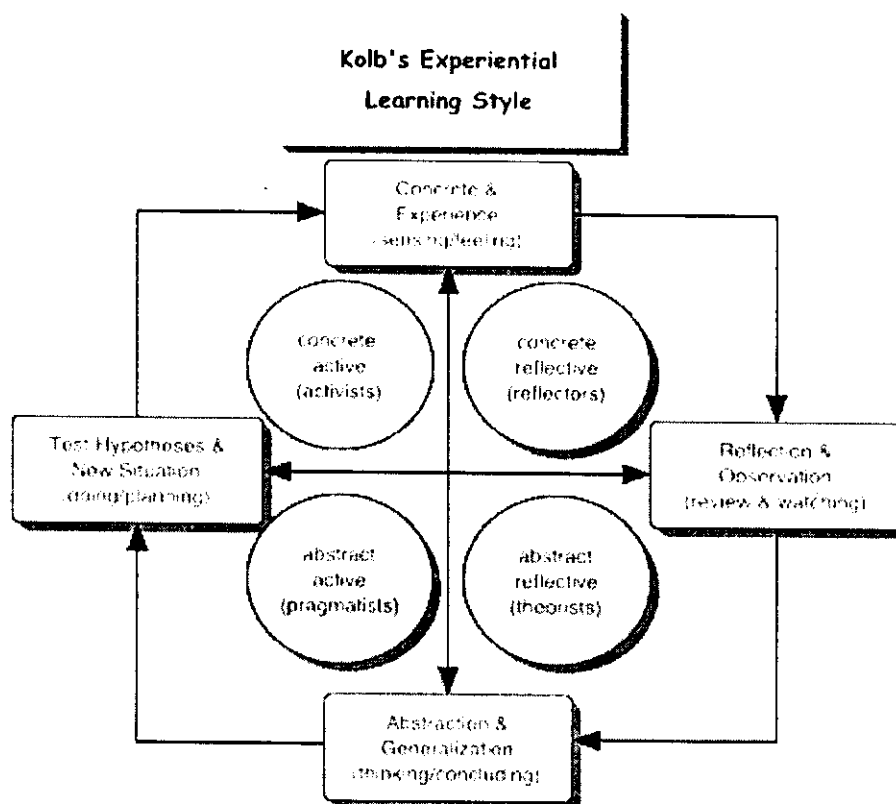


FIGURE 7 Kolb's experiential learning style

Source: Clark, 2000: 1

1) The first dimension, "active processor" and "reflective processors", running horizontally, are people who based upon '*thought and emotional processes*'. The left end is the active processor and who makes sense of an experience by immediately using the new information (responsive feelings). The right end is the reflective processor who makes sense of an experience by reflecting on and thinking about it (controlled feelings).

2) The second dimension, "concrete perceiver" and "abstract perceiver", running vertically, are people who based upon '*task*'. The top of the dimension is the concrete perceiver who absorbs information through direct experience, by acting, sensing, feeling, and doing the tasks (performing). The bottom of the dimension is the abstract perceiver who takes in information through analysis, thinking, and watching the task (observing).

Indeed, Kolb's Learning Style model is actually a two-process model as described in

Figure 7 on Page 52. In the following paragraph, Clark (2000) describes these two learning models from two dimensions:

1) The first model is four steps of learning processes. They are composed of:

- Review and Watching: Learners prefer learning situations such as lectures that allow the role of impartial objective observers. These individuals tend to be introverted or reflective. Thus, lectures are helpful to these learners.

- Thinking: Learners rely heavily on logical thinking and rational evaluation. These individuals tend to be more oriented towards things and symbols, and less towards people. Thus, case studies, theoretical reading and reflective thinking exercises help these learners.

- Feeling: Learners rely heavily on feeling-based judgments. These individuals tend to be empathetic. Thus, specific examples, group work, or peer feedback help these learners.

- Doing: Learners rely heavily on experimentation. These individuals tend to be extroverts. They want to touch everything. Thus, problem-solving, small group discussions, peer feedback, or self directed work assignments help these learners.

2) The second model is the four learning styles used within the learning process. They are composed of:

- Reflectors (or Divergers): Learners like to learn using reflective observation and concrete experience such as logs, journals, and brainstorming.

- Theorists (or Assimilators): Learners like to learn using abstract conceptualization and reflective observation such as lecture, papers, analogies, and like to ask questions.

- Pragmatists (or Convergents): Learners like to learn using abstract conceptualization and active experimentation such as laboratory work, fieldwork or observations.

- Activists (or Accommodators): Learners like to learn using concrete experience and active experimentation such as simulation, case study, and homework.

Kolb divides the two dimensions into four quadrants or four personal learning styles:

1) Divergent Learning Style

2) Assimilative Learning Style

3) Convergent Learning Style

4) Accommodative Learning Style

In the academic environment, students come to the classroom with their preferred learning styles, therefore all of these dominant learning styles should be addressed (Merrill. 2003: 1). That is, when teachers are considering the design of a learning process for an active learning classroom environment, they should be aware of the impact of learning style. Carrier and Sales (Roy. 1997: 66; citing Carrier & Sales. 1987), Stice and Dunn (1985) state that if instructional design is matched to student learning style preference, then it should have a positive impact on student achievement. This is also supported by Stitt-Gohodes (Brown. 2003: 2; citing Stitt-Gohodes. 2001) who states that 'knowing this type of information can help instructors develop course structures that provide a better fit between instructional goal and students' learning style preferences. The impacts of recognizing students' learning styles on the classroom learning environment can be summarized in the following criteria (On purpose associates. n.d.):

1) Curriculum: The teachers must place emphasis on intuition, feeling, sensing, and imagination, in addition to the traditional skills of analysis, reason, and sequential problem solving.

2) Instruction: The teachers should design their instruction methods to connect with all four learning styles, using various combinations of experience, reflection, conceptualization, and experimentation.

3) Assessment: The teachers should employ a variety of assessment techniques, focusing on the development of "whole brain" capacity and each of the different learning styles.

Learning style research is more involved in business and education. The following paragraphs are examples of the studies of impact of learning styles on education.

Gee (Diaz & Cartnal. 1999: 131-132; citing Gee. 1990) studies the impact of learning style variables in a live teleconference distance education class. The purpose of the study was to examine the influence of student learning style preference on student achievement using the Canfield Learning Style Inventory. The outcomes of this study indicated that the differences in learning styles affected student achievement in various comparisons; for example, successful distance education students favored an independent learning environment while successful on-campus students showed a preference for working with others.

Clariana (1997) researches on learning style in CAL-computer-assisted learning. The Kolb Learning Style Inventory (LSI) is administered pre and post study. Three surveys are implemented. The first survey was implemented with thirteen to fourteen year-old students of mathematics. They are treated with individualizing approximately 30 minutes of computer-assisted learning per day over five months. The second survey was implemented with nineteen to twenty-one year-old students in computer mathematics instruction. They received approximately 3 hours per week over a five-week period of time. The third survey was implemented with adult education majors enrolled in a microcomputer course. They received approximately 3 hours per week over a five-week period of time. The results of these three diverse CAL experiences and different learner populations are the same; that is, a general shift occurred in learning style towards the Concrete Experience and Active Experimentation dimension.

Diaz and Cartnal (1999) compare student-learning styles in an online distance learning class with an equivalent on-campus class. The purpose of the study is to compare the student learning styles of two online health education classes with an equivalent on-campus class. The Grasha-Riechman Student Learning Style Scales is administered to determine student social learning preferences in six learning style categories. The results show that students enrolled in the on-campus class are statistically more dependent learners than the distance group.

Taweelap (2003) also conducts a study of learning styles and achievements in Sciences of Mathayomsuksa III of students through sciences activity set by 4-MAT system. The study uses Lertlop's learning style questionnaire, which is developed from Kolb's experiential learning style inventory. The study found that the learning styles of students were not changed after learning by 4-MAT system. That meant that students normally used their own learning styles to study new things. The study also found that the achievements of students were significantly different among learning styles. In short, the benefits of using learning styles support individual learning and help to organize the learning process. Also, the learning activity should be concerned with the differences between of learning styles of the students.

Brown (2003) reports from the studies of Rush and Moore, the feasibility of promoting learner adaptability through training, that students whose cognitive styles were more field dependent were able to change the strength of their style through training, which suggests that cognitive style may be a flexible construct and malleable over the long term.

Davis and Franklin (2004) investigated the impacts of students' learning style preferences. The subjects were students who volunteer to solicit and spend two hours working through activities and taking various learning style preference assessment. Those students enrolled in calculus-based physics. The pretest and post-test research design was employed. The purpose of the study was to examine the course grade and the correlation between personality types, sociological learning style preference and performance on pre- and post-test. Little correlation was found.

Ingham, Meza and Price (n.d.) studied a comparison of the learning styles and creative talents between Mexican students and American students who were undergraduate Engineering Students. The aims were to better understand the impact of cultural difference on learning and creative performance. Data on learning style were collected from 203 Mexican students and 283 American students. The learning style was assessed using the Productivity Environment Preference Survey and creative performance with the Tel-Aviv Activities and Accomplishment Inventory. Various findings are indicated from the study. Results of discriminated analysis procedures revealed learning style and creative performance differences between the two groups.

Lefkowitz (2002) investigated the effects of traditional presentation versus learning-style presentation of course content in medical/legal issues in health care on the achievement and attitudes of college students. The aims were to examine college students' learning styles and to compare the achievements and the attitudes of them between CAP-Contract Activity Package- and traditional instruction. The results documented the differences among college students' learning style and demonstrated statistically increased achievement test scores and attitude test scores when CAP rather than traditional teaching is employed.

SECTION 2: ICT-Mediated Science Education.

One of the broad methods of education reform is using ICT-Information and communication technology as tools for learning. In science education, Newton and Rogers (2001) point out that "the development of ICT in science education has reached a point where its benefits for young science learners are now broadly recognized" (Newton & Rogers. 2001: 31). Actually, ICT is not an innovation for students; students often use ICT for fun, finding information, or doing presentation. It is recognized as a tool for initiative and independent

learning. Students use ICT not only as a tool for fun but also as a tool to explore and analyze their problem and to creatively exchange information with peers. Therefore, they should learn how to employ ICT to enable more rapid access to the ideas and experiences of a wide range of people, communities and cultures. David and Yocam (Reid. 2002: 9; citing David & Yocam. n.d.) point out from the Apple Classrooms of Tomorrow (ACOT) project that the importance of the use of ICT in professional development of the use of ICT will be seen in schools. Similarly, Sandholtz and Dwyer (1997) suggest that technology integration is best realized when learning empowers students as thinkers and problem solvers. ACOT (Reid. 2002; citing ACOT. n.d.) reports the four impacts on student achievements from a number of researches into using ICT in classroom. They are:

- 1) Mastering the fundamental skills of reading, writing, and arithmetic. A number of researches show that students with routine access to technology learn these basic skills faster and better when they have a chance to practice them using technology.

- 2) Becoming proficient users of technology. Studies show that once students become familiar with technology, they quickly develop proficiency in its use.

- 3) Preparing students with 21st century skills. Studies have revealed that in classrooms where technology is used, students change their attitude by: interacting more frequently with their peers and teachers than in traditional classrooms, organising and accomplishing their work, and working in collaboration with others. In addition, they employ inquiry and problem-solving skills.

- 4) Motivating students to higher levels of achievement. Studies show that more students finish high school and many more consider attending college when they routinely learn and study with technology. Some studies show that students who participate in student-centered learning programs score consistently higher in every subject area on standardized tests.

"Thinking about the computer's role in education does not mean thinking about computer, it means thinking about education" (Osborne & Freeman. 1998: 146; citing Ellis. 1974). The following section will review the role of the computer and its advantages for science education, especially in Physics.

2.1 ICT and a Paradigm Shift in Education

Having discussed the necessary mechanisms of education reform, especially in science education, ICT is considered to be one of those mechanisms. The increasing use of ICT in education is supported by many researches. For instance, Braak's research (2001) on the factors influencing the use of computer-mediated communication (CMC) by secondary school teachers in Brussels reports that "the use of information and communication technology (ICT) in teaching is steadily increasing, just as it is in other sectors of society" (Braak. 2001: 41). Scaife and Wellington (1993: 15) make the same point for science education. "Information Technology (IT) has an important part to play in enriching Science and Technology Education".

Indeed, the increasing use of ICT in education results from a number of factors. These are summarized below:

- 1) Pedagogy is changed in a number of ways, for instance; from instruction to construction and discovery; from teacher-centred education to learner-centred education; from absorbing material to learning how to navigate and how to learn; from learning as torture to learning as fun; and from teachers as transmitter to teacher as facilitator (Scaife & Wellington. 1993: 20; citing Cerych. 1985; Reid. 2002: 6; citing Tapscott. 1998; Braak. 2001: 41; citing Hawkrige. 1990).

- 2) Society is changed from school to wider perspective in terms of lifelong learning (Scaife & Wellington. 1993: 20; citing Cerych. 1985; Braak. 2001: 41; citing Hawkrige. 1990).

- 3) Economy: The increasing needs of industry demand greater competence in ICT skills (Scaife & Wellington. 1993: 20; citing Cerych. 1985).

- 4) Technology that is changed from linear to hypermedia learning, from one-size-fits-all to customized learning.

Looking at ICT from the learner's perspective, Kemmis; et al. (Scaife & Wellington. 1993: 24-27; citing Kemmis; et al. 1977) summarize four paradigms of the role of ICT in education:

- 1) The instructional paradigm: the aim is to teach the learner as a given piece of subject matter, as drill and practice, tutorials such as CAI-Computer Assisted Learning.

- 2) The revelatory paradigm: the aim is to guide students through a process of learning by discovery such as computer simulation.

- 3) The conjectural paradigm: the aim is to let students manipulate the technology

and test their own ideas and hypotheses using modeling, LOGO or spreadsheet.

4) The emancipatory paradigm: the aim is to use computers as a labour saving device in order to calculate, tabulate data, analyse statistically or draw graphs by using a database, and data-handlers or data-loggers.

Moreover, the impact of an educational paradigm shift by ICT also impacts on others elements in education such as teaching method, relationships between teacher and students and also the school management. On this point, Reid's research (2002) summarizes the three domains:

1) Changing the Teaching Method: Research shows that when teachers learn to use ICT, they make a dramatic change in their teaching such as preparing their teaching material or teaching tools, using web site information to help students understand better things like doing online field trips, using technology to conduct their labs by data-logging, word processing, spreadsheet and presentation software, and so on. Changing the teaching method in these ways can encourage students to produce more meaningful work, enhance active learning, and concentrate on a higher level of concepts.

2) Changing the Teacher/Learner Relationship: Research shows that the relationship between teachers and students develops into one of 'co-learners' as a result of the active use of information technology. Teachers and students can help each other. Teacher should learn to arrange their teaching classes in the way of new learning environment.

3) Changing the Administration and Expanding Professional Networks: Research shows that the school administration is subjected to change in several ways such as by providing computer, software and network support for the teaching and learning process, school business and communication or collaborative work in the exchange of ideas with peers.

A variety of research findings on the impact of technology on student achievement are abridged and summarized as follows (ACOT. 2002):

1) Students will improve their basic skills—reading, writing, and arithmetic, if they have a chance to practice those skills using technology.

2) Students who engage in technology spend more time on basic learning tasks than students who use a more traditional approach.

3) Students can achieve their potential with an individualized curriculum which is customized by educators who use ICT as teaching tools.

4) Students show a higher level of comprehension when they have the opportunity to use technology in acquiring and organizing information.

5) Students can communicate and express their ideas more clearly and powerfully, which results from accessing a broader range of resources and technologies.

7) Students have greater confidence in their abilities, and develop higher levels of self-esteem when they use technology regularly.

2.2 How ICT Can Be Related To Science Education.

In Thailand, the written statements in the National Educational Act of B.E.¹ 2542 state the significance of integrating ICT into all education systems: formal, informal and life long learning. The question is how to integrate them into related areas, in particular, how ICT can be related to science education.

Beginning with the classroom learning environment, there are many researches and theories pointing out these factors related to the classroom improvements arising from ICT. Reflecting upon the research of Mooij and Smeets (2001), Shahrinin and Butterworth (2002), Krajcik (2002), and Newton (n.d.), the results show that computer technology such as handheld technology, modeling and computer simulation programs can improve children's understanding of science.

In science education, Harrison (editor 1992: 72-73), Pickersgill (Kelleher. 2000: 33; citing Pickersgill. 2000), Scaife and Wellington (1993: 31-32) agree that ICT demands a new strategy and a new practice in the science classroom. It allows teachers to do things and encourages more meaningful learning in science than can be done without ICT. Looking at the science students' view, they normally use ICT for collecting data tools. In addition, ICT also offers more exciting ways of representing or displaying information, communication, presentation, group work and collaborative thinking. Computers provide a way of extending science work into other curricular areas and beyond. Therefore, it is vital in helping students to concentrate more on exploring science than do the traditional ways of learning.

In short, ICT is considered to be the new role of future science classroom. Its functions can be summarized below:

¹ B.E. means Buddhist Era

1) Data capture and control

Science learning involves recording data during an experiment. There is a lot of ICT equipment that can be used to collect data and help students control the experiment. The sensing and monitoring instruments used for things such as data logging are the favorite technology that can be used in education because it can produce and manipulate data while the students are working (Kelleher. 2000: 33; Harrison editor. 1992: 73).

2) Information handling

Any meaningful information from the students' experiments in the science classroom normally shows in tabling or plotting a graph of related variables, which is considered to be difficult for students in manipulating those raw data. There are many software packages can be used in these tasks such as spreadsheet, database or data logging (Harrison editor. 1992: 73; Kelleher. 2000: 34; citing Pickersgill. 2000; Scaife & Wellington. 1993: 33).

3) Simulation

The computer simulation programs allow students to perform experiments that they would not have been able to do in real life. For example, in computer simulation programs as artificially changing factors, students can observe the effects of, for example, pollution on an ecosystem or the output from a power generator when the pressure or temperature of the stream is altered. Although the activities should not replace standard classroom practice, it can be used imaginatively to extend learning experiences (Harrison editor. 1992: 73; Kelleher. 2000: 34; citing Pickersgill. 2000; Scaife & Wellington. 1993: 33).

4) Communication

Communication, especially scientific communication, is considered an important part of science education. Students can strengthen communication skills, group work and decision-making skills by using software such as graphics, word processing and desk top publishing (DTP) to plan, display findings and precipitate interaction between students (Harrison editor. 1992: 73; Kelleher. 2000: 34-35; citing Pickersgill. 2000).

5) Research Tool

There are a large number of researches, information and encyclopedias in CD-ROM or database format that actively challenge teachers and students to search for references (Kelleher. 2000: 36; Scaife & Wellington. 1993: 33).

2.3 ICT Elements for Learning in Science

This study reviews the information and communication technology tools that will be used in a learning process of the study in three main areas:

2.3.1 Computer Simulation Program

Computer simulation programs are recognized as an efficient and effective way of teaching and learning complex, and dynamic systems. This software usually requires users to supply parameters representing different conditions by which the computer simulation program can predict new outcomes (Newton & Rogers. 2001). Scaife and Wellington (1993: 45) suggest five types of computer simulation programs used in science and technology education.

- 1) Direct copies of existing laboratory activities: e.g. titrations.
- 2) Simulation of industrial processes: e.g. the manufacture of sulphuric acid.
- 3) Simulation of processes: too dangerous, too slow, too fast or too small.
- 4) Simulation involving non-existent entities: e.g. ideal gases, frictionless surfaces, and perfectly elastic objects.
- 5) Simulation of models or theories: e.g. kinetic theory, the wave model of light.

The advantages of using computer simulation programs in science education can be defined in terms of cost, time, safety, motivation, control and management. Conway (1997) makes a similar list of benefits of the computer simulation program. Moreover, reflecting upon the work of Roblyer, Edwards, Havriluk, he suggests that many teachers find that simulations offer effective supplements to real lab, either to prepare students for making good use of the actual labs, or as follow-ups with variations on the original experiments.

However, there are some disadvantages of using computer simulation programs in science education. They can be defined in terms of variables, unquestioned models, caricatures of reality, confusion with reality, and double idealizations. Therefore, teachers have to consider the educational value of the knowledge content presented by software. Newton and Rogers (2002: 53-54) suggest the following areas of consideration for software evaluation: 1) suitability of content; 2) appropriate level of content; 3) reliability, accuracy and objectivity; 4) availability or currency; 5) focused enquiry; 6) Intranets; and 7) remodeling information.

Computer Simulation Programs in Physics

Jimoyiannis and Komis (2001) research on using computer simulation programs for teaching and learning physics in secondary school: a case study of students' understanding of trajectory motion and the role of computer simulation programs in the development of functional understanding of the concepts of velocity and acceleration in projectile motions. The results show that students working with computer simulation programs exhibited significantly higher scores in the research tasks. The findings strongly support that computer simulation programs may be used as an alternative instructional tool, in order to help students confront their cognitive constraints and develop functional understanding of physics.

2.3.2 Data-logging and Its Components

For science education, the nature of science knowledge is shifting from science as a collection of facts and processes to science as conceptual and technological tools that allow people to describe and explain how the world works (Mee, A. 2002). Data-logging is considered to be one of the technological tools that become an important part in learning in science as shown in Mee, A. 's research which points out that many countries since 1980, particularly the UK and the USA, use data-logging in school (ibid.). It is because data-logging technology has become sufficiently user-friendly and affordable that it is more widely adopted (Mee, A. 2002: 1; citing Newton. 1998). Scaife and Wellington (1993: 31) point to the importance of data-logging in science education by asking: "how can students develop their practical skills and understanding of scientific procedures if they do not use, for example, data-logging equipment?".

Many educators define data-logging and its functions in the following ways:

1) Data-logging is the systematic process of recording structured information by computer equipment rather than by hand as the scientist, and science students have logged in general (Scaife & Wellington. 1993: 61).

2) Data-logging is a microcomputer-based laboratory (MBL) which is used for experimental procedures, which involve linking a probe or probes to a computer, which can be viewed on the computer screen as calibrated data. These data are usually presented as a line graph, drawn in real time as the events take place (Man. 2000; citing Friedler & McFarlane. 1997).

3) Data-logging is the activity by which measurements are collected during an

experiment by sensors and then sent to a computer for processing (Barton. 1997: 64).

4) Data-logging is an automatic data-collecting method. It can store large quantities of data, aggregate data over times, and computers can process and report them (Draper. 1999: 1).

5) Data-logging is a process that involves obtaining physical measurements directly from sensors and storing them in the computer's memory. It is useful for practical work especially in the science laboratory (Newton & Rogers. 2001: 8).

6) Data-logging is the collection and storage of information in practical work using software tools rather than doing it by hand (Mee, A.2002: 1).

It is concluded in this study that data logging is computer software, which is used as a microcomputer-based laboratory (MBL) for collecting and manipulate experimental data in terms of tabulating, graphing and modeling.

The components of a microcomputer-based laboratory can be classified into four components as shown in Figure 8 with an example shown in Figures 9 and 10 on Page 65:

Elements of a Data Logging System

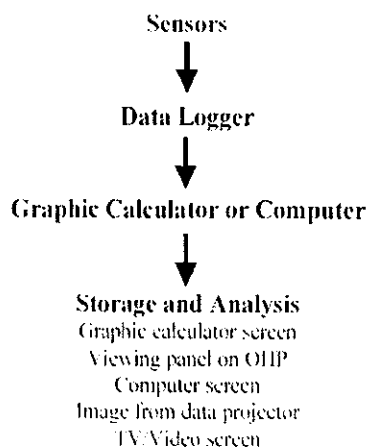


FIGURE 8 Elements of a Data-Logging System

Source (http://www.psi-net.org/common/datalogging_intro.pdf)

Model 4 - Use Data Logger Directly with Computer

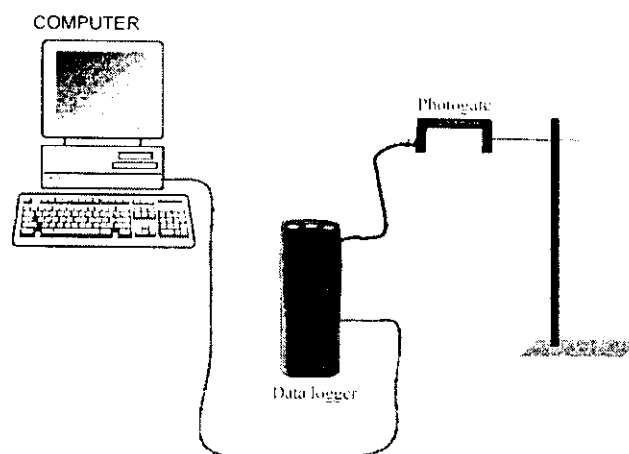


FIGURE 9 Using photogate elements of a Data-Logging System

Source (http://www.psi-net.org/common/datalogging_intro.pdf)

Computer logger, computer, motion sensor, spiral spring and weight with card attached.

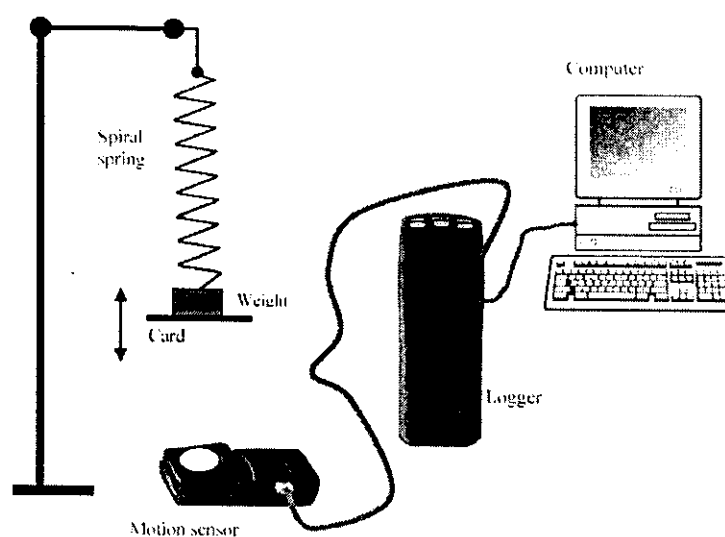


FIGURE 10 Using motion sensor elements of a Data-Logging System

Source (http://www.psi-net.org/common/datalogging_intro.pdf)

1) Sensors: They are transducers that translate into an analogue signal of the changes taking place in the parameter being measured. The variation in the physical quantity

is then converted into a voltage signal that is recognised by a device called an interface box or data logger. They are for example temperature sensor, light sensor, sound sensor, motion sensor, and so on.

2) Data Logger: This is an instrument that converts the voltage signal of the sensor to a digital signal, which can be read by the computer or graphic calculator.

3) Computer: This is a set of computers which transfer the digital signals from the sensors or the data logger for any use. In some situations, students can represent a computer with a graphic calculator.

4) Software: This is a kind of computer software. When the digital signal/data is transferred to the computer or graphic calculator, it should be manipulated or displayed in a suitable form by using a range of software, for instance, data-logging software; spreadsheets; database; or graphic packages.

Questions of the use of data-logging in practical science and the claim that somehow it can improve learning outcomes are challenged by many science educators. The following paragraphs summarize the advantages of using data-logging in education:

1) Speed or Time saved in doing experiments. Students acquire immediately and directly representation and data access because computers can log much faster than humans. For students, the time bonus is not wasted, they can develop skills in observation, discussion, brainstorming and questioning during experiments. (Kelleher. 2000: 33; Draper. 1999: 2; Barton. 1997: 65; Scaife & Wellington. 1993: 61; Harrison editor. 1992: 73)

2) Memory. A computer has a greater capacity for retaining and accessing a large amount of data than the human memory. Moreover, the quality of data transferred from a sensor is highly precise (Newton & Rogers. 2001: 125; Scaife & Wellington. 1993: 61).

3) Perseverance. A computer can keep on logging data all the time. Through this ability, students can capture data that would be difficult to capture through traditional means. There are a number of intrinsic properties of data-logging which contribute unique measurement properties (Newton & Rogers. 2001: 125; Kelleher. 2000: 33; Scaife & Wellington. 1993: 61; Harrison editor. 1992: 73).

4) Manipulation. A computer can re-manipulate and present data in the form students needs to use which helps students to gain data to understand the relationship between the variables being measured. On the other hand, it is a useful tool for teacher

demonstration (Newton & Rogers. 2001: 125; Kelleher. 2000: 33; Scaife & Wellington. 1993: 61).

5) Expanding students' observations and the potential of their investigations. Students can monitor data during different activities. They can see how experimental data vary during their exploration or testing of hypotheses. As a result, they can compare and study relationship between various factors and materials during their experiment (BECTA. 2003; Newton & Rogers. 2001: 125; Barton. 1997: 65; Harrison editor. 1992: 73).

6) Communication of meaning. A computer can present data in a variety of formats to enhance students' understanding (Scaife & Wellington1993: 61).

7) Stimulating. A computer normally can stimulate students' imagination and curiosity. Therefore, it can help students more an active learning process (Barton. 1997: 65; Scaife & Wellington1993: 61).

8) Analysis Opportunities. The information obtained from data-logging can be presented in graphic format which is a major tool for reporting measurements and supporting an exploratory mode of learning (Newton & Rogers. 2001: 126).

Designing a data-logging activity

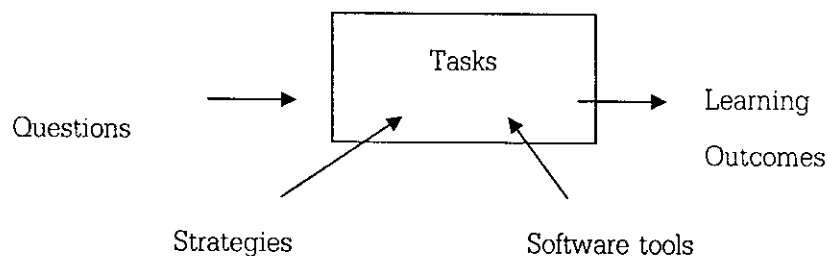


FIGURE 11: The factors which contribute to the design of a data-logging task

Source: Rogers. 2002: 76

When designing a data-logging activity, clear visions of the learning objectives are required. Roger (2002: 71) states, "The chief value of data-logging to practical science is not the process of automated data-gathering but the processes of analysing and interpreting the data". Therefore, teachers need to design data-logging activities which match those objectives and train students' skills in interpreting graphs, viewing graphs, reading value, describing variables,

relating data, making predictions and translating a description into mathematical forms. These tasks are also related to the other three factors as Rogers (2002) suggests about the design of data-logging tasks. The relationship of those tasks and factors are shown in Figure 11 on Page 67. The first factor is 'Question' which clearly simplifies, and gets to the point what teachers need their students to investigate. The second factor is 'Strategies' which are related to steps in problem- solving. The third factor is 'Software tools' which teachers provide for their student.

A variety of research has been conducted into the use of data-logging in education especially in science education as presented in the following paragraphs:

Newton (n.d.) researches on approaches to successful implementation of data-logging in the science classroom by drawing on the experience of science teachers skilled in its use. The results from this study are summarized from transcribable interview tape recorded in four main frameworks:

1) Needs identification: teachers need to use data-logging in terms of the attributes of the technology, and the benefits which it can bring to their science teaching and also the affective domain factors relating to students' personal response to the use of ICT.

2) Goal Clarity: the drive to use data-logging needs to be given clarity to help to identify what could be done differently by science teachers employing the technique. It can be improved by planning opportunities within work schemes to use this technique.

3) Complexity: this refers to the difficulties and extent of change required by individuals new to using data-logging which differs from the traditional practical science; therefore, teachers need to understand, and perceive this technology in their classroom organization and management.

4) Practically, in order to integrate data-logging into science teaching, adequate resources need to be available. The impact of using data-logging is from the quality of this innovation, and also the time of use in the curriculum material.

NG and Yeung (2000) investigate using data-logging in a technical secondary school in Hong Kong in three Physics experiments: Bouncing ball; Centripetal force of a pendulum at its lowest position and Resistance of a light-bulb filament by using questionnaire and interview. The results show that 1) Students strongly agreed that data-logging could enhance data measurement, data recording and presentation of results, 2) Data-logging could assist data analysis during experiments and 3) Data-logging could assist the manipulation of apparatus and

the observation of phenomena. Moreover, their study also reports that data-logging impacts on scientific inferences, inducing curiosity, enhancing collaborative learning, and developing a sense of achievement. The teachers' interviews raised two opinions about the actual implementation of data-logging activities in the laboratory 1) the number of computers for student activities, and 2) teachers' IT competence in experimenting with the data logger.

Gipp (2001) investigates postgraduate teacher training in using data-logging and inquiry learning in science. The teachers work in primary schools and most of them have no background in science. Two aims of the training are to investigate and train the teacher in the use of data loggers, spreadsheets and presentation, and to give them the opportunity to experience the inquiry style of learning in science. The study found that data-logging is well suited for inquiry learning in science and helps to promote an understanding of science as a way of inquiry and not just an accumulation of facts and theories.

Friedler and McFarlane (1995, 1997) conduct a study to determine the effect of using data-logging in primary education. The results show that seven and eight year-olds exposed to data-logging show an improvement in their ability to read, interpret and sketch line graphs when compared to those using traditional apparatus.

Friedler and McFarlane (1997) examine the use of data-logging in terms of graphic drawing ability. The results show that data-logging improves the manual graph drawing ability of 14-year old students, but not 16-year old students.

Barton (1997) researches on the comparison between computer-aided, using data-logging, and conventional practical work in school science. The results show that data-logging could change the nature of children's thinking in experimental work in science in four areas 1) simultaneous collection and presentation of data, 2) focus effect of the computer screen, 3) graphing skills and 4) pupil/teacher interaction. For the simultaneous collection and presentation of data, the student will complete their work within half the time when compared with the practical work; however, the results show that the immediate presentation of data does not seem to be significant in affecting the students' understanding of those data. For the focus effect of the computer screen, students use the screen for their discussion, sharing their experience, and explaining their interpretations and ideas. For graphing skills, which is an important skill for students, the results show that data-logging is a major factor in improving students' skills in this area. Moreover, it can prevent the serious problem students face when

trying to produce manual plots of moderately difficult data. Therefore, they have much more time to work on the data analysis, which is considered more important. For pupil/teacher interaction, data-logging has provided a powerful tool which teachers can use to develop ideas and to probe students' understanding. But it is time-consuming for teachers to develop the most effective ways of using it in emphasis towards interpretation and evaluation.

Reid (2002) studies the integration of ICT into the classroom. In his review of literature, he noted that "in Physics, students who use the data-logging software and other generic software such as word processing and spreadsheet tend to focus more on the higher-level concepts rather than the less meaningful tasks such as manual recording and plotting".

Mee, A. (2002) summarizes from a review of a number of researches which were carried out with all age group students who use data-logging, and from her own work about "whether students who use data-logging as a tool in Leaving Certificate Physics practical work would be at a disadvantage when drawing graphs manually". The results show that the use of data-logging can improve students' ability to understand and interpret graphs, to predict the shape of an emerging graph, to develop higher-level thinking, and to work collaboratively. In addition, she found a positive effect on the development of scientific enquiry skills and promotion of discussion among the students.

2.3.3 Generic Software

The following generic software is the general-purpose software that can be used as a tool in science education:

1) Spreadsheet

This program is useful for helping students in manipulating data, performing complex calculation, or producing graphs as a learning tool to extend their investigations (Harrison editor. 1992: 75; Turner & Dimarco. 1998: 237).

2) Word Processor

This program is a useful 'thinking' tool that enables students to edit their work such as reporting on their investigations, developing a variety of communication skills, consolidating learning, or encouraging collaborative work (Harrison editor. 1992: 79; Turner & Dimarco. 1998: 233).

3) Database

This program is used for storing information or data during an investigation or

experimentation. Students can use its features in a more systematic manner by looking for patterns, making predictions, testing hypotheses, drawing and discussing interpretations (Scaife & Wellington. 1993: 58; Turner & Dimarco. 1998: 240). Smart (Scaife & Wellington. 1993: 58; citing Smart. 1988) claims that the uses of database can encourage students, exploratory talk in small groups around the computer. Moreover, this software gives more responsibility to the students and develops skills in forming and testing hypotheses.

4) Presentation

This program can transfer tacit knowledge to explicit component. It also promotes active learning through group work and presentation.

5) Desktop Publishing (DTP) and Graphics.

This program can be used for manipulating images, graphs, and drawings. It is vital for students to show their work in a graphic mode and make it more interesting (Turner & Dimarco. 1998: 242).

SECTION 3: Practical Work and Assessment

The aims of this section are to suggest that practical work in Physics is very important in science lessons. The literature draws on two related items: practical work and assessment techniques.

3.1 Practical Work

Practical work is widely used in the science classroom. It refers to a variety of tasks such as communication, observation, investigation, reporting, manipulation and discipline (Christofi. 1988). Woolnough (1994: 107) makes the same point that practical work is more important in science education. Moreover, he points out that practical science not only investigates but also exercises, experiences, and demonstrates. All of these tasks require an ability of problem-solving, the performance of routine laboratory tasks and making observations. Also, this method can help students learn science knowledge, understand relationships, and receive an explanation of a phenomenon. It seems like "a bridge between a realm of objects and observable properties on the one hand, and the realm of ideas on the other hand" (Millar. 2002). Similarly, Frost (1995) argues that practical work is a key means of learning scientific theory by capturing systematic information about the natural world. However, it is science

educators who make this dilemma come true through the activities that are assigned to students who should reflect scientific knowledge and science as practice (Roth & Gilmer. 2002).

Hodson's research (Newton & Rogers. 2001: 34; citing Hodson. 1990) reports many advantages of practical science. They are motivation, interest and enjoyment, teaching laboratory skills, enhancing the learning of scientific knowledge, giving insights into scientific method, developing expertise, and developing a certain 'scientific attitude' such as open-mindedness, objectivity, and willingness to suspend judgment.

Wellington (1998) concludes the advantages in three main domains:

1) Cognitive argument: Practical work can improve students' understanding of science and promote their conceptual development by allowing them to 'visualize' the laws and theories of science. It can illustrate, verify or affirm 'theory work'.

2) Affective argument: Practical work is motivating and exciting. It generates interest and enthusiasm, and helps learners to remember things and make them stick.

3) Skills argument: Practical work develops manipulative, higher-level and transferable skills in observation, measurement, prediction and inference.

However, in terms of transferable knowledge, Lave (1988) argues that the results of learning transfer experiments range from positive to negative. When Lave investigates learning transfer directly across situations, the results are constantly negative. Therefore, when students do practical work, they should concentrate on the importance of steps in the practical work and work accurately on the following items:

1) Data Collection and Recording: Learning in science is related to observation and measurement in which the accuracy is concerned with how close a reading is to its true value and the precision is part of the accuracy which can be controlled by the experimenter.

2) Data Processing: This stage is related to drawing conclusions and presenting the findings. The number of places of decimal in provided raw data should be concerned. Students can choose to present processed data in term of tables or graphs.

3) Planning: To prevent the wasting of time and laboratory resources, good planning is a vital mechanism that involves using methods, preventing systematic error from methods, choosing instruments, and knowing what steps to take when an error occurs.

4) Evaluation and communication: The students should make their decisions about their experiment, which has proved or disproved a hypothesis. They can use the assessment of

reliability of the experimental result or use the evaluation of the experimental result. Communication skills are vital because students may discuss the results with fellow-students or teachers, following teacher-assessed coursework, or writing work to show their understanding and good planning in design and evaluating experiments.

5) Assessment and Tasks: This stage is related to the experimental skills, which students have been practicing during their course. According to Mee and Crundell (2001), these skills are:

5.1) Planning Skills: These include the ability to identify and define a problem using lab sheet and knowledge, the ability to choose effective and safe procedures and describe suitable apparatus and methods to solve the given problem.

5.2) Implementing Skills: These include the ability to set up apparatus efficiently and use it safely and efficiently, the ability to record the observations and measurements, and the ability to identify sources of systematic and random error.

5.3) Analyzing Evidence and Drawing Conclusions Skills: These include the ability to analyse the observations and present them in appropriate ways.

5.4) Evaluating Evidence and Procedure Skills: These include the ability to show an awareness of the limitations imposed by the apparatus on any results obtained.

As discussed above, practical work requires students to be active participants. Therefore, it is significant for teachers to be concerned about designing a good practical activity for the students' experience. The following planning checklist in Table 4 on Page 74 was published by NCC (1989) -The National Curriculum Council in the United Kingdom to guide the teacher in the selection and planning of learning experiences for students.

TABLE 4 PLANNING CHECKLISTS (NCC 1989)

Will the learning experience give students an opportunity to:

- Develop scientific strategies and skills; Develop an attitude appropriate to working scientifically;
 - Develop basic scientific concepts;
 - Apply scientific ideas to real-life problems including those which require a design and technological solution;
 - Work collaboratively and communicate scientifically with others;
 - Develop an understanding of the relationship of scientific ideas to spiritual, ethical and moral dilemmas;
 - Discuss the way in which scientists work?
-

Will the experience:

- Stimulate curiosity;
 - Relate to the interests and everyday experience of the students;
 - Appeal to both boys and girls and those of all cultural backgrounds;
 - Help students to understand the world about them through their own mental and physical interaction with it;
 - Involve the use of simple and safe equipment and materials;
 - Involve resources and strategies available to teachers;
 - Contribute to a broad and balanced science curriculum, bearing in mind experiences already selected?
-

Source: Newton & Rogers. 2001: 36.

Physics and Practical Work

Hunt and Minstrell (1994: 51) state that 'Physics is the important gateway to other courses in science, therefore failure to understand elementary physics may serve as a barrier to students' developing careers in a number of important and interesting fields'. Physics represents a collective attempt by scientists to make sense of the physical world or natural phenomena. In order that students convert abstract knowledge into natural phenomena, the science teacher has to develop teaching techniques that motivate the students.

Learning physics always involves doing practical work such as observation and measurement, which require both precise and accurate work. It is sometimes called 'the

science of measurement' (Mee & Crundell. 2001: 5). Normally, students will be trained by seeing a demonstration of a Physics experiment, or by doing one for themselves. Those are much more worthwhile than reading a description of it. The aims of teaching and learning practical physics are summarized below (ibid.: 1):

- 1) To demonstrate phenomena and laws that supports the theories of Physics.
- 2) To test hypotheses find out if theories are correct.
- 3) To measure physical quantities, although students could more easily look them up in a book.
- 4) To develop manipulative skills in order to learn how to use measuring devices.
- 5) To provide training in the use of apparatus to ensure that expensive equipment is not damaged.
- 6) To communicate the results of an experiment or investigation to others.
- 7) To plan, implement, analyze the evidence from, and evaluate an experiment in order to complete the requirements of specification or syllabus.

According to the constructivist approach, physics teachers know that students come into classroom with many ideas and experiences about the concepts they are trying to teach. Therefore, a number of researchers claim that the 'constructivist' approach has come from a physics context (Carey; et al. 2002: 223). However, many teachers teach students with traditional style, talking theories of Physics. The teachers may sometimes use modeling to explain phenomena. Therefore, it is through practical work that students can change theoretical in the classroom to life. This can be seen by solving a problem in a laboratory through which students can construct their own understanding by experimentation and investigation (Mee & Crundell. 2001: 3).

When students work in a laboratory, the experimentation and investigation skills needed in Physics can be summarized in four basic skills, areas which are identical to steps in solving a problem:

- 1) Planning
- 2) Implementing
- 3) Analyzing evidence and drawing conclusions
- 4) Evaluating evidence and procedures

Mccullough (2000) studies the effect of introducing computers into an introductory Physics problem-solving laboratory. The purpose is to determine the effects of replacing traditional data collection and analysis tools with a computer data collection and analysis tool. Four different effects are examined: achievement, attitude, group behavior and gender. The design of the study is the experimental computer treatment group and the control traditional treatment group. The results show that there are statistically significant differences in the achievements of the two groups of students. But it doesn't affect the students' overall grades. There are no differences in student attitudes about the course and computer tools between the two groups. The observation data supports the suggestion that groups in the computer treatment spend more time discussing the analysis of the problem than group in the traditional treatment.

3.2 Assessment Techniques

Assessment is an important tool used to measure how students understand the learning objectives. It is also used to improve students' learning. Turner and Dimarco (1998: 149) agree that "assessment is the heart of teaching and learning". They suggest four types of assessment methods. They are:

- 1) Summative Assessment
- 2) Formative Assessment
- 3) Evaluation
- 4) Diagnosis.

The important issue is 'how to collect the evidence for assessment'. Leask (2001: 280) and Newhouse (1996: 6) suggest two methods of teaching and learning assessment. They are:

1) A qualitative method (how well). This tends to use a Criterion-referenced assessment. Data are collected through observation, interview, questioning, analysis documents, diaries, video, photographs, discussion, focus groups and brainstorming.

2) A quantitative method (how much). This tends to use a Norm-based assessment and tends to be summative in purpose but in some cases a criterion-referenced assessment can be used. Data are collected from statistical returns, questionnaires, school management information systems, or other sources that can be reduced to numerical form.

Sarasin (1999) suggests ways of assessing and evaluating students. Those ways are considered to be an important component of the planning and organization process for teachers. She suggests that the teacher should use both formative and summative assessment in order to judge competency. However, constructivism places more value on the concept of personal evaluation than assessment for reporting and is more concerned with individual development than group comparisons (Newhouse. 1996). Therefore, whatever assessment method is chosen, Turner and Dimarco (1998: 149) argue that the assessment should focus on measuring the learning outcome and focus on the characteristics of good assessment which are summarized below:

- 1) Having a clear purpose and employing appropriate methods consistent with that purpose
- 2) Being integral to a unit of work and lesson plan
- 3) Reflecting the aims and objectives of a unit of work
- 4) Revealing what students know, understand and can do
- 5) Accumulating evidence as a basis for making a professional judgment
- 6) Providing feedback for students, teachers and parents
- 7) Promoting a positive sense of achievement in students

Furthermore, teachers can choose other methods of assessment of students' understanding such as marking from homework, marking from a class discussion, marking from an informal test, or the end of unit test marks. This study uses both the qualitative method and the quantitative method for evaluating a student's achievement.

Focusing on the aims of the formative assessment, Daw and Sinbh (2002: 279) summarize them in three criteria 1) Reflect on students' learning in a structured and systematic fashion, 2) Engage in discourse with teachers regarding students' progress and what they need to do to improve and 3) Develop greater awareness of, and competence in, the processes of learning. The aims of formative assessment have three main benefits: improving generic skills; encouraging motivation; and differentiation.

Woolnough (1994: 18) states on student assessment in science that formative assessment aims to diagnose and helps to develop a successful learning experience. The summative assessment aims to assess achievement and grade. Both assessments are necessary and a potentially beneficial aspect of science teaching.

Looking at the learning situation, students have a twofold task. One is to learn data such as facts, skills, concepts, or problem-solving strategies. Another is to use skills, facts, or concepts in some way such as solving a problem or carrying out a task, or making a judgment (Biggs & Kevin. 1982: 3). Therefore, educators have to evaluate how much students learn and how well they learn. The two approaches SOLO taxonomy-a Structure of Observed Learning Outcome and Bloom's taxonomy-Taxonomy of Educational Objectives are useful methods for learning outcome evaluation.

3.2.1 SOLO-Taxonomy.

Biggs and Collis are Australian educators who originated this scheme in 1982. They proposed a difference between the cognitive structure of an individual, called the Hypothetical Cognitive Structure-HCS and the structure of the actual responses of an individual, called the structure of the observed learning outcome-SOLO (Newhouse. 1996). HCS sets the upper limit of functioning and can be used to label a person but cannot be measured with any sense of accuracy. The SOLO Taxonomy indicates a person's current level of functioning in terms of learning outcome and can be measured but cannot be used to label a person since it is dependent on the context within which the person is working (ibid.).

The SOLO Taxonomy is a useful method, which is a modification of the original theory of Piaget's theory of stages of development (Biggs & Collis. 1982: 19). It is a model of evaluating students' competence in which they typically experience as they learn (Solomon. 2002; citing Kennedy. 2001). The five stages of SOLO Taxonomy are presented below (Atherton. 2003):

1. Pre-structural: The student shows a simple acquiring bit of unconnected information, which has no organization and makes no sense.
2. Uni-structural: The student shows a simple and obvious connection. Their significance is not grasped.
3. Multi-structural: The student shows a number of connections but there is a lack of meta connections between them.
4. Relational: The student shows an appreciation of the significance of the related parts as a whole.

5. Extended Abstract: The student shows a connection beyond the given subject and generalizes to transfer the principle and ideas underlying the specific instance.

An empirical study of Biggs and Collis, and the study of Harttje and Purdie 1998 (Chan; et al. 2002: 515; citing Biggs & Collis. 1982; Harttje & Purdie. 1998) in applying SOLO Taxonomy on student's learning outcomes strongly recommended that SOLO is suitable for measuring different kinds of learning outcomes, different levels of students, and different types of assessment.

3.2.2 Bloom's Taxonomy of Educational Objective.

Benjamin Bloom proposed this method in 1956. This method is a framework for a basic approach to monitoring students' learning outcome. Bloom's taxonomy (Dennison & Kirk. 1990: 12; citing Bloom. 1964) is identified in four domains: psychomotor (physical activity); cognitive (knowledge); affective (feeling) and interpersonal (relationships with others). In the cognitive domain, there are six levels of cognitive learning: knowledge; comprehension; application; analysis; synthesis and evaluation. However, when these six levels of cognitive domain were applied to monitor students' learning outcome in a classroom, they need to be expanded to meet the needs of individual subjects (Christofi. 1988: 10-12; Sarasin. 1999). Teachers use questioning strategies to evaluate students' understanding in the cognitive domain. The questioning techniques are presented in Table 2 on Page 80-81. These techniques are described as follows (Amos. 2000; Sarasin. 1999: 28-29; Clark. 1999):

Level 1 Knowledge: the objective of this level is new knowledge. Teachers use questions, which make students recall memorized information, fact, terms, formulas, principles, and so forth. The key words are: define, describe, identify, know, label, list or match.

Level 2 Comprehension: the objective of this level is using information. Teachers use questions, which rephrase what the students have learned, to summarize, to make comparisons, to draw conclusions, or to otherwise show that they have understood. The key words are: convert, distinguish, estimate, explain, extend, generalize, give examples, infer, predict or summarize.

Level 3 Application: the objective of this level is applying new knowledge. Teachers use questions to help the students identify what they already know and what they do not know about a problem. This process will help them get the model, method or principle to solve the problem. The key words are: demonstrate, modify, operate, prepare, produce, relate, show,

solve or use.

Level 4 Analysis: the objective of this level is a specific idea or body of knowledge. Teachers use questions, which focus on breaking down the whole into parts and identify relationships that exist among these parts, and reveal principles of organization. The key words are: diagram, differentiate, distinguish, illustrate, infer, point out, relate, select, separate or subdivide.

Level 5 Synthesis: the objective of this level is the ability to express themselves and to think independently. Teachers use questions, which elicit personal reactions, opinions, and thoughts and show a sense of creativity, using information that they have learned. The key words are: categorize, combine, compile, devise, design, explain, generate, organize, plan, rearrange, reconstruct, revise or tell.

Level 6 Evaluation: the objective of this level is a critical sense to evaluate ideas to which they have been exposed or work that they have done. Teachers use questions which lead them to judge, to show expertise that involves skills developed at the lower levels (knowledge, comprehension, application, analysis, and synthesis). The key words are: appraise, compare, conclude, contrast, criticize, describe, discriminate, explain, justify, interpret or support.

TABLE 2 BLOOM'S TAXONOMY OF QUESTIONS

Purpose		Example
Lower order question		
Recall	To test what has been remembered	Who is...? What is...? Where are...? When did...?
Comprehension	To check the understanding of what is recalled	Can you describe...? What are the differences between...? Explain why...? Explain what is meant by...?
Application	To see if a student can directly apply the rules or knowledge recalled	How would you classify these invertebrates? In which circuit would the bulb light? How does this apply to plants?

TABLE 2 (continued)

	Purpose	Example
Higher order questions		
Analysis	To see if a student can identify causes or reasons, make inferences, deduce and conclude. Requires students to think critically	Why...? What would happen if ...? What would be the effect on...? What can you infer from...? What do your results show...?
Synthesis	To encourage the creation of new ideas from existing information. (There is a creative element to this process)	How would your life change if you got your food in the same ways as plants get theirs? What do you think would happen if there were suddenly no frictions? What features might a new marsh animal have?
Evaluation	To encourage judgment, reasoned argument and opinions.	In what ways are...? Which is the best? How effective is...? Do you believe that ... is it good or bad? What do you think of...? What are the advantages and disadvantages of ...? Which of these is the most important?

Source: Amos (2000: 9; citing Bloom. 1956)

In learning situations, Bloom also suggests four levels of learning. They are memory, understanding, application, and transfer (Dennison & Kirk. 1990: 12).

3.2.3 Systematic Classroom Observation

Classroom learning environment, especially 'interaction' is considered an important factor in educational development (Kelsey. 1999: 11). The 'interaction' is the integral part of learning and communication. In the learning context, learning is a social process involving the transfer of information (Kelsey. 1999; citing Bandura. 1977) and the communication is the process of sharing information involving a didactic exchange (Kelsey. 1999; citing Holmberg.

1938). The interactions in the classroom, teacher-student interactions, can promote student achievements and a positive attitude (Kelsey. 1999; citing Kryspin & Feldhusen. 1974). Flanders (Kelsey. 1999; citing Flanders. 1964) suggests that the more indirect the teaching style, the greater the student achievement.

Various educators define the meaning of interaction: 1) a series of reciprocal influence or interdependencies of influences (Kelsey. 1999: 11; citing Salomon. 1981); 2) reciprocal events requiring two objects and two actions which involve behaviors of individuals and groups who directly influence one another (Kelsey. 1999: 12; citing Wagner. 1994).

Wagner (Kelsey. 1999: 11; citing Wagner. 1994) claims the educative benefits of interactions and point out the various types of interactions occurring in the learning atmosphere:

- 1) Increase participation in the learning environment.
- 2) Develop communication between students and instructor.
- 3) Receive feedback of assignment.
- 4) Enhance elaboration and retention of content.
- 5) Support learner control/self-regulation of learning pace and sequence.
- 6) Increase motivation to learn.
- 7) Negotiate understanding of content.
- 8) Team building for group projects.
- 9) Discovery of content and self.
- 10) Exploration of the scope, depth and breadth of new ideas.
- 11) Clarification of understanding of expectations.
- 12) Closure, knowing when to end a project.

In terms of measuring what occurs in a teaching or learning classroom environment, Cangelosi (1991) suggests using four types of classroom observation:

- 1) Structured observation
- 2) Ecological observation
- 3) Ethnographic observation
- 4) In-class rating scale

For the measurement of classroom learning environment, Cangelosi (1991) recommends 'ethnographic observation' for a formal classroom observation in which the observer responds to the classroom learning environment by selecting events and activities to be recorded as they occur. Ethnographic observation like FIAC (Flanders Interaction Analysis Categories) is a systematic classroom observation methodology. Ned Flanders developed this methodology in 1970. FIAC is the verbal interaction between students and teacher that has been used extensively in classroom observation studies. There are ten categories of verbal communication as shown in Table 3 on Page 84. There are seven categories used when the teacher is talking, two categories for when students are talking, and one category used when there is silence.

Looking at a systematic classroom observation, the coding system is considered to be an important component of the process. When focusing on a science lesson, the coding system of FIAC should be modified. This is supported by numerous studies of FIAC which point out that it is very useful, but some studies point out that it should be modified when it needs to be used for a different objective (Wragg, 1999). For example, the STAR¹ project has modified a new coding system, SPOC²-Science Process Observation Categories, to monitor pupils' science process skills (Cavendish; et al. 1990: 46-56).

¹ The STAR project is the Science Teacher Action Research project which has been tested to combine the advantage of 'project based' and 'school-focused curriculum development' (Cavendish; et al. 1990: 46-56).

² SPOC-Science Process Observation Categories- is a structure observation instrument of the STAR project. This instrument will look at the eight science process skills: observing; interpreting; hypothesizing; planning; measuring; recording; raising questions and critically reflecting (Cavendish; et al. 1990: 46-56).

TABLE 3 FLANDERS INTERACTION ANALYSIS CATEGORIES

Actor	Action	Code
Teacher Talk	Response	1. Accept Feeling. Accepts and clarifies an attitude or the feeling tone of a pupil in a non threatening manner. 2. Praises or Encourages. Praises or encourages pupil's action or behavior. Jokes that release tension, but not at the expense of another individual, nodding head, saying um, hmm or go on are included 3. Accepts or uses ideas of students. Clarifying, building, or developing ideas suggested by a pupil. Teachers' extensions of pupil ideas are included but as teacher brings more of his own ideas into play, shift to category five.
	Initiation	4. Asks questions. Asking a question about content or procedures, based on teacher ideas, with the intent that the pupil will answer. 5. Lecturing. Giving facts or opinions about content or procedures, expressing his own ideas, giving his own explanation or citing an authority other than a pupil. 6. Giving directions, commands or orders to which a student is expected to comply. 7. Criticizing or justifying authority. Statements intended to change pupil behavior from a non-acceptable to an acceptable pattern, bawling someone out, stating why the teacher is doing what he is doing, and extreme self-reference.
Pupil Talk	Response	8. Pupil-talk-response. Talk by pupils in response to teacher. Teacher initiates the contact or solicits pupil statement or structures the situation. Freedom to express own ideas is limited.
	Initiation	9. Pupil-talk-initiation. Talk by pupils that they initiate. Expressing own ideas, initiating a new topic, freedom to develop opinions and a line of thought, like asking thoughtful questions, going beyond the existing structure.
Silence		10. Silence. Pauses, short periods of silence and periods of confusion in which communication cannot be understood by the observer 1.

Source: Flanders. 1970

The coding categories of SPOC are 1) Seating for target, 2) Number of children, 3) Audience/interaction, 4) Teacher, 5) Curriculum focus of the teacher and 6) Curriculum area of the pupil. The interaction coding is classified into these categories:

- 1) Non-talk pupil activity
- 2) Dialogue involving the pupil
 - Making observations
 - Using measuring instruments
 - Using other material or equipment
 - Collecting or clearing equipment
 - Copying from book or worksheet
 - Planning independently
 - Reading book or worksheet
 - Recording
 - Waiting for teacher
 - Waiting for other students
- 3) Other pupil talks
 - Discussing observation
 - Hypothesis
 - Discussing specific plans or processes
 - Recording
 - Critical reflection
 - Interpretation
 - General planning
 - Measurement
 - Raising questions
- 4) Teacher talk
- 5) Non-talk teacher activity

The other research such as Wallace (Solomon. 2002: 22; citing Wallace. 1986) classifies pupils' interactions in her study in 6 categories:

- 1) Negotiating e.g.: arranging collection of apparatus and turn-taking in the experiment.
- 2) Removing tension e.g.: when disappointments have occurred.
- 3) Giving help and tutoring e.g.: reiterating what the teacher meant, or explaining the task.
- 4) Non-task talk e.g.: for greeting and stroking as they settle into their pairs.
- 5) Negotiating knowledge e.g.: agreeing or disagreeing about what colors, measurements or tastes they perceive.
- 6) Constructing meaning which will be explored separately.

For well over a century, research has demonstrated the importance of interactions

(Kelsey. 1999: 13; citing Bandura. 1997; Dewey. 1938; Holmberg. 1983; Stanford & Roark. 1974; Wagner. 1994). The fully interactive classroom leads to increased learning outcomes and increased student satisfaction (Kelsey. 1999; citing Bauer & Rezabek. 1992; Bovierie; et al. 1997; Sholdt; et al. 1995).

SECTION 4: Conclusions

The ideas from the literature review lead to the development of an integrated approach to ICT-mediated learning in Science. It can be summarized that the model drew upon the main ideas of Constructivism, Constructionism, an active-learning model of Watkins (1998), the Constructivist learning environment of Jonassen (1999), the Constructivist Design for Learning (CDL) of Gagnon and Collay (2001), and the model of science-learning package of Sawathanapaiboon (2003). This model is suitable for use within the constraints of a school environment which needs to be supplied with an IT-network, microcomputers, science laboratory software kits.

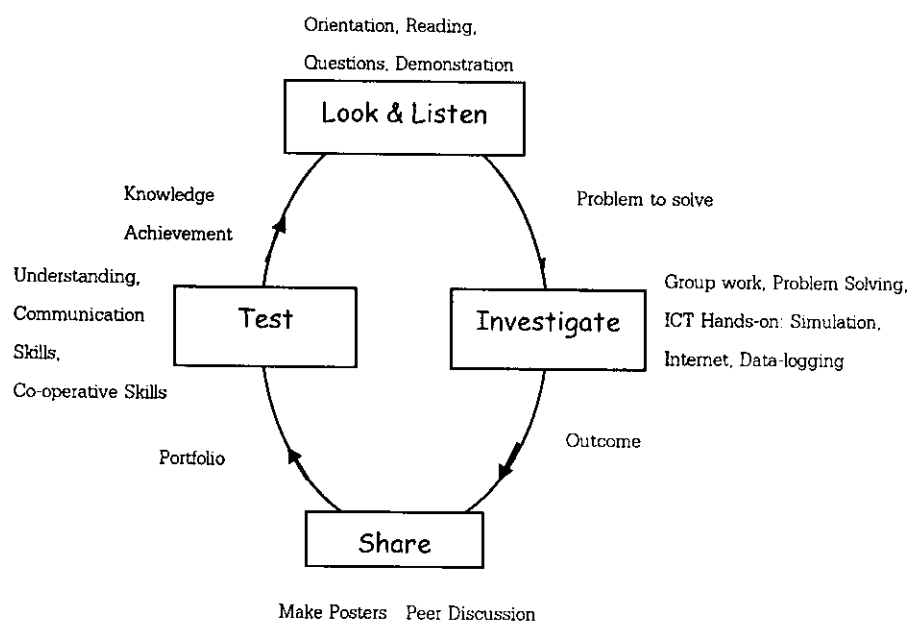


FIGURE 12: **List**-The integrated ICT-mediated learning in Science model

4.1 LisT, The Integrated ICT-mediated Learning in Science Model

The model of integrated approach to ICT-mediated learning in Science is composed of four learning stages as shown in Figure 12 on Page 86:

Stage 1: Look and Listen. This stage is the orientation stage. The aims are to provide students with an understanding of the objectives of the topic and to promote an active learning atmosphere, reading, curiosity, questioning and sharing their knowledge with peers. Therefore, students are provided with an opportunity to learn from the visual experience, active reading, demonstration, or a computer simulation program where they could acquire a new experience.

Supporting Ideas from Theory and Research

This stage was initiated by reflecting upon the ideas of Constructivism. Students enter the classroom with prior knowledge and teachers have to encourage students to think and construct new knowledge by themselves. The active teaching and learning atmosphere allows for reading, explaining, questioning, and demonstration. This can be used in the classroom to support combining prior knowledge of the students with new experiences (Harrison editor. 1992). Using questions to guide learning is a common teaching technique, and one that Bruner (Amos. 2002: 10; citing Bruner. 1985) describes as a 'Scaffolding' which is considered to be a more useful way of thinking.

Garnett and Tobin (Amos. 2002: 11; citing Garnet & Tobin. 1988) also made arguments that effective teaching included using questions that could monitor the development of the students' understanding. There were many kinds of questions classified in Bloom's taxonomy of questions. The best results about using questions have been from teachers who considered using types of questions and their tactics of asking those questions (Brown & Wragg. 1993). Furthermore, Amos (2002) suggested three categories of teacher's questions 1) promoting of thought and understanding, 2) the encouragement of enquiry and investigation and 3) assessment. This technique was an important part of the learning process to help students understanding in science.

It is clear that a questioning environment is a complex and important activity. It was a powerful way of communicating with students. However, the effectiveness of questions is determined by the teachers' own knowledge and understanding of science.

Procedure of this stage:

- 1) Teacher and students show understanding of the aims of the lesson.
- 2) Teacher provides students with the initial content of the lesson by letting them read the contents.
- 3) The teacher encourages the students to ask questions about their doubts or what they are thinking about.
- 4) Teacher starts lesson with questions that are related to their daily experiences or daily news. This process will stimulate the students' curiosity and encourage thinking, and peer discussion.
- 5) Teacher explains to students new concepts following the objectives of the lesson by means of lecturing, demonstrating, questioning, using a computer, or other learning materials.
- 6) Teacher lets students raise questions related to learning topics, daily life and their doubts. This will be useful for their investigation.

Stage 2: Investigate: This stage is an integrated ICT-mediated hands-on activity. The aim is to develop an understanding of a concept by combining the students' prior knowledge or experiences with a new situation. Students invest new knowledge through their own hands-on experience.

Supporting Ideas from Theory and Research

This stage was considered because 'Investigation' is a method of learning in science. This process could help students to clarify concepts. White (1998) stated that investigation was a useful method for students. It could be used for amendments of the descriptive propositions and for checking the accuracy of its predictions. In most science learning, students investigate phenomenon through 'hands-on science'. Woolnough (1994: 99) also agreed with the importance of scientific investigation in that when students worked through the investigation, at a level according to their own potential, it would provide them with a sense of personal achievement. The results would build up their self-confidence and encourage them to tackle challenging tasks. However, Bettencourt (1993: 47-48) pointed out that hands-on science was not the only way to facilitate students' construction of knowledge by doing things physically, but also it was the way that students could undertake discussion, imaging, and reflection. In

addition, students got an opportunity to use ideas in different situations by structuring their questions while working. Therefore, teachers who did not focus upon transferring knowledge to students should provide a particular activity to allow the students to construct knowledge based upon experience rather than just being engaged in physical activity (Tobin & Tippins. 1993: 10-11). Elstgeest (Amos. 2002: 10; citing Elstgeest. 1985) suggested that teachers should use the following sequence of questions to encourage investigation and develop process skills. They are:

- 1) Attention-focusing questions to draw students' attention to the salient features of situation.
- 2) Comparison questions to draw students' attention to similarities, differences and pattern.
- 3) Measurement questions to make qualitative observation to quantitative.
- 4) Action questions to encourage the next step in testing ideas.
- 5) Problem-posing questions to provide students with a challenge upon which to work.

This stage was also considered in group work techniques or collaborative learning techniques in which Linn and Burbules (1993: 93-98) claimed that they were the ways of framing concepts through the communicative aspect of group interaction. The mechanism of group interaction was from motivation to meet the expectations of the group, acquiring the appropriate ideas of group members, assessing knowledge distributed among group members, negotiating an understanding with group members, monitoring progression of group members, hints or feedback ideas by group members, and dividing the task among group members. These mechanisms can benefit students by giving them the opportunities to solve a problem, practice brainstorming, and learn to make decisions with others.

Also, students learned by ICT hands-on activities. The ICT was considered to be another learning material to be used in the science classroom. The ideas of learning material were supported by the work of Bruner. Bruner (Bruner. 1960, 1977: 21) believed that learning material was the best stimulus for the learning process for students. He also suggested that the heart of the educational process consisted of providing aids and dialogues for translating experience into more powerful systems of notation and ordering. Moreover, he suggested that teachers should arrange an environment to help students discover their own knowledge in three stages in learning. These stages were the action-'Enactive' stage, the images-'Iconic' stage and

symbol-'Symbolic' stage.

Moreover, investigating science through ICT was supported by the work of Jonassan (n.d.; 1999). Jonassan proposed the use of 'Mindtools'- a computer-based tool for the Constructivist Learning Environment (CLE). The objectives of mind tools were to drive the experiential learning. Examples of mind-tools are for instance, databases, computer simulation programs, or multimedia. Jonassan claimed that these mind tools could extend the cognitive functioning of learners during the learning process. Also, they engaged the learners in operations while constructing knowledge. Therefore, students in the CLE environment ought to be provided with questions, problems, or projects to interpret and solve. Addition, Jonassan agreed that during the solving process, students needed a problem representation such as video, simulation, or virtual worlds for introducing the problem and engaging learners. A cognitive tool such as computer tools could engage and facilitate cognitive processing.

Procedure of this stage:

- 1) Students work in groups around a computer or laboratory instruments that will be used for investigation. The number of members in a group is dependent on the class environment such as the number of students in class, the number of computers in class or the number of instruments.

- 2) Students in a group apply a problem-solving technique to be investigated.

- 3) Students do initial investigation. Then, they construct their own ideas through instruments, computer programs, or the Internet. For some scientific activities students are assigned practical work to be investigated by hands-on activity using handhelds equipment, probe, data-logger, data-logging software and computers to explore their investigation. Through the use of ICT, a teacher can let students repeat their exploration as often as they need within the timeframe.

- 4) Students discuss and draw on their own understanding from the knowledge they learn during the investigation.

During the investigation, teacher and students get the benefits from lesson. Students are active in discussing, brainstorming, writing and sharing ideas with their peers. Similarly, teachers would actively facilitate group work in which they could monitor the performance of students.

Stage 3: Share: This stage is a presentation stage using outcomes from students' understanding. The aims are to encourage students to use their higher order thinking-skills to communicate an importance of science to the public in a creative way by using ICT. In this stage, students are also trained to share ideas and to listen to others' opinions.

Supporting Theory and Research

This stage was initiated by the ideas that learning was a social process of making sense of experience in terms of what was already known (Tobin & Tippins, 1993). Teachers should provide an opportunity for students to synthesise their knowledge. Then, students had to present the knowledge in various ways by writing, drawing, using symbols, and assigning language to what was known.

Procedure of this stage:

- 1) Students use their higher order thinking skills to synthesise their understanding in terms of a scientific issue.
- 2) Students share knowledge with other students or the public by using generic software in terms of posters. The generic software that can be used for creating posters includes desktop publishing (DTP), spreadsheet, presentation software or web publishing.
- 3) Teachers let students show their poster, creating discussion and sharing ideas with others.
- 4) Students evaluate their own work.

Stage 4: Test: This stage is a summative stage. The aims are to let students evaluate themselves in acquiring knowledge and to learn at their own pace. In addition, the outcomes of this evaluation also provide significant information for teachers. Teachers can use this information to improve their teaching strategies in the next lesson.

Supporting Theory and Research

Student self-assessment is one of the creativity components. Students can recognize themselves and reflect on their own progression. Shepard (2002) argues for the significance of student self-assessment in many aspects such as serving cognitive purpose, increasing students' responsibilities for their own learning and promoting a more collaborative relationship between teachers and students. Reflecting upon the research of Klenowski (Shepard, 2002; citing Klenowski, 1995), his work drew on the case studies of student self-evaluation in both an

Australian and British site. The results showed that this method of assessment is formed more interesting by students. Also, it may improve students' honesty in assessing their work because they have to prepare the evidence. This stage would be used as formative assessment. It was supported by Rowntree (Christofi. 1988: 12; citing Rowntree. 1977) who pointed out that the assessment had to take place at intervals during the course because the teacher would get to know the students in order to teach them better. During a practical science lesson, students learned a variety of skills on practical work. For instance, they learned how to control their experiments and how to establish most of the basic concepts of science. Thus, the formative assessment during a practical science lesson was to be considered. The students had to be assessed in a range of skills such as manipulative skills, communication skills, drawing skills in creative arts, and so on. (Christofi. 1988).

Procedure of this stage:

- 1) Teachers summarize the knowledge that students had learned from this lesson as a conclusion statement.

- 2) Students make a self-assessment.

In addition, in order to get more advantages from this learning model, teachers have to work closely with technicians who provide the necessary tools for the learning environment. The tools were computer networking, computer software and laboratory instruments, and learning material.

CHAPTER 3

RESEARCH METHODOLOGY

This chapter describes in details the research and development methodology (R&D) setting in three broad sections. The first section describes the process of developing research instruments, the second section describes research design, and the last section describes the ways in which the data are analyzed.

SECTION 1: Developing Research Instruments

1.1 How the integrated approach to ICT-mediated learning in Science was developed

1.1.1 The format of the integrated approach to ICT-mediated learning in Science.

1.1.2 Lesson plan for the integrated approach to ICT-mediated learning in Science.

1.1.3 Selecting ICT tools for the integrated approach to ICT-mediated learning in Science.

1.2 How the assessment of the package was developed.

1.2.1 Achievement

1.2.2 Learning style

1.2.3 Creativity in scientific communication

1.2.4 Learning environment

SECTION 2: Research Design

2.1 Population and Sample

2.2 Research Methodology

SECTION 3: Data Analysis

3.1 Statistics for examining the quality of research instruments

3.2 Statistics for testing the hypotheses

3.3 Descriptive Statistics

SECTION 1: Developing Research Instruments

1.1 How the Integrated Approach to ICT-mediated Learning in Science was developed

The integrated approach to ICT-mediated learning in Science aimed to integrate the **LisT** learning model, a variety of teaching strategies, learning styles and the uses of ICT in science education. This approach was initiated by the integration of the uses of hands-on activities, group work, lecture, demonstration, or labs which were supported by the work of Gallagher (1993). He said that these elements could help learning in science. Moreover, he also strongly suggested that group work was a very important strategy when it was used to help students talk about their ideas with other students. The following steps were designed to develop the integrated approach to ICT-mediated learning in science in this study:

1.1.1 The Format of the Integrated Approach to ICT-mediated Learning in Science.

When planning to use ICT in science learning, the structure of the integrated approach to ICT-mediated learning in Science was considered an important learning aid. This study developed the structure of the approach in terms of a learning package. It was developed from the ideas of the active learning approach using ICT. A Thai slogan was inserted to encourage students during the learning process. The idea of the learning booklet came from the work of Savathanaphaibul (2003), Taweelap (2003), and many educators such as Vongyai (1982), Kapfer (1972), or Duane (1973) (Taweelap. 2003; citing Vongyai. 1982; Kepfer. 1972; Duane. 1973). They all agreed that the learning booklet was a useful learning aid, which could support students in the learning process. This study summarizes use of the booklet in two aspects:

1) Teacher's aspect. This material was considered to be a complete teaching material which was developed over a considerable period of time in order to ensure appropriacy to the students' needs.

2) Students' aspect. This material was considered to be a complete learning aid in which students could learn by themselves and in collaboration with their peers.

Moreover, the group-work techniques were inserted into the learning booklet. Therefore, students were benefited from collaborative work rather than learning by themselves. The format was composed of the following items:

1) Lesson Plan: The aim was to integrate ICT mediated learning into the school science curriculum. This is described in greater detail in section 1.1.3.

2) Lesson Unit: The aim was for the concepts of the lesson to be learned. Each unit was divided into subunits by learning process and topic.

3) Learning Objectives: The aim was to identify learning objectives in developing students' knowledge, competence, thinking skills, inquiry skills, problem-solving skills and creativity in scientific communication.

4) Learning Outcomes: the aim was to specify the expected science abilities of students. They were followed by the Sub-strand of Science (MOE. 2003).

5) Contents: The aim was to explain the scientific concepts of the learning unit. The contents were arranged in sequence by lesson plan and Physic Book I (MOE. 2003). The appropriate functions of ICT were integrated into these contents.

6) Learning Process: The aim was to apply four stages of the **LisT** Model into the lesson. Each stage aimed to develop students in these broad areas:

Learning Episode	Objectives
Stage 1: Look and Listen	To develop thinking skills
Stage 2: Investigate	To develop inquiry skills and problem-solving skills.
Stage 3: Share	To develop higher order thinking skills and creativity in scientific communication skills.
Stage 4: Test	To develop self-assessment.

7) Activities: The aims were to help students actively acquire knowledge and construct their own knowledge through their own hands-on activities. The activities were designed in six patterns as described in Table 4 on Page 96.

TABLE 4 **List** MODEL ACTIVITY PATTERN

Activity Pattern	Objectives of Activity
1. 'Thinking by Reading & Listening' การอ่านและการฟังนำไปสู่ความคิด	- to encourage students by stimulating curiosity - to combine prior knowledge with new experience - to stimulate students through questioning techniques
2. 'How Things Work!' ชวนกันคิด	- to encourage students to construct their own ideas - to encourage peer discussion - to promote meaningful learning through questioning
3. 'Learning by Doing' สืบปากว่าไม่เท่าตาเห็น สืบตาเห็นไม่เท่ามือคลำ	- to provide students with an opportunity to acquire experience from their own activities - to mediate ICT into the lesson using a variety of ICT tools such as computer simulation programs, data logging and the internet.
4. 'Creating the Learning Society' สร้างสังคมอ่านสู่สังคมแห่งการเรียนรู้	- to encourage students to synthesize their understanding - to encourage students to consider the importance of scientific communication and quality of life - to encourage student presentation of scientific knowledge to the other students or the public at large - to encourage students to listen to others' opinions
5. 'Knowing Your Pace is Knowing Yourself' ประเมินตนเองเมื่อรู้ทัน	- to encourage students to evaluate their own progress - to investigate what they have learned - to monitor their own progress

1.1.2 Lesson Plan for the Integrated Approach to ICT-mediated Learning in Science

This study was conducted with Year-10 students at Key Stage 4 at Triam Udom Suksa Pattanakarn School in Bangkok. This school used Physics text book I developed by The Ministry of Education and the IPST in 2003. This study focused on the topic of Force and Motion, motion in one-dimension and the Newton's Law of motion. Consequently, the lesson plans were developed following the school curriculum and the **LisT** Model. This model utilized the uses of ICT into lessons. The processes of developing lesson plans for the integrated approach to ICT-mediated learning in Science are described as follows:

1) Study of the Sub-strand 4 for Force and Motion of Key Stage 4, learning objectives and expected learning outcomes from the National Curriculum Sub-strand 4 of Key Stage 4. The two standards, Standard Sc 4.1 and Standard Sc 4.2, which related to the study was summarized in Table 5.

TABLE 5 SUB-STRAND 4 FORCE AND MOTION IN THE NATIONAL CURRICULUM OF
B.E 2542¹.

Standard Sc 4.1: The student should be able to understand nature of electromagnetic force, gravitational force and nuclear force, have experienced investigative processes and communicate the knowledge acquired and make use of it correctly and morally. At the end of the highest grade of each level the student should be able to :- 1. investigate, analyze and explain the relationship between force, motion of particles or objects in gravitational field, magnetic field, electric field, also make use of the knowledge. 2. analyze and explain nuclear binding forces and forces between particles.

¹ B.E. 2542 means A.D.1999

TABLE 5 (continued)

Standard Sc 4.2: The student should be able to understand types of motion of natural objects, have experienced investigative processes and possess a scientific mind, communicate knowledge acquired and make good use of it. At the end of the highest grade of each level the student should be able to :- 1. experiment and explain relationship between displacement, velocity, acceleration in linear motion and perform calculations to find relevant quantities. 2. investigate and explain simple harmonic motion, circular motion, projectile motion, also make use of them.

Source: MOE. 2003

2) Analysis of the concepts of motion in one dimension and Newton's Law of Motion from the school curriculum and from Physics text book I (MOE. 2003). The 4 learning units for this learning package were designed by researcher as shown in Table 6 on Page.

3) Integrate the uses of ICT and its activities into those lessons as shown in Table 6 on Page 99. The details processes are described as follows:

3.1) Design of a number of the integrated ICT-mediated activities into lessons.

3.2) Design the total period for this learning package by 34 hours.

TABLE 6 LESSON PLAN : FORCE AND MOTION FOR YEAR-10 AT KEY STAGE 4

Learning Unit			
Subject: Science for Year-10 at Key Stage 4		Lesson	4 units
Unit title: Force and Motion		Period	34 periods
Unit	Lesson Outline	Activity	Period
0	Introduction and Orientation	-	2 p
1	Motion in 1 dimension		
	- Position and Displacement	S, D,G	2 p
	- Speed Velocity and Acceleration		6 p
	- Free Falling		4 p
2	Force and Newton's Laws of Motion		
	- Force	I, D,G	2 p
	- Newton's Law of motion		8 p
3	Weight and Newton's Law of Gravitation		
	- Weight in various gravitational fields	I, G	2 p
	- Newton's Law of Gravity		2 p
4	Frictional Force and Its application		
	- Friction and its effects	S, I, G	6 p
	- Application of Newton's laws of motion		
Total hour			34 p

Note:

1. one period is equal to 50 minutes

2. p = period

3. S = Computer Simulation Program

D = Data-logging

G = Generic software

I = Internet

3.3) Analyses of learning objectives against the first three main criteria of Bloom's Taxonomy: Knowledge, Comprehension, and Application. Then, the learning outcomes of each lesson plans was designed as shown in Table 7. This was used for considering the number of questions in summative assessment for the achievement.

TABLE 7 ANALYSIS OF LEARNING OBJECTIVES AGAINST BLOOM'S TAXONOMY

Lesson Outline and Learning Objectives	Learning Outcomes for Bloom's taxonomy			Total
	Knowledge	Comprehension	Application	
1. Motion in 1 dimensions				
- Position and displacement				
- Velocity, Speed, Acceleration	1	2	6	9
- Free falling				
2. Force and Newton's Laws of Motion	-	3	3	6
- Force				
- Newton's laws of motion				
3. Weight and Newton's Law of gravity	-	1	2	3
- Weight				
- Newton's Law of gravity				
4. Frictional Force and Its application				
- Friction				
- Application of Newton's laws of motion	-	3	2	5
Total	1	9	13	23

1.1.3 Selecting ICT Tools for the Integrated Approach to ICT-mediated Learning in Science

A variety of ICT tools were selected for the integrated approach to ICT-mediated learning in Science. They can be summarized in the following selected items.

1) Computer Simulation Software

There were a variety of computer simulation software that were designed to support the learning of Physics-Force and Motion. Newton and Rogers (2002) suggested seven criteria to be considered in selecting software for learning. They were 1) suitability of content, 2) appropriate level of content, 3) reliability 4) accuracy and objectivity, 5) availability and currency which was focused on inquiry, 6) intranet, and 7) remodeling information (Newton & Rogers. 2002: 53-54). The processes of selecting appropriated computer simulation software for this study were summarized in Figure 13.

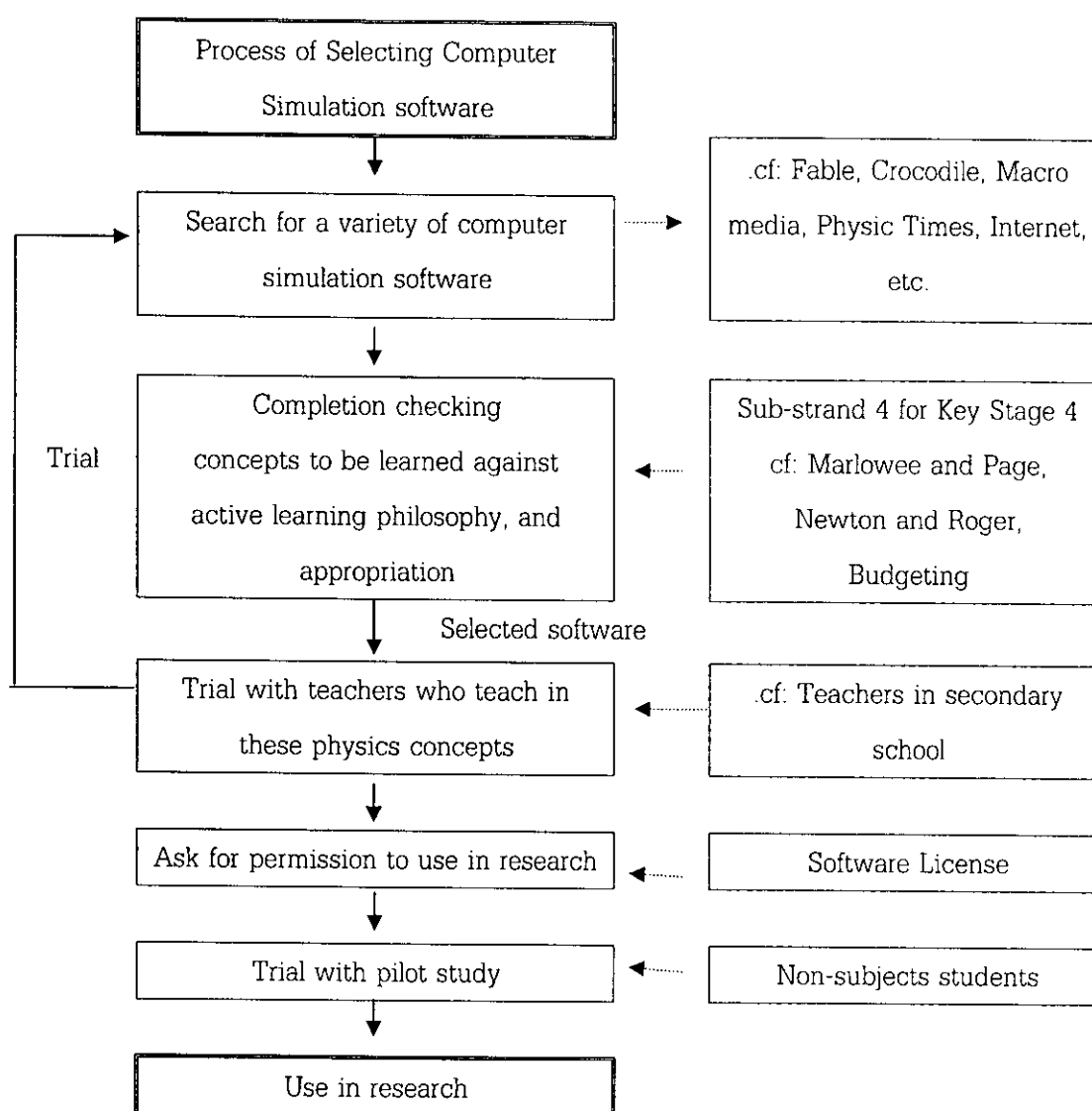


FIGURE 13: Process for selecting computer simulation software

By the process described in Figure 13, this study found some differences in terms of use, contents and objectives for the studied software. Therefore, this study selected Fable

Multimedia Software and some simulation software on the internet for 4 reasons 1) covering the required concepts to be learned, 2) ease of use for initiating the concept to be learned, 3) ease of use for students and 4) no time consuming. Moreover, all teachers who were involved in the selecting phase agreed with the choice of software for the learning units of this study.

2) Data Logging Software

There are numerous examples of data-logging software packages for educational practical science kit. They provided similar functions of practical science work mostly in live data collection, data manipulation and data presentation. The interesting criterion of selection was the ease of use in the secondary classroom learning environment. The selection steps were summarized in Figure 14.

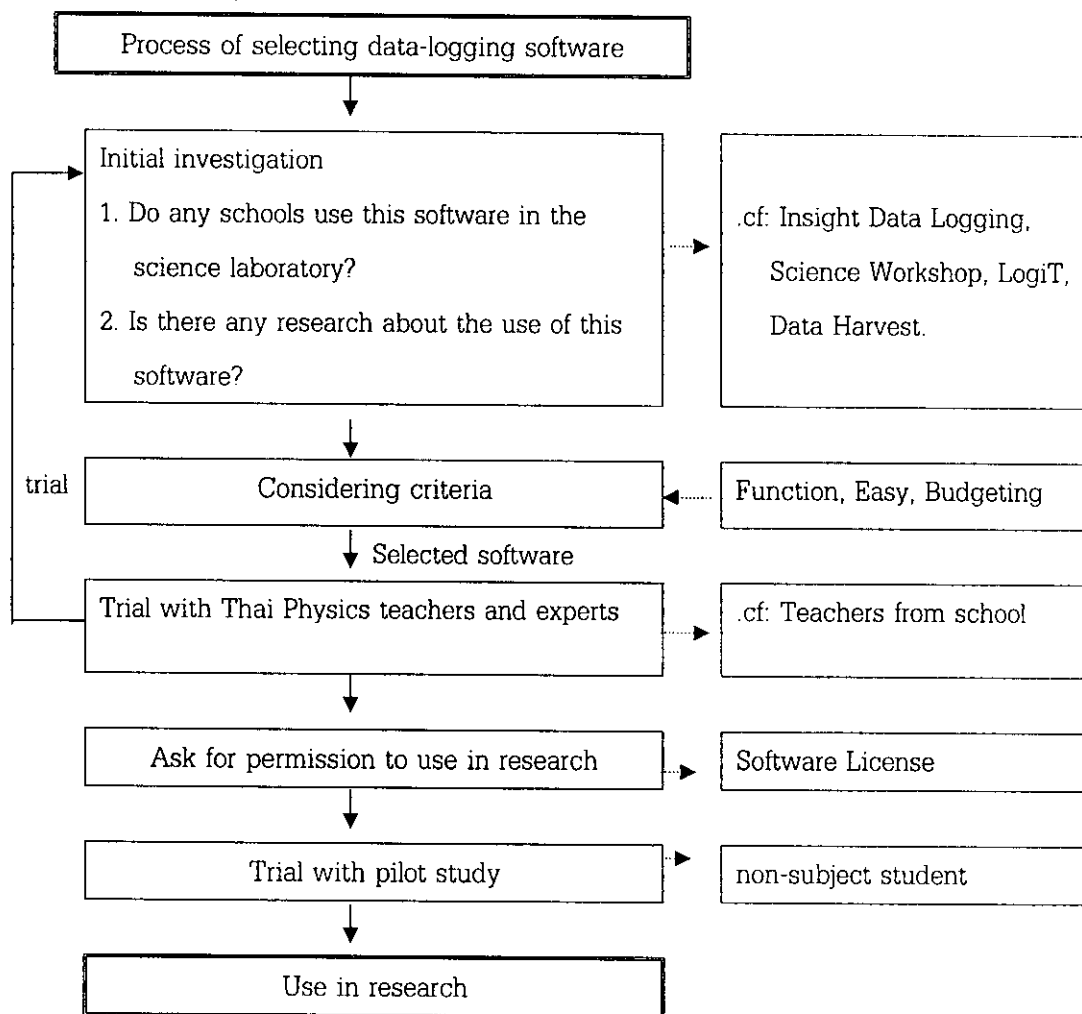


FIGURE 14: Process for selecting data-logging software

By the process of selection in Figure 14, this study found that there was little difference between each example of data logging software. All data logging software have their own

interesting function. This study selected the 'Insight Data-logging Software' for 5 reasons. The reasons were 1) widely used in secondary science school, 2) easy to use for Thai secondary school, 3) accuracy, 4) functions for a practical work of key-stage 4, and 5) free license was granted for this study.

3) Internet

In the process of learning, teachers may demonstrate or let students explore new experiences from other learning resources such as related web sites. The selection processes for the related web sites were the same as for the process of selection of computer simulation software.

4) Generic software

The generic software for this study was the standard generic software, which was normally used in the school environment. They were word processor, spreadsheet, presentation software, or web publishing.

The teachers used this learning package as learning aids for Physics text book I (MOE. 2003). The reliability of this package was evaluated as follows:

1) Five experienced teachers (Appendix 1) evaluated the integrated approach to ICT-mediated learning in Science. The evaluated criteria were learning objectives and learning outcomes which were written in the Sub-strand 4 of the science curriculum of Key Stage 4. The other evaluated criteria were the appropriacy of the contents, the learning process, and the language. The researcher passed this learning package to five experienced teachers. Later recieve, they were interviewed by researcher. The aims were to recieve their comments and suggestions. These are summarized as follows:

1.1) They agreed with the use of this learning package as learning aids for Physics at Key Stage 4, 'Force and Motion' Module.

1.2) Additional suggestions were the editing of the language, timing, and the numbers of activities in this learning package.

1.3) They suggested a training session for teachers on the use of ICT laboratory instruments before the study began.

Then, the researcher edited this learning package and applied for a pilot study.

1.2 How the Assessment of the Approach was developed

Five instruments were developed upon four dependent variables of this study. The five dependent variables were achievement of students, learning style of students, creativity in scientific communication of the students, and learning environment. The assessment methodology and its instruments were described as follows:

1.2.1 Achievement

Both summative assessment and formative assessment were performed to measure the achievement of students. The following section describes the developing process of these assessments:

1.2.1.1 Summative assessment

For the summative assessment, four options for each question were developed for the Tests. The questions were developed from Bloom's Taxonomy of questions in cognitive domain: knowledge, comprehension, and application. Processes of developing the Tests were presented as follows:

- 1) Analyses of learning objectives against six main criteria of Bloom's Taxonomy: knowledge, comprehension, application, analysis, synthesis and evaluation.

- 2) The researcher developed 45 questions under Bloom's Taxonomy of questions in cognitive domain technique. These questions were approved by five experienced teachers who were experienced in teaching physics in terms of content validity, learning outcomes and language. The index of item-objective consistency (IOC) was shown in Appendix 3(a).

- 3) The IOC of 45 questions which scored under 0.5 was redeveloped using five experienced teachers' suggestions. The suggestions involved updating language and using mathematics symbols. Then, 40 questions were selected by advisors of this study and the researcher to evaluate the validity and reliability of the Tests.

- 4) The 40 questions were tried out with 205 students who were studying Year-11 level of the science program. They were 79 students from Benjamarachalai School in Bangkok, 66 students from Wat-Bavornnivet school in Bangkok, and 66 students from Makutmuengraj School in Rayong province. The level of difficulty (p) and the level of discrimination (r) are shown in Appendix 3(b).

- 5) Then, 23 questions were selected using these criteria 1) the difficulty (p) index of

the selected 23 questions was between [0.2, 0.8], and 2) the discrimination (r) index of the selected 23 questions was above 0.20. The selected 23 questions are summarized in Table 8.

6) The reliability of this try-out was 0.81.

TABLE 8 SUMMARY OF NUMBER OF QUESTIONS USED FOR THIS STUDY

Learning Unit	Hours	No. of Questions		
		Try-out	Significant	Selected
0. Introduction and Orientation	2	-	-	-
1. Velocity and Acceleration	12	13	11	9
2. Newton's Law of Motion	10	9	7	6
3. Weight	4	6	5	3
4. Friction and Its Applications	6	12	7	5
Total	34	40	30	23

1.2.1.2 Formative assessment

It was claimed in a variety of research that formative assessment could raise student achievements (Harlen, 2003: 7). During the lesson, students were assigned to work in groups, so that task scores were accumulated from practical science work, group investigation and self-test.

The processes of this assessment were described as follows:

1) Practical science work was measured in the ICT laboratory. Students explored their investigation using data logging, computer simulation program, or the Internet. The rubrics for this investigation were developed by the researcher and were approved by advisors.

The criteria for the rubrics of data logging investigation were:

- Setting hypotheses
- Doing experiments
- Making observations

- Writing conclusions
- Interpreting graphs

2) Group investigation was measured by exploring an external learning resource on the Internet. The rubrics were developed by the researcher and were approved by advisors.

The criteria for the rubrics of using learning resources (Computer simulation program or Internet) were:

- Setting up the searching goal
- Making observations
- Writing conclusions
- Using ICT as a tool for research

The investigated tasks were scored by the researcher and a trained assistant researcher. Then, the mean scores from each task were accumulated for the formative assessment.

3) Self tests: There were a number of short questions at the end of lessons used for the self tests. The students answered these questions to evaluate their own understanding. The self tests were scored by the researcher. The results were accumulated for formative assessment

4) The proportion of all collected scores during class for the formative assessment is summarized in Table 9 on Page 107.

TABLE 9 TASKS FOR FORMATIVE ASSESSMENT

Tasks	Mark
Lesson 1.	
1.1 Investigating by using data logging for velocity, acceleration, free falling	30
1.2 Self tests	30
Lesson 2.	
2.1 Investigating by using data logging for Newton's law	15
2.2 Self tests	25
Lesson 3.	
3.1 Investigating by internet and spreadsheet	15
3.2 Self tests	15
Lesson 4.	
4.1 Investigating by internet	12
4.2 Self tests	15
Task assessment	157

1.2.2 Learning style

This study developed the new learning style questionnaire. This questionnaire was modified from Kolb's experiential learning style inventory in 1985 and from Lertlop's learning style inventory in 1992. The aim of this questionnaire was to classify the learning styles of students. The steps of developing this questionnaire are described as follows:

- 1) Studying the experiential learning styles inventory of Kolb (1985) and his method for classifying four learning styles.
- 2) Studying the research and learning style inventory of Lertlop (1992).

3) Designing the structure of the new learning style questionnaire. The questionnaire consisted of 3 parts; Part 1 for General instructions, Part 2 for Student's Information, and Part 3 for 12 Questions with 4 ranking style answers.

4) The student ranks each answer of each question with 4, 3, 2 or 1. The 4 meanings of the ranking style answers are:

- 4 for the answer that is the same as the student's characteristics
- 3 for the answer that is most like the student's characteristics
- 2 for the answer that is slightly like the student's characteristics
- 1 for the answer that does not describe the student's characteristics

5) The learning style questionnaire has been approved by three experienced educators and advisors.

6) The researcher used their comments for setting the learning style questionnaire for this study.

7) The learning style of students was interpreted using the following method:

7.1) the four answers of each question represented the four learning behaviors of information processing of Kolb's learning style. They were CE - Concrete Experience, RO - Reflective Observation, AC - Abstract Conceptualization and AE - Active Experience. The character a, b, c or d represented the four learning behaviors of each question as shown in Table 10.

TABLE 10 THE QUESTIONS AND ANSWERS FOR EACH LEARNING BEHAVIOR

Learning Behavior	Question and Answer											
	1	2	3	4	5	6	7	8	9	10	11	12
1. Concrete Experience	a	a	c	c	d	a	b	a	a	A	a	a
2. Reflective Observation,	b	d	a	b	a	d	a	b	d	C	b	d
3. Abstract Conceptualization	c	b	b	d	b	b	d	c	b	D	c	b
4. Active Experience	d	c	d	a	c	c	c	d	c	B	d	c

7.2) all four answers of each question were ranked by each student. They were ranked by comparing each answer with their characteristic of preferred learning style.

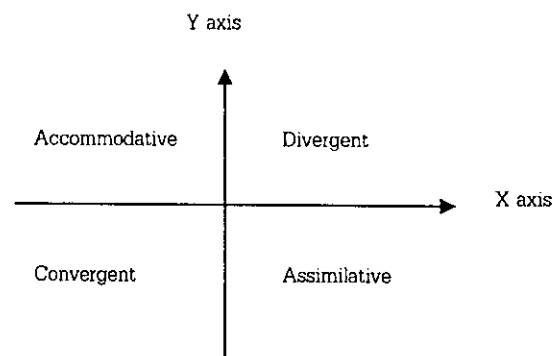
7.3) Total rank scores of learning behavior were summarized into CE-total score, RO-total score, AC-total score and AE-total score.

7.4) the co-ordinates (x, y) of learning style quadrant, following Kolb's experiential learning style method, were calculated by the following method:

X axis value is calculated by subtracting AE-total score from RO-total score.

Y axis value is calculated by subtracting AC-total score from CE-total score.

7.5) the co-ordinate (x, y) was the co-ordinate for an individual learning style quadrant. They were:



Quadrant 1: Divergent Learning Style

Quadrant 2: Assimilative Learning Style

Quadrant 3: Convergent Learning Style

Quadrant 4: Accommodative Learning Style

8) The reliability of this questionnaire was evaluated using α -Conbrach Coefficient.

9) The first try-out for the reliability of the questionnaire was conducted.

9.1) Four hundred questionnaires were distributed to 7 schools. They were Assumption School, Wat-Noinoppakhun School, Chanhunbumpen School, Pattharaphukdee School, Demonstration School of Rajchaphat Thepsatree University, Demonstration School, Patuwan Demonstration School, Srinakharinwirot University, and Saint Fran Sissavia Nonthaburi School.

9.2) Three hundred and eighty-two questionnaires were returned for reliability analysis.

9.3) Due to a misunderstanding concerning the use of the ranking style questionnaire, only 280 questionnaires were used to perform the reliability test as shown in Table 11.

TABLE 11 RELIABILITY OF THE FIRST EVALUTION PHASE OF LEARNING STYLE QUESTIONNAIRE WITH α - CONBRACH COEFFICIENT

Learning Style	Reliability
1. Divergent Learning Style	0.72
2. Assimilative Learning Style	0.70
3. Convergent Learning Style	0.71
4. Accommodative Learning Style	0.70

10) The second try-out for the reliability of this questionnaire

10.1) to prevent further misunderstanding about the use of the ranking style questionnaire, the questionnaire was redesigned in a new format. This questionnaire was tried out with 50 students who were Year-10 students of the secondary science program of Patuwan Demonstration School, Srinakharinwirot University. There was no student who could not use this ranking style questionnaire. The reliability of this try-out was shown in Table 12.

TABLE 12 RELIABILITY OF THE SECONDARY EVALUATION PHASE OF LEARNING STYLE QUESTIONNAIRE WITH α - CONBRACH COEFFICIENT

Learning Style	Reliability
1. Divergent Learning Style	0.71
2. Assimilative Learning Style	0.66
3. Convergent Learning Style	0.71
4. Accommodative Learning Style	0.72

10.2) the three α -Conbrach Coefficient was greater than 0.70 (Saiyot & Saiyot, 1995: 209) which can be used for this study. The second α -Conbrach Coefficient for assimilative learning style was lower than 0.70, the researcher modified the questions of this learning style. In order that, the new learning style questionnaire could be used for this study.

1.2.3 Creativity in Scientific Communication

The performance of creativity in scientific communication of the students was presented in terms of posters. Student used their HOT - higher order thinking skills and the use of ICT to generate posters. The HOT was the upper level of cognitive domain of Bloom's taxonomy. They were analysis, synthesis and evaluation. Those posters were scored using rubric for creativity in scientific communication. This rubric was developed following the SOLO Taxonomy. The process of developing this instrument is described as follows:

1) Specifying five grades following SOLO taxonomy:

Extended Abstract	with excellent	scoring 5
Relational	with good	scoring 4
Multi-structural	with Neutral	scoring 3
Uni-structural	with Modify some	scoring 2
Pre-structural	with Reedited	scoring 1

2) Defining criteria for the creativity in scientific communication of students as follows:

1. Theme
2. Communication
3. Essay
4. Multimedia and Photographic Design
5. Using ICT
6. Target Group

3) Defining the weight for scoring the student's performance in those 6 criteria. The scoring was double score (or weight was 2) for the criteria of communication, essay and target group. The other criteria are single score.

4) The criteria were approved by five experienced educators. They all agreed with using this rubric for this study. Some of them made comments and suggestions. These were the number of scorers, and a specific kind of ICT for reducing the bias of ICT skills. The results are shown in Appendix 3(c) and Appendix 3(d). Then, the rubric scheme was developed for this study.

1.2.4 Learning Environment

This study used an ethnographic observation methodology - the formative classroom observation that Cangelosi (1991: 45) claimed could be used to evaluate a classroom-learning environment. The learning environment considered for this study was classroom interactions.

Two observation methods were developed:

1.2.4.1 Developing CBI-computer-based Interaction Analysis Categories for the Integrated ICT-mediated Classroom Learning Environment.

The **List** learning model was applied to the classroom for this study. The classroom-learning environment for this study focused on classroom interactions during lessons. Video-recordings were chosen as an appropriate technique for classroom observation. The proposed classroom-learning environment- was different from a traditional science classroom, so that CBI- a new observation coding system was developed to interpret this learning environment. This CBI was modified from various classroom observation methods and researches such as from the original ten categories of FIAC-Flanders Interaction Analysis Categories. But, FIAC was commented by the STAR project that its coding category was not enough to monitor some activity of science process skills in a science classroom (Cavendish; et al. 1990: 10). Therefore, this study modified the additional coding category from other researches and studies as the following:

1.1) Applying the six situations to the science lesson which were classified by the work of Jennings (1995). They were: 1) Questioning; 2) Demonstration; 3) Exposition; 4) Watching; 5) Investigation; and 6) Work.

1.2) Applying the coding system from SPOC (Cavendish; et al. 1990: 46-56).

1.3) Applying six categories of student interaction during practical science work, which was classified by Wallace (1986).

1.4) Applying three categories of student interaction on using data-logging for a practical science activity. These categories were classified by the study of Barton (1997). They were 1) Group discussion, 2) Sharing experience, and 3) Explaining interpretations and ideas.

1.5) Applying three categories on the method of how a student spent time in front of the computer from the philosophy of computer software (Marlowe & Page, 1998: 135). They were: 1) Student was active, but mostly absorbing rather than using information; 2) Student spent a lot of time passively watching the screen; and 3) Student was actively engaged in problem-solving.

The processes for developing this new CBI coding system for this study were summarized in Figure 15 on Page 114.

The CBI coding system for this study consisted of 25 categories. They were 11 categories for the lecture situation, 6 categories for activity in front of the computer, 7 categories for practical science work, and 2 categories for general situations. The validity of this coding system was evaluated by five experienced educators in terms of language and use for evaluating the integrated ICT-mediated science classroom-learning environment. This instrument researcher used the IOC technique and interview. All the them agreed with using this coding system for this study. The IOC shows 1.00. But some of them pointed out that some CBI might be modified for an appropriated coding when applying them into a real situation. Then, the new coding system was proposed for this study. Five experienced educators also made some comments on coding techniques and suggested that the observed data were also important for qualitative discussion. Then, the CBI was modified by the researcher and was approved by advisor before using for this study. The final coding system is shown in Table 13 on Page 115.

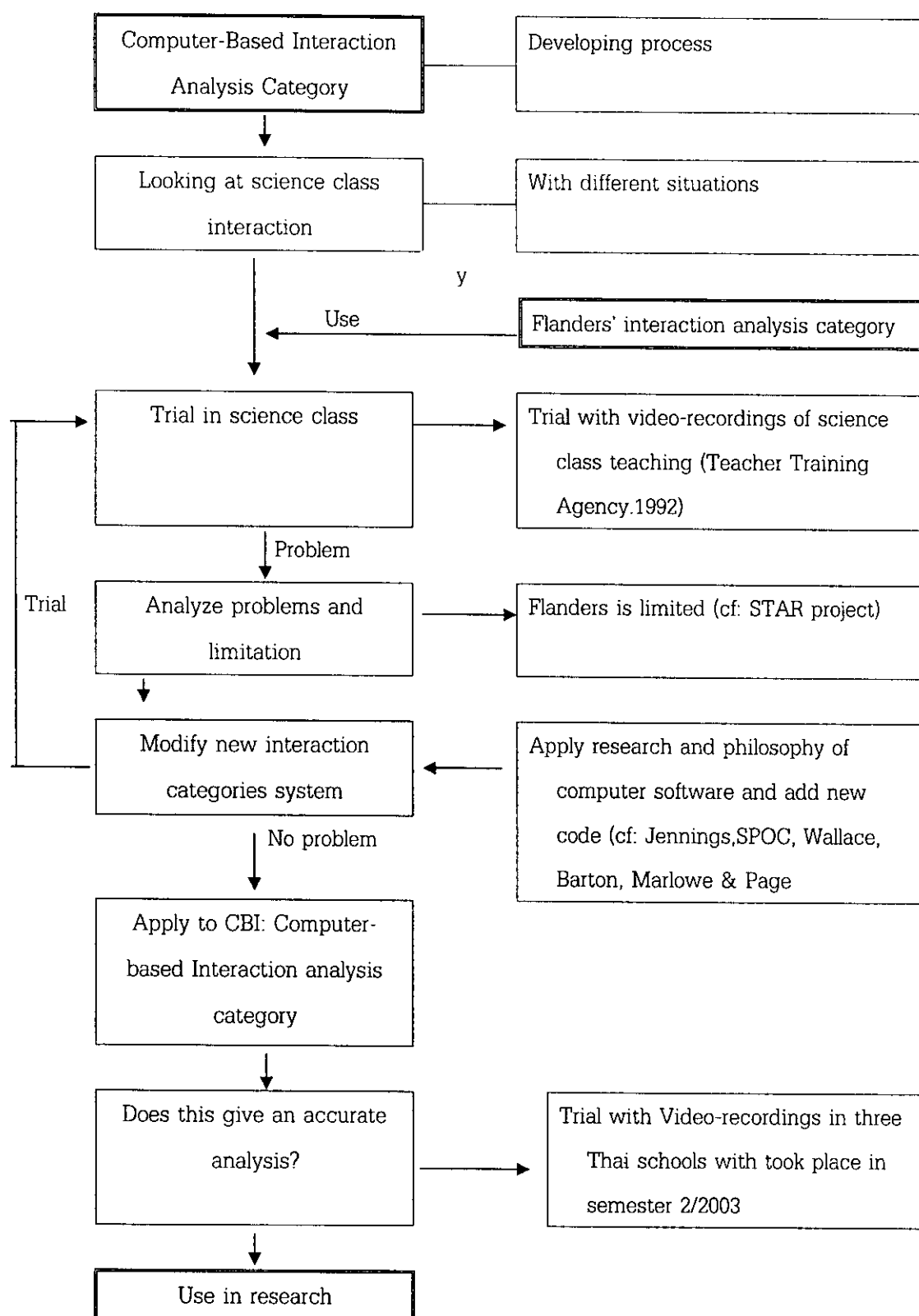


FIGURE 15: The developing of Computer-based Interaction Categories

TABLE 13 CBI-COMPUTER-BASED INTERACTION ANALYSIS CATEGORIES FOR THE
INTEGRATED ICT-MEDIATED CLASSROOM LEARNING ENVIRONMENT

Code	Meaning	Developed from
1	Teacher praises or encourage students	FIAC
2	Teacher accepts student's ideas	FIAC
3	Teacher posts questions	FIAC
4	Teacher lectures/demonstrates	FIAC
5	Teacher gives directions	FIAC
6	Teacher criticizes	FIAC
7	Students respond to teacher	FIAC
8	Students initiate ideas/actions	FIAC
9	Students work with books/worksheet	SPOC
10	Students discuss with peers	Jennings
11	Students work in front of computers	Marlowe & Page
12	Students are actively using information from computers	Marlowe & Page
13	Students are passively using computers	Marlowe & Page
14	Students discuss with each other	Marlowe & Page
15	Students help each other	Marlowe & Page
16	Student plans for investigation	Jennings
17	Students make observations	SPOC, Jennings
18	Students use instruments	SPOC, Jennings, Barton
19	Students discuss observations	SPOC, Wallace, Jennings SPOC, Wallace Jennings,
20	Students raise questions	Barton SPOC, Wallace Jennings,
21	Students reflect on the observations	Barton
22	Students conclude the findings	SPOC, Wallace
23	Teacher facilitates students' work	-
24	Teacher monitors class	-
25	Unidentified	FIAC

Source: Modified from FIAC (1970); Marlowee & Page (1998); SPOC (Cavendish; et al. 1990: 46-56); Wallace (Solomon. 2002: 22; citing Wallace. 1986); Jennings (1995); Barton (1997)

1.2.4.2 Developing an Observational Learning Environment Questionnaire

This study utilized an observational form for observer. The aim was to track the reflection from the observer's view during a classroom period. The 10 questions of the observational learning environment questionnaire were modified from the work of Marlowe and Page in 1998. The validity of questions was evaluated by three experienced educators in terms of appropriate use for evaluating an integrated ICT-mediated classroom-learning environment before use in the research. The researcher passed this questionnaire to three experienced educators and made an appointment for interview. Then, the researcher used comments from three experienced educators to rebuild this observational learning environment questionnaire. The final items in the questionnaire were approved from by an advisor and are shown in Table 14.

TABLE 14 INDEX OF ITEM-OBJECTIVE CONSISTENCY OF THE OBSERVATIONAL
LEARNING ENVIRONMENT QUESTIONNAIRE

No	Observed Question
1	Students are totally involved in learning process.
2	Students interact with teacher and other students.
3	Students demonstrate their understanding in learning topic through acting and discussion.
4	Students enjoy the activity.
5	Students actively pay attention
6	Students post or reflect questions.
7	Teacher enjoys this learning activity.
8	Teacher can integrate learning process to the content.
9	Teacher is an important actor for this learning process and students' participations.
10	Teacher sees tremendous improvement in students' work and comprehension.

Source: Modified from Marlowe & Page. 1998: 90-91.

This study employed an ethnographic methodology. The learning environment was measured using video-recording and the observational learning environment questionnaire. These observational instruments were randomly documented through the study.

At the beginning of this study, it was very important to clarify to the classroom teacher the objectives of the classroom observation. Therefore, a meeting was set-up between the classroom teacher and the researcher before embarking on classroom observation. In the first period of the class, the teacher had introduced students to the researcher in order to understand the objectives of this study. She also explained to students the objectives of the video recording.

This study used only one video recording camera. The recording procedure was set to capture the classroom situation by turning the camera around the classroom. At the beginning of this study, it was noticed that students frequently looked at the video recording camera. Later on, when this instrument was integrated into the classroom learning environment, they showed that they had become familiar with this instrument.

Numerous video recording tapes were interpreted into CBI-computer-based interaction coding categories by the researcher and a trained research assistant. A tally sheet was a chosen technique to record the interpretations. The interpreting procedure from video-recording tapes was the interval recording method using one minute per interpretation following the study of Cohen; Manion and Morrison (2002: 309).

The second instrument, the observational learning environment questionnaire, was used to observe the classroom-learning environment by the observer. The scale for observing criteria were 5 rating scale: 5 represented "very good"; 4 represented "good"; 3 represented "fair"; 2 represented "less" and 1 represented "least".

SECTION 2: Research Design

This study investigated students who were taught using the integrated approach to ICT-mediated learning in Science, module-Force and Motion at Key Stage 4. The **List** learning model was a learning process for this learning package. Four dependent variables were considered in this study: achievements of students; learning style of students; creativity in

scientific communication of student and learning environment. The following paragraphs describe the research methodology for this study.

2.1 Population and Sample

Population

The population of this study consisted of students who were active in a secondary school science curriculum in Year-10 at Key Stage 4.

Sample

The subjects were 82 students from two classrooms of the science program in Year-10 at Key Stage 4. They were studying during the first semester of the academic year 2004 at Triam Udom Suksa Pattanakarn School in Bangkok Thailand.

Sampling Technique

This study addressed a specific sampling technique described in the following steps:

1) The 'School' was selected from secondary science schools that aimed to improve their students' achievement by using ICT for science learning. Moreover, the school environment was provided with computers and networking.

2) The 'Teacher' was selected from teachers who taught Physics-'Force and Motion' at Year-10 at the selected school.

3) The 'Class' was selected from Year-10 science class which were taught by the selected teacher.

4) The 'Students' were subjects who learned in the selected class that was taught by the selected teacher.

2.2 Research Methodology

This study was a research and development methodology. There were four outstanding dependence variables: achievement of students; learning style of students; creativity in scientific communication of students and learning environment. The following paragraphs describe the research methodology of these four dependence variables.

2.2.1 Achievement

Research methodology was One-Group Pretest Post-test Design (Saiyot and Saiyot, 1995: 249) as in Table 15.

TABLE 15 RESEARCH METHODOLOGY FOR ACHIEVEMENT OF STUDENTS

Group	Achievement Pretest	Experiment	Achievement Post-test
E	T_i	X	T_i

Where

E Means Experimental Group

X Means the integrated approach to ICT-mediated learning in Science

T_i Means Achievement mean score of students

When $i = 1$ Pretest

$= 2$ Post-test

2.2.2 Learning style

Research methodology was the One-Group Pretest Post-test Design (Saiyot and Saiyot, 1995: 249) as described in Table 16.

TABLE 16 RESEARCH METHODOLOGY FOR LEARNING STYLE OF STUDENTS

Group	Learning Style Pretest	Experiment	Learning Style Post-test
E	T_i	X	T_i

Where

E Means Experimental Group

X Means the integrated approach to ICT-mediated learning in Science

T_i Means Learning style of students

When $i = 1$ Pretest

$= 2$ Post-test

2.2.3 Creativity in scientific communication

Research methodology was the One-Group Post-test Only Design as described in Table 17.

TABLE 17 RESEARCH METHODOLOGY FOR CREATIVITY IN SCIENTIFIC COMMUNICATION OF STUDENTS

Experiment	Poster	Mean Score
X		T_i

Where

X Means the integrated approach to ICT-mediated learning in Science

T_i Means Creativity in scientific communication mean scores of students

When $i = 1, 2, \dots, n$ Poster no. 1, 2, ...n

2.2.4 Learning Environment.

Research methodology was ethnographic methodology as described in Table 18.

TABLE 18 RESEARCH METHODOLOGY FOR LEARNING ENVIRONMENT

Experiment	CBI Frequency
X	T_i

Where

X Means the integrated approach to ICT-mediated learning in Science

T_i Means Mean Frequency for CBI coding profile

When $i = 1, 2, \dots, n$ Lessons

SECTION 3: Data Analysis

The statistics used for this study were defined in three categories: basic statistics, statistics for examining the quality of research instruments and statistics for testing hypotheses. The SPSS for windows version 10.0 was the statistical package of this study.

3.1 Statistics for Examine the Quality of the Research Instruments

1) E_1/E_2 : This method was an educational recommendation method that was used to evaluate the effectiveness of the integrated approach to ICT-mediated learning in Science.

$$E_1/E_2 \text{ is } 80/80$$

$$E_1 = (X/A) \times 100$$

$$E_2 = (Y/B) \times 100$$

E_1 means percentage of the total effectiveness of each learning unit.

X means test score of lesson units

A means total mark of lesson units

E_2 means percentage of the total effectiveness of learning package

Y means post-test score

B means total mark of post-test

2) Content Validity was the statistics that was used for evaluating and selecting appropriate research instruments. The instruments, which were evaluated by this method, were achievement test, rubric of creativity in scientific communication, questions and answers of the learning style questionnaire, and the computer based interaction (CBI) code for the learning environment. The statistics was IOC (Index of Item-Objective Consistency). The value of IOC was between [-1, +1]. These research instruments were calculated from the mean score of experienced persons. The items that showed mean score of IOC lower than 0.5 were redesigned

$$IOC = (\sum R/N)$$

IOC means Index of Item-Objective Consistency

$\sum R$ means Summation of experienced persons' mark

N means A number of experienced persons

3) Reliability was the statistics used to find the consistency of each item of research instrument. Three statistics were used in this process:

3.1) Reliability: Index of Kuder-Richardson 20 was a statistics used for evaluating the achievement tests and the learning style questionnaire.

3.2) Difficulty: This statistics was used for classifying questions by the difficulty of each question in the achievement tests. The difficulty index of selected questions was between [.20, .80] (Saiyot & Saiyot. 1996: 182-185).

3.3) Discrimination: This statistics was used for classifying students into two groups: high-performance and low-performance. This study uses a discrimination index of point biserial correlation statistics, which was used for classifying students into two groups. This statistics was used for the achievement tests. The discrimination index of selected questions was greater than or equal to 0.20 (Saiyot & Saiyot. 1996: 185-196).

3.2 Statistics for testing the hypothesis

Four dependence variables of this study were tested by the following research methodology.

1) Paired T-test

This statistics was used for evaluating the achievement of students with one group Pretest Post-test design (Saiyot & Saiyot. 1995). This study used t-value at $\alpha = 0.05$ ($t_{.05} = 1.684$) (Wongratana. 2001: 360).

2) Chi-square test (χ^2)

This study used 2 Chi-square statistics: Chi-square goodness of fit test and Friedman test. These statistics were used for evaluating the effectiveness of the integrated approach to ICT-mediated learning in Science to the learning style of students and creativity in scientific communication of students.

2.1) Chi-square goodness of fit test

This study used χ^2 at $\alpha = 0.05$ ($\chi^2_{.05} = 5.99$) (Wongratana. 2001: 359).

2.2) Friedman Chi-square test (χ^2)

This study used χ^2 at $\alpha = 0.05$ ($\chi^2_{.05} = 5.99$) (Wongratana. 2001: 359).

2.3) The pair wise comparison test for the Friedman test

3) Regression

This statistics was used for evaluating the effects of the integrated approach to ICT-mediated learning in Science to the learning environment. This study focused on how classroom interactions impacted on the classroom learning environment or atmosphere.

4) One-way ANOVA

This statistics was used for evaluating the effects of the integrated approach to ICT-mediated learning in Science to the learning style, creativity in scientific communication and learning environment.

3.3 Descriptive Statistics

This statistics was used for describing the impact of the integrated approach to ICT-mediated learning in Science with regard to the classroom-learning environment and others influence: Mean, Standard Deviation, Percentage, etc.

CHAPTER 4

FINDINGS

The main idea behind this study was to investigate how the achievement of students could be improved by the use of ICT, a wide range of information and communication technologies with the active learning methodologies being integrated into the curriculum and classroom. The purposes of this study were as follows:

- 1) To develop an integrated approach to ICT-mediated learning in Science for the science curriculum entitled Force and Motion Module, which was designed based on active learning pedagogy for students in Year-10 (aged 14-15) at Key Stage 4 (Mathayom Suksa 4).
- 2) To investigate how the achievement of students could be improved.
- 3) To explore how ICT could change the learning style of students.
- 4) To investigate how the creativity in scientific communication of students could be improved.
- 5) To examine how ICT could change the classroom learning environment.

Four variable measurements were investigated. They were achievement, learning style, creativity in scientific communication and learning environment. The hypotheses of this study were:

- 1) The performance of the integrated approach to ICT-mediated learning in Science is 80/80.
- 2) The achievement of students on the post-test would be higher than that of the pretest.
- 3) The learning style of students is changed.
- 4) The creativity in scientific communication of students would be improved by the uses of ICT.
- 5) The learning environment becomes an active learning environment enhanced by classroom interactions.

A variety of research instruments were developed to determine the effects on students and the classroom learning environment. They were the integrated approach to ICT-mediated learning in Science; tests; learning style questionnaire; creativity in scientific communication rubric scheme; video-recording and classroom observational learning environment questionnaire.

This chapter reports research findings in three sections. The first section describes the general characteristics of the sample. The second section describes the reliability of this study: validity and reliability analyses of the learning package. The last section describes data analysis of four variable measurements.

SECTION 1: The General Characteristics of The Sample.

This study was trialed in Year-10 of secondary school science, at Triam Udom Suksa Pattanakarn School in Bangkok Thailand, in the first semester of the academic year 2004. There were 8 science classrooms of Year-10 in this school. A teacher who taught Year-10 classes in which the students' grades were at different levels was selected for this study. The selected teacher was experienced in teaching physics and ICT skills. During the time of the study, she was in charge of 2 science classes. The subjects for this study were 82 students.

Normally, in this school, students learned Physics for 4 hours a week, 2 hours in a traditional classroom and 2 hours in a laboratory. This study focused on the integration of ICT into science lessons, which were conducted using **List** learning model. Thus, through the limitations of the physical classroom learning environment, this study used three different types of classroom. They were a traditional classroom, a computer-mediated laboratory and a networking computer room. Five personal computers were installed in the computer-mediated laboratory and twenty computers were installed in the networking computer room.

Students were grouped and they stayed in these groups for the whole period of this study. Each group consisted of 4 or 5 members. For this study, there were twenty groups. When students learned ICT practical science activities, each group of students shared one computer or one set of ICT laboratory equipment with another group. The general data of these subjects are shown in Table 19 on Page 126.

TABLE 19 GENERAL DATA OF STUDENTS

Group	Classroom No. 1			Classroom No. 2		
	Male	Female	Total	Male	Female	Total
Group 1	4	-	4	-	4	4
Group 2	4	-	4	-	4	4
Group 3	2	2	4	-	4	4
Group 4	4	-	4	4	-	4
Group 5	1	4	5	-	4	4
Group 6	-	4	4	4	-	4
Group 7	-	4	4	4	-	4
Group 8	-	4	4	-	4	4
Group 9	-	4	4	4	-	4
Group 10	2	3	5	2	2	4
Total	17	25	42	18	22	40

For the requirements of ICT skills such as using Internet and generic software which was indicated in the Educational Acts of B.E.2542, students who studied at Year-10 had already met these requirements. Only the teacher was trained to understand the **LisT** learning model and to use the computer simulation program and ICT laboratory instruments which were used for the integrated approach to ICT-mediated learning in Science.

SECTION 2: Reliability of the Study

The pilot study was examined in 3 phases:

1.) The first phase was trialled with one student who studied in Year-10 of Triam Udom Suksa Pattanakarn School in Bangkok and who was not a subject of the experimentation phase of this study. The aim was to explore the possibility of using this approach in this study. Problems and suggestions were found. They were language misunderstandings, timing problems and a request for the ICT laboratory manual. The researcher accepted these

suggestions to edit this learning package and related manuals. Then, the second version of this learning package was written and determined by advisors before use in the second phase.

2.) The second phase was trialled with 8 students who were studying on the science program in Year-10 at Benjamarachalai School in Bangkok but who were not subjects of the experimentation phase of this study. Problems and suggestions were found. They were language misunderstandings, timing problems, problems with a number of activities and with the manual. The researcher used these suggestions to edit this learning package and related manuals. Then, the third version of this learning package was written and determined by advisors before use in the third phase.

3.) The third phase was trialled with one class. The students were from Year-10 at Benjamarachalai School in Bangkok. They were not the same group as that of the second phase and were not subjects of the experimentation of this study. The aim was to examine the first hypothesis of this study; the performance of the integrated approach to ICT-mediated learning in Science was 80/80. After students learned each unit, they were scored for E_1 using the examination of that unit. Till the last unit ended, they were scored with Tests for E_2 . The performance of the approach in the pilot study was calculated. The results were greater than 80/80 (Appendix 3(d)).

Therefore, the performance of this learning package was recommended by educational methodology and it was used for the experimentation phase of this study. In addition, the researcher modified the third version of this learning package using some suggestions and problems that were found in this phase. Then, the last version of this learning package was written and approved by advisors before use in this study.

SECTION 3: Data Analysis

The research methodology of the study was one group pretest post-test design. The paired T-test, Chi-square goodness of fit test, Friedman test, one-way ANOVA, and Regression analysis were used to analyze the data collected at the beginning, during, and end of the trial (May to August 2004).

3.1 Achievement

The second hypothesis, tested by paired t-test, was that the achievement of students on the post-test would be higher than that of the pretest. This hypothesis was examined by summative assessment. The results are shown in Table 20.

TABLE 20 COMPARISON OF THE ACHIEVEMENTS OF THE STUDENTS ON THE POST-TEST AND THE PRETEST

Achievement of students	N	Mean	S.D.	t	df	p-value
Post-test	82	34.79	7.83	19.927	81	0.000**
Pretest	82	15.02	6.43			

** $p < 0.01$

Since the p value was less than the 0.01 level of significance, thus, the mean score of the post-test was statistically higher than that of the pretest at the 0.01 level of significance; therefore, the achievements of the students was improved after using the integrated approach to ICT-mediated learning in Science.

The scores from various tasks during lessons are summarized in Table 21.

TABLE 21 THE MEAN SCORE FOR FORMATIVE ASSESSMENT

Task	Mark	Mean	SD	Percentage
Task 1. Practical Work by Using Data Logging				
1.1 Acceleration	15	11.061	2.221	73.74
1.2 Free fall	15	12.110	2.055	80.73
1.3 Newton's law of motion	15	12.274	1.599	81.83
Total of Task 1	45	35.445	3.891	78.77

TABLE 21 (continued)

Task	Mark	Mean	SD	Percentage
Task 2. External Learning Resource on the Internet				
2.1 Weight	15	9.927	3.074	66.18
2.2 Newton's law of motion	12	8.085	1.476	67.38
Total of Task 2	27	18.012	3.687	66.71
Task 3. Self Tests	85	59.701	6.81	70.24
Total	157	113.159	9.92	72.08

In Table 21, the total mean score of task 1 was 35.445, 78.77%, task 2 was 18.012, 66.71% and task 3 was 59.701, 70.24%. The total mean score was 113.159, 72.08%.

3.2 Learning Style

The third hypothesis, tested by Chi-square goodness of fit, was that the learning style of the students was changed. The four learning styles of students are shown in Table 22.

TABLE 22 LEARNING STYLE OF STUDENTS ON THE PRETEST AND POST-TEST

Learning style of students	Pretest n (%)	Post-test n (%)
1. Divergent Learning Style	21 (25.6)	16 (19.5)
2. Assimilative Learning Style	5 (06.1)	24 (29.3)
3. Convergent Learning Style	9 (11.0)	17 (20.7)
4. Accommodative Learning Style	47 (57.3)	25 (30.5)
Total	82 (100)	82 (100)

In Table 22, the number of students of divergent learning style was 21 for pretest and 16 for post-test. The number of students of assimilative learning style was 5 for pretest, and 24

for post-test. The number of students of convergent learning style was 9 for pretest and 17 for post-test. The number of students of accommodative learning style was 47 for pretest and 25 for post-test.

The changing of these four learning styles from pretest to post-test is summarized in Table 23. The number of 1, 2, 3 and 4 in pretest and post-test columns were: 1 denoted divergent learning style; 2 denoted assimilative learning styles; 3 denoted convergent learning style and 4 denoted accommodative learning style. The 'Non-Changed' column showed a number of students whose learning style on the pretest was the same as the learning style on the post-test. Also, the 'Change' column showed a number of students whose learning style on the pretest was not the same as the learning style on the post-test.

TABLE 23 CHANGING OF LEARNING STYLE OF STUDENTS ON THE PRETEST AND THE POST-TEST

Pretest learning style	Post-test learning style				Total	Summary		
	1	2	3	4		Non-changed	Changed	Total
1	4	5	7	5	21	4	17	21
2	1	1	2	1	5	1	4	5
3	3	3	2	1	9	2	7	9
4	8	15	6	18	47	18	29	47
Total	16	24	17	25	82	25	57	82

In Table 23, the total number of changed learning style students was 57 and the number of non-changed learning style students was 25. Therefore, the number of changed learning style students was higher than the number of non-changed learning style. These two groups, changed and non-changed, were examined using the Chi-square goodness of fit test (χ^2). The results are shown in Table 24 on Page 131.

TABLE 24 COMPARISON OF THE NUMBER OF CHANGED AND NON-CHANGED
LEARNING STYLE OF STUDENTS

Learning Style change	N	χ^2	df	p-value
1. Non-Changed	25	12.488	1	0.000**
2. Changed	57			

** $p < 0.01$

Since the p value was less than the 0.01 level of significance, the number of students with a changed learning style was statistically higher than that of the non-changed learning styles of students at the 0.01 level of significance. In short, the learning style of most students changed. Therefore, the learning style of students was changed after using the integrated approach to ICT-mediated learning in Science.

The in-depth examination was performed to examine the changing pattern of learning style by Chi-square goodness of fit test. The results are shown in Table 25.

TABLE 25 COMPARISON OF THE CHANGED AND THE NON-CHANGED LEARNING
STYLE OF EACH LEARNING STYLE TYPE

Learning Style (Pretest)	Migration (Post-test)		Total	χ^2	df	p-value
	Non-Changed	Changed				
1. Divergent	4	17	21	8.048	1	0.005**
2. Assimilative	1	4	5	1.800	1	0.180
3. Convergent	2	7	9	2.778	1	0.096
4. Accommodative	18	29	47	2.574	1	0.109

** $p < 0.01$

Since the p value of the divergent learning style was less than the 0.01 level of significance, the number of changing learning style of students was statistically higher than

that of the non-changing learning style of students at the 0.01 level of significance. This meant that the only students found statistically to have developed a new learning style were students who in the pretest had a divergent learning style after using the integrated approach to ICT-mediated learning in Science.

In Table 25 on Page 131, since the p value of the convergent learning style, assimilative learning style and the accommodative learning style of students were greater than the 0.05 level of significance for these three types of learning style, the number of students whose learning style changed was not statistically higher than that of the non-changing learning style students at the 0.05 level of significance. It meant that, most students of assimilative learning style, convergent learning and accommodative learning style did not change their learning style after using the integrated approach to ICT-mediated learning in Science.

The in-depth examination was performed secondly to examine the changing for each pair of learning style by Chi-square goodness of fit test. The results were shown in Table 26.

TABLE 26 COMPARISON OF THE CHANGED AND THE NON-CHANGED LEARNING STYLE OF EACH PAIR OF LEARNING STYLE

Migration of Learning Style (Pretest to Post-test)		N	Total	χ^2	df	p-value
From Divergent	to Assimilative	5	12	0.333	1	0.564
	to Convergent	7				
From Divergent	to Assimilative	5	10	0.000	1	1.000
	To Accommodative	5				
From Divergent	to Convergent	7	12	0.333	1	0.564
	to Accommodative	5				
From Assimilative	to Divergent	1	3	0.333	1	0.564
	to Convergent	2				
From Assimilative	to Divergent	1	2	0.000	1	1.000
	to Accommodative	1				
From Assimilative	to Convergent	2	3	0.333	1	0.564
	to Accommodative	1				

TABLE 26 (continued)

Migration of Learning Style (Pretest to Post-test)		N	Total	χ^2	df	p-value
From Convergent	to Divergent	3	6	0	1	1.000
	to Assimilative	3				
From Convergent	to Divergent	3	4	1	1	0.317
	to Accommodative	1				
From Convergent	to Assimilative	3	4	1	1	0.317
	to Accommodative	1				
From Accommodative	to Divergent	8	23	2.130	1	0.144
	to Assimilative	15				
From Accommodative	to Divergent	8	14	0.286	1	0.594
	to Convergent	6				
From Accommodative	to Assimilative	15	21	3.857	1	0.050
	to Convergent	6				

* $p < 0.05$

In Table 26, since the p value of the accommodative learning style was equal to the 0.05 level of significance, the number of changing learning style of accommodative learning style students to the assimilative learning style was statistically higher than that of the convergent learning style students at the 0.05 level of significance. It meant that more accommodative learning style students on the pretest changed their learning style to the assimilative learning style than to the convergent learning style. For the other pairs of changing learning styles, the p value of those pairs was greater than the 0.05 level of significance. Thus, the number of the pretest learning style students of these pairs was not statistically different from that of the post-test learning style students at the 0.05 level of significance. This means that the changing of learning style of these pairs did not migrate to a specific learning style.

This study promotes group work. The considerable amount of collected data can be used to discover the patterns of learning styles combination. The results show 4 patterns of learning style combination in Table 27 on Page 134. Pattern 1: students from only one type of

learning styles are in group, Pattern 2: students from two different types of learning styles are in group, Pattern 3: students from three different types of learning styles are in group, and Pattern 4: students from four different types of learning styles are in group.

TABLE 27 THE NUMBER OF STUDENTS IN EACH OF FOUR DIFFERENT TYPES OF LEARNING STYLE COMBINATIONS

Pattern of learning styles combination	Number of students	%
Pattern 1: One type of learning style in group	4	4.90
Pattern 2: Two types of learning style in group	36	43.90
Pattern 3: Three types of learning style in group	29	35.40
Pattern 4: Four types of learning style in group	13	15.90

ANOVA was carried out in order to examine any possible variations in achievement of students among the four patterns in which students were clustered using one-way-ANOVA. The results are shown in Table 28.

TABLE 28 ANALYSIS OF VARIANCE RESULTS FOR ACHIEVEMENT SCORE AMONG PATTERNS

	Sum of Squares	df	Mean Squares	F	p-value
Between Patterns	426.700	3	142.233		
Within Pattern	4542.776	78	58.241	2.442	0.070
Total	4969.476	81			

* $p < 0.05$

Since the p value of the variations in achievement of students among the patterns was greater than the 0.05 level of significance, the difference of student achievement was not statistically significant among the patterns at the 0.05 level of significance. Therefore, the different types of learning style in group did not have an effect on student achievement.

3.3 Creativity in Scientific Communication

The fourth hypothesis was that the creativity in scientific communication of students was improved by the use of ICT. The research methodology of the hypothesis was post-test only design. The Friedman Test was used to test the hypothesis. Three posters were scored using rubric scheme. The results are shown in Table 29.

TABLE 29 COMPARISON OF THE CREATIVITY IN SCIENTIFIC COMMUNICATION OF STUDENTS AMONG THE THREE POSTERS

Poster	N	Mean	S.D.	Test Statistics	df	p-value
Poster 1	82	15.585	3.711	$\chi^2 = 107.473$	2	0.000**
Poster 2	82	19.915	5.029			
Poster 3	82	25.024	4.449			

** p < 0.01

In Table 29, the p value was close to zero, which was less than the 0.01 level of significance. Therefore, the difference of creativity in scientific communication of the students was statistically significant among the three posters at the 0.01 level of significance. Therefore, the creativity in scientific communication of students changed because of ICT.

In order to answer the hypothesis, the difference of the mean score of three posters was performed using pair wise comparison. The results are shown in Table 30.

TABLE 30 PAIR WISE COMPARISON OF THE CREATIVITY IN SCIENTIFIC COMMUNICATION OF STUDENTS AMONG THE THREE POSTERS

Poster	Mean score	Poster		
		Poster 1	Poster 2	Poster 3
		15.59	19.91	25.02
Poster 1	15.59	-	19.91-15.59 = 4.32**	25.02-15.59 = 9.43**
Poster 2	19.91	-	-	25.02-19.91 = 5.11**
Poster 3	25.02	-	-	-

**p < 0.01

Referring to Table 30 on Page 135, there was a statistically significant difference in the creativity in scientific communication between poster1 and poster2, between poster1 and poster3, and between poster2 and poster3 at the 0.01 level of significance. In Table 30, the mean score of poster 3 was statistically the highest and the mean score of poster2 was statistically higher than that of poster 1 at the 0.01 level of significance. Therefore, the creativity in scientific communication of students was improved because of ICT.

This study made an in-depth analysis between the creativity in scientific communication of students and learning style combination. The patterns in group were explained above. The results are shown in Table 31.

TABLE 31 DESCRIPTIVE STATISTICS OF THE MEAN SCORES OF POSTERS BY
LEARNING STYLE COMBINATIONS

Pattern of learning styles combination	N	Mean	S.D.
Pattern 1: One type of learning style in group	4	58.000	0.000
Pattern 2: Two types of learning style in group	36	59.000	6.879
Pattern 3: Three types of learning style in group	29	65.414	9.898
Pattern 4: Four types of learning style in group	13	54.615	12.487

In Table 31, the mean score of the three posters of Group 1 was 58.000. The mean score of the three posters of Group 2 was 59.000. The mean score of the three posters of Group 3 was 65.414. The mean score of the three posters of Group 4 was 54.615.

ANOVA was carried out in order to examine any possible variations in creativity in scientific communication of students among the groups in which students were clustered using one-way-ANOVA. The results are shown in Table 32 on Page 137.

TABLE 32 ANALYSIS OF VARIANCE RESULTS FOR CREATIVITY IN SCIENTIFIC COMMUNICATION SCORE AMONG GROUPS

	Sum of Squares	df	Mean Square	F	p-value
Between Groups	1256.340	3	418.780	5.210	0.002**
Within Group	6270.111	78	80.386		
Total	7526.451	81			

**p<0.05

Since the p value of the variations in creativity in scientific communication of students among the groups was less than the 0.01 level of significance, there were significant differences among the groups at the 0.01 level of significance. Therefore, the different types of learning style combination effected on creativity in the scientific communication of students.

3.4 Learning Environment

The hypothesis of this study stated that the learning environment was changed for the active learning environment by classroom interactions. Therefore, this study employed an ethnographic methodology. The learning environment was measured using video-recordings and the observational learning environment questionnaire. These observational instruments are randomly documented through the study. Numerous video recording tapes were interpreted into frequency and percentage of CBI as shown in Table 33 on Page 138.

TABLE 33 FREQUENCY AND PERCENTAGE OF CBI DURING THIS STUDY

Interaction	Observed interaction frequency				Summary	
	Stage1	Stage2	Stage3	Stage4	Total	%
1. Teacher praises or encourages students	22	12	6	4	44	0.77
2. Teacher accepts student's ideas	60	0	0	12	72	1.26
3. Teacher posts questions	180	28	6	128	342	6.00
4. Teacher lectures/demonstrates	517	54	0	327	898	15.75
5. Teacher gives directions	70	56	34	12	172	3.02
6. Teacher criticizes	30	16	4	28	78	1.37
7. Students responds to teacher	151	0	0	113	264	4.63
8. Students initiate ideas/actions	39	16	0	37	92	1.61
9. Students work with books/worksheet	70	0	0	22	92	1.61
10. Students discuss with peers	175	0	0	115	290	5.09
11. Students work in front of computers	20	242	358	0	620	10.87
12. Students are actively using information from computers	20	226	282	0	528	9.26
13. Students are passively using computers	0	40	20	0	60	1.05
14. Students discuss with each others	20	134	270	0	424	7.44
15. Students help each other	16	106	264	0	386	6.77
16. Students plan for investigation	0	22	0	0	22	0.39
17. Students make observations	0	76	0	0	76	1.33
18. Students use instruments	0	112	0	0	112	1.96

TABLE 33 (continued)

Interaction	Observed interaction frequency				Summary	
	Stage1	Stage2	Stage3	Stage4	Total	%
19. Students discuss observations	0	28	0	0	28	0.49
20. Students raise questions	0	16	16	0	32	0.56
21. Students reflect on observations	0	6	4	0	10	0.18
22. Students conclude the findings	0	22	6	0	28	0.49
23. Teacher facilitates students' work	16	134	156	0	306	5.37
24. Teacher monitors class	12	216	290	0	518	9.08
25. Unidentified	113	20	0	75	208	3.65
Total	1,531	1,582	1,716	873	5,702	100

The second instrument, the observational learning environment questionnaire, was used to observe the classroom-learning environment. The data was performed using descriptive statistics, which are shown in Table 34.

TABLE 34 SUMMARY OF THE OBSERVATIONAL LEARNING ENVIRONMENT
ATMOSPHERE

Atmosphere	Observed Classroom Atmosphere				Summary	
	Stage1	Stage 2	Stage3	Stage4	Total	%
1. Students are totally involved in learning process.	36	35	27	16	114	10.26
2. Students interact with teacher and other students.	32	35	28	15	110	9.90
3. Students demonstrate their understanding in learning topic through acting and discussion.	36	35	26	17	114	10.26

TABLE 34 (continued)

Atmosphere	Observed Classroom Atmosphere				Summary	
	Stage1	Stage 2	Stage3	Stage4	Total	%
4. Students enjoy the activity.	36	30	28	14	108	9.72
5. Students actively pay attention in activity	29	39	25	10	103	9.27
6. Students post or reflect questions.	30	39	24	10	103	9.27
7. Teacher enjoys this learning activity.	38	36	25	15	114	10.26
8. Teacher can easily integrate learning process with the content.	39	37	25	16	117	10.53
9. Teacher is important actor for this leaning process and students' participations.	41	32	23	19	115	10.35
10. Teacher sees tremendous improvement in students' works and comprehension.	34	38	26	15	113	10.17
Total	351	356	257	147	1,111	100.00

In Table 34, the top five highest frequencies are shown: teacher lectures or demonstrations, students reflect on observations, students conclude findings, teacher monitors class and students discuss with each other.

Both the learning environment instruments were performed by regression analysis. The frequency of classroom interactions was an independent variable and the observational learning environment atmosphere was a dependent variable. These data were entered into the regression analysis, and the output is shown in Table 35 on Page 141.

TABLE 35 TEST FOR THE SLOPE OF A LINEAR RELATIONSHIP BETWEEN CLASSROOM INTERACTIONS AND CLASSROOM LEARNING ENVIRONMENT

(a)					
	Sum of Squares	df	Mean Square	F	p-value
Regression	252.051		252.051		
Residual	1460.915		52.176	4.831	0.036*
Total	1712.967				

* p < 0.05

(b)	
Model	B
Constant	29.615
Classroom Interactions	0.003903

Referring to Table 35(a), since the p value was less than 0.05, there was a linear relationship between the classroom interactions and the classroom-learning environment, at the 0.05 level of significance. Therefore, referring to Table 35(b), the predicting equation for the classroom learning environment was given by

$$y = 29.615 + 0.003903 x$$

Where y was Classroom learning environment

x was Classroom interactions

This shows that the classroom interaction affected the classroom learning environment. Moreover, it can be summarized that when the classroom interaction increased by 1 interaction, the atmosphere of classroom-learning environment would be increased by 0.003903. On the other hand, when the classroom interaction decreased 1 interaction, the atmosphere of classroom-learning environment would be decreased by 0.003903.

The in-depth examination was secondly performed to examine the classroom-learning environment for the non ICT-Mediated classroom (Stage 1 and Stage 4 of 'LisT' learning model) using Regression analysis. The results are shown in Table 36 on Page 142.

TABLE 36 TEST FOR THE SLOPE OF A LINEAR RELATIONSHIP BETWEEN CLASSROOM INTERACTIONS AND CLASSROOM LEARNING ENVIRONMENT IN NON-ICT-MEDIATED CLASSROOM

(a)					
	Sum of Squares	df	Mean Square	F	p-value
Regression	10.040	1	10.040		
Residual	279.710	14	19.979	0.503	0.490
Total	289.750	15			

* $p < 0.05$

(b)	
Model	B
Constant	28.972
Classroom Interactions	0.001433

Referring to Table 36(a), since the p value was greater than 0.05, there was no linear relationship between the classroom interactions and the classroom-learning environment, at the 0.05 level of significance.

In conclusion, when there were no ICT activities in the stage of lessons, the classroom interactions did not affect the classroom learning environment. As the results in Table 35 shown when the ICT activities were integrated into the lesson, the classroom interactions did affect the classroom learning environment.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

This is the concluding chapter of this study. It comprises several sections organised in such a way that abridged research findings are summarized, and discussions and recommendations are presented.

5.1 Summary

The main idea behind this study was to investigate how the achievement of students could be improved by the use of ICT, a wide range of information and communication technologies with active learning methodologies being integrated into the curriculum and the classroom. The purposes of this study were as follows:

- 1) To develop an integrated approach to ICT-mediated learning in Science for the science curriculum entitled Force and Motion Module, which was designed based on active learning pedagogy for students in Year-10 (aged 14-15) at Key Stage 4 (Mathayom Suksa 4).
- 2) To investigate how the achievement of students could be improved.
- 3) To explore how ICT could change the learning style of students.
- 4) To investigate how the creativity in scientific communication of students could be improved.
- 5) To examine how ICT could change the classroom learning environment.

In order to achieve the purposes of this study, an integrated approach to ICT-mediated learning in Science in the classroom was developed. A learning process, the **List** learning model (Figure 16), was developed for this approach. '**List**' is an abbreviation for 4 stages of a learning episode: Look and Listen; Investigate; Share and Test. This learning process and appropriate ICT for science education were integrated into learning units. The ICTs were selected in such a way that science learning activities such as investigation, practical science work, inquiry, collaboration and sharing are supported. Four different effects on students were

examined, namely, achievement; learning style; creativity in scientific communication and learning environment.

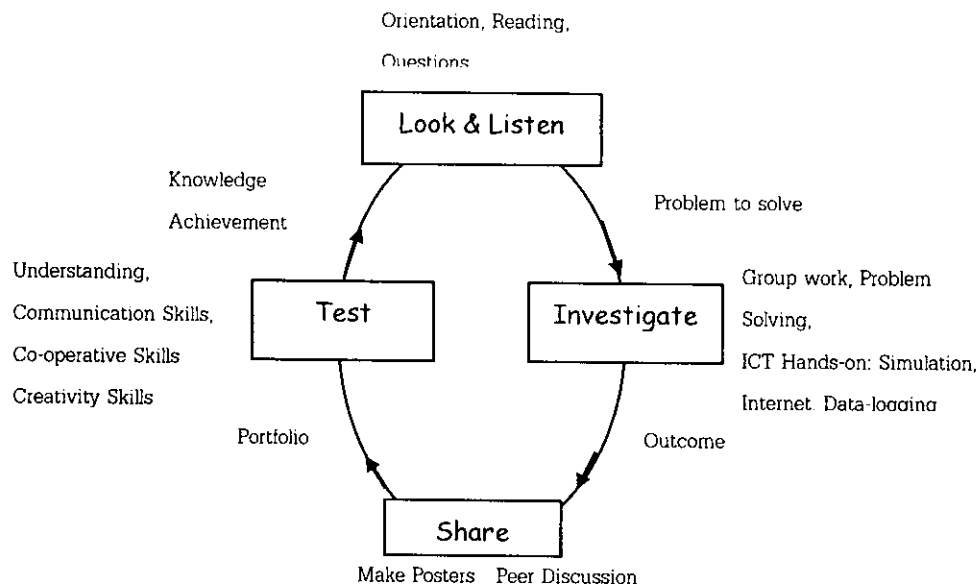


FIGURE 16: **LisT**-The ICT-mediated learning in Science model

Hypotheses:

- 1) The performance of the integrated approach to ICT-mediated learning in Science is 80/80.
- 2) The achievement of students on the post-test would be higher than that of the pre-test.
- 3) The learning style of students is changed.
- 4) The creativity in scientific communication of students would be improved by the use of ICT.
- 5) The learning environment becomes an active learning environment enhanced by classroom interactions.

The subjects were 82 students in the science program in Year-10 at Key Stage 4 who are studying in the first semester of the academic year 2004 at Triam Udom Suksa Pattanakarn School in Bangkok Thailand.

Variables of the Study

The integrated approach to ICT-mediated learning in Science is the only independent variable. The dependent variables, on the other hand, composed of the following factors.

- 1) Achievement: knowledge, comprehension and application (according to three main areas of cognitive domain of Bloom's taxonomy).
- 2) Learning style: divergent learning style, assimilative learning style, convergent learning style and accommodative learning style (according to Kolb's experiential learning styles).
- 3) Creativity in scientific communication- in terms of posters.
- 4) Learning environment- in terms of classroom interactions.

Research Methodology

The four steps of research methodology are described as follows:

In the first development phase, problems in science education and the possible ways to solve those problems are discussed. The research conceptual framework and research instruments were set up. They were the integrated approach to ICT-mediated learning in Science, tests, learning style questionnaire, rubric score scheme for evaluating creativity in scientific communication, CBI-computer-based interaction coding system, and observational learning environment questionnaire. The pilot study of the approach was trialled 3 times. Based on the result of the first trial, the second version of the learning package was written.

The second development phase began with trial of the second version of the integrated approach to ICT-mediated learning in Science, the third version of the learning package was written. The validity and reliability of research instruments were examined.

The third development phase was trialled with the third version of the integrated approach to ICT-mediated learning in Science. The aim of this trial was to examine the performance of the approach. Since the performance of this learning package was greater than 80/80, the first hypothesis was accepted.

The fourth development phase was the experimentation phase. It took place in the first semester of the academic year 2004. The subjects were 82 students who were studying in Year-10 of the science program at Triam Udom Suksa Pattanakarn School in Bangkok Thailand.

Research Findings

1. Achievement

To answer the first research question, "Can the achievement of students be improved by the use of ICT?", the summative assessment was considered to explain the achievement of students.

The summative assessment was examined by paired T-test, which indicated that the mean score of the post-test was statistically higher than that of the pretest at the 0.01 level of significance ($t=19.927$, $p=0.000$). It is therefore concluded that the achievement of students was improved because of ICT.

2. Learning style

To answer the second research question, "Is the learning style of students changed by the use of ICT?", the learning style questionnaire was developed to examine the change in learning style of students.

The learning style questionnaire was examined by Chi-square goodness of fit, which indicated that the proportion of the changed learning styles of student in the post-test was statistically higher than that of the non-changing of learning styles of students at the 0.01 level of significance ($\chi^2 = 12.488$, $p=0.000$). As a result, the learning style of students was changed because of the use of ICT.

3. Creativity in scientific communication

To answer the third research question, "Can creativity in the scientific communication of students be improved by the use of ICT?", the rubric score scheme following the SOLO Taxonomy was developed to examine the creativity in scientific communication of the students.

The rubric score was examined by the Friedman test, which indicated that there was a statistically significant difference in the creativity of scientific communication of students among the posters at the 0.01 level of significance ($\chi^2=107.473$, $p=0.000$). Therefore, the creativity in scientific communication of students changed because of ICT. By using the pair wise comparison of the Friedman test however, the positive development of creativity in the scientific communication of students was shown. Hence, the use of ICT contributed to the creativity in scientific communication of students.

4. Learning Environment

To answer the fourth research question, "Can learning environment be improved by the use of ICT?", the CBI-computer-based interaction coding system and the observational learning environment questionnaire were developed to examine the learning environment.

The CBI and the observational learning environment questionnaire were examined by the Regression Analyse, which indicated that there was a linear relationship between the classroom interactions and the classroom learning environment, at the 0.05 level of significance ($F=4831$, $p=0.036$). Again, the learning environment was enhanced by the use of ICT.

5.2 Discussions

This study represents the first step in identifying the use of ICT and how it is integrated into the curriculum and classroom context. The findings from this study agree with the five hypotheses. The ICT can be utilized in science learning in a classroom context. These findings are similar to previous research and studies. To get more detail, the in-depth analyses are summarized according to these four effects on students: achievement; learning style; creativity in scientific communication; and learning environment. The discussion below begins with the learning process and is followed by the four investigating effects.

1) Learning process

The '**LisT**' learning process was developed into the classroom. It is a consensus among the researcher and teachers involved in this study that the 4 stages of '**LisT**' can be applied into science study. Problems and suggestions during the study are described as follows.

Normally there are numerous contents in the core course of the science curriculum for Key Stage 4. The selected content in physics, Force and Motion, is a part of the core course. The effects of huge content were observed, especially from the 'look and listen' stage. It was found that out of 898 minutes, teachers could not arrange an appropriate time interval for active learning activities. Reducing the number of posters in the share stage might solve this problem so that students will spend less time on this stage and have more time for other activities.

Findings from observations suggested that course organization should be rearranged. Before introducing some topics in physics, students should possess basic mathematics

competency. It was noticed that mathematics and physics, which are interrelated, were not taught and learned in a proper order. In addition, from interviewing teachers in other science areas such as chemistry, it was discussed that they have to spend some time explaining required mathematics for their lessons. As a result, rearrangement of subject sequencing is strongly suggested.

In terms of the physical classroom environment, it was found that the classrooms are too small to accommodate the large number of students. Classroom facilities are not complete as well as being obsolete. In the classroom, there is no computer network and no ICT equipment to facilitate the learning process. Existing computer rooms, however, bear a heavy schedule so that supporting all requirements is made difficult. When this study was conducted, the ICT-mediated classroom was introduced in the stage of 'investigation' and 'share'. Classroom interactions indicated that the classroom-learning environment had changed from a passive learning one to an active learning one. The statistical result, ($F=4.831$, $p=0.036$), is supported by the previous statement.

For questioning, a main factor of active classrooms, it is not a simple teaching and learning strategy and the outcomes had strong effects on the students' achievement and attitude (Amos, 2002). In the stage of 'look and listen', it was found that most of the questions, 342 out of 374, were initiated by the teacher whereas the rest came from the students. It was believed that the success of using questioning in classroom stems from the teacher's skills and techniques (ibid.). The observed teacher questions were mostly "closed" questions rather than "open" or "reflective" types. Most were 'recall' questions, the lower order questions in Bloom's taxonomy. Therefore, training on using questioning in the classroom is an important strategy. This was supported by the study of Cotton (2001) which indicated that posing questions during instruction provides a more positive effect on students' achievement than teaching without questioning. In addition, in the stage of 'look and listen', it was noticed that most students dare not pose questions during instruction. This may result from the Thai education system in which the atmosphere of an active classroom has not been encouraged. Posing written questions seems to be favored by students. The number of questions written by students was increased and many of them were useful for instructional purposes. Some interesting questions from students include 'What would the world be like if there is no friction?', or 'Why does rain drop down to the Earth, not go up?'. These questions showed students' ability to relate the

topics to their daily life. Also, it was found that more questions from students came in during the stage of 'investigate' and 'share' when they were actively using ICT for experiments and posters. Most questions were examples of these question classification: elaboration and exploration, based on Alsop, Gould and Watts (2002). The increase in questions shows that students were engaged in learning. Therefore, questioning techniques can be used for improving science understanding and it should be promoted in the classroom, whenever possible.

2) Achievement

The findings indicated that the achievement of students was improved because of ICT. Clearly, the achievement was derived from various objectives of the '**LisT**' learning process in which students were provided with ICT opportunities. In addition, they made use of the formative assessment information during study to develop the ways they learned.

Furthermore, students normally have different levels of ability. The learning activities of this study were provided in such a way that students collaborated with peers, discussed the outputs, and helped each other. Therefore, in this social activity, it was believed that more advanced students can help less advanced members operate within their ZPD-zone of proximal development (Vygotsky. 1978: 86, Khaemane; Dechakrup & Pornkul. 2000: 12). For promoting interactions among teacher and students, especially in ICT activities, the uses of ICT were designed and it was found that this goal was achieved. Moreover, the increase in classroom interactions between teacher and students was also observed. The findings are similar to those of Kennedy (1984) which indicated that students who use ICT in Physics show their progression by their interactions on changing ideas and discussing the experiment (Solomon. 2002; citing Kennedy. 1984).

Students showed their abilities in using data logging and its equipment; students could perform the experiments on a trial and error basis. It was noticed that they spent more time on observations, discussions and writing conclusions. By doing so, the students learned more and developed their own understanding of the lesson. This was evident from the high quality paper work, which could never have been produced in the traditional laboratory. The statistics of this practical work showed 78.77%. The outcomes of using data logging in supporting science learning found in this study were similar to those of Ng and Yeung (2000), Gipps (2001) and Mee, A (2002). During the active learning phases, the Internet was also available as an external

learning resource. Students used the Internet whenever they needed. They could get access to useful external learning resources including simulation programs available on the Internet. Their conclusions reveal their abilities in using the facility mentioned above. As in the studies of Cox et al. (n.d.); Newhouse (2002); Gipps (2001); Holubec; Johnson and Johnson (1994); Andre (1986); Neo and Neo (n.d) and Underwood (1998), the result of this study clearly shows that ICT can support student achievement in science study.

3) Learning Style

It was found from this study that the learning style of students was changed with statistical significance. This agrees with previous studies by Sutcliffe (1993) and Schoroeder (Blackmore.1996; citing Schoroeder. 1996), that learning style could be changed when students were treated with some situations. However, some researchers, such as Taweelap (2003), pointed out the alternative result.

The changing in learning style of this study might result from a variety of ICT activities and group interactions. As many educators have claimed, ICT will change the students' way of learning. In this study, students were provided with opportunities to use a wide range of ICT such as computer simulation, data logging, the Internet and generic softwares. Then, changing of learning style, depending on environment, was found ($\chi^2 = 12.488$, $p=0.000$). However, it was learned, statistically ($\chi^2 = 8.048$, $p=0.005$), that the only students found to have developed a new learning style were students who in the pretest had a divergent learning style

The pattern of learning style migration was examined. It turned out that there is no statistical pattern of learning style migration. At this point, a further study of lasting of learning style shift is recommended.

The arrangement of learning activities for balancing learning style is rather problematic. But if it can be done, it will benefit all students who normally have different learning styles. In student groupings, it was found that, among many groups of 4, there were 4 group patterns of combination of learning styles. The 4 patterns were pattern 1, pattern 2, pattern 3 and pattern 4 in which the number of different learning style were 1, 2, 3 and 4 respectively. It was indicated that different learning style combinations did not, statistically ($F=2.442$, $p=0.070$), effect on student achievement. It can be concluded that a variety of learning activities of **'LisT'** supported these four learning styles.

4) Creativity in Scientific Communication

This study indicated that the use of ICT contributed to the creativity in scientific communication. Using brainstorming techniques together with higher order thinking skills, students could select the theme and use ICT in designing the posters. It was noticed that they could share their management skills by putting the right person in the right job. Skills on using computer software and accessing the Internet were not a problem. Students helped each other. The existing computer room was linked through the network so that they could easily search for appropriate information. Moreover, the use of ICT could support them in designing both computer graphics and pattern of content. They could produce posters on time with better quality. Many researchers, such as Patarakin and Visser (2003) and Neo and Neo (n.d.), also saw the power of new technology in facilitating creativity and collaborative learning.

The effect of learning styles combination on creativity in scientific communication was also examined. From the examination, the results indicated that the different types of learning style grouping pattern, statistically ($F=5.210$, $p=0.002$), had an effect on creativity in scientific communication. That is, when students are engaged in collaborative work, they could share their ideas and skills with peers so that the most suitable learning style combination led to quality posters. This agrees with the study of Loveless (2002) and Kirton (n.d.) which said that creativity arises from the interactions between the 'intelligence' of individuals and ways of focusing their creativity (Loveless. 2002; citing Csikszentmihalyi & Gardner. 1994, Barlow. 2000: abstract). A further study of the suitability of learning style combination is advised.

5) Learning Environment

The learning environment of this study focused on classroom interactions and it revealed that the learning environment was enhanced by the use of ICT. This was the result from the objectives of the four stages of **List** in which active learning activities were promoted. It was observed that numerous interactions between teacher and students were increased when students were active in various hands-on activities. Using ICT, it was noticed that students enjoyed this activity and were engaged in experiments and exploring the Internet. The discussions and questionings came while sitting in front of instruments and computers and also when the teacher facilitated work group. This result had an impact on the classroom learning environment. This was supported by in-depth analyses. The results from non-ICT-mediated classroom ($F=0.503$, $p=0.490$) did not show the active learning environment during the stage of

'look and listen' and 'test'. Koul and Fisher (2002) saw the outcomes of an active learning environment in the science classroom. They concluded that the ultimate aim of education can be achieved through positive attitudes towards learning by creating an enjoyable and productive learning environment. Newhouse (2002) also saw the impact of ICT on the learning environment. This study, therefore, recommended that ICT can be used in a new science study. However, teachers are the ones who should provide students with an ICT learning environment so that a wide range of outcomes will be achieved.

5.3 Recommendations

This section provides suggestions for future science-learning research that focuses on the integration of information and communication technology into the future science classroom. It also serves as an interesting point for improving science education especially in the classroom context.

For school administrators

1) Since the extent of ICT implementation in education has affected the structure and functioning of school, curriculum, teacher and student, the ICT master plan of a school must be addressed urgently. ICT facilities should be provided for teachers and students in such a way that they can be easily accessed to all with equal opportunities and used to support the teaching and learning processes throughout the curriculum.

2) Because a wide range of ICT were applied in the classroom especially in science lessons, schools should set up a policy for using ICT in the classroom. ICT training and seminars are other important activities that schools should consider and support.

3) The influence of mathematics on ability in science should be recognized. The school curriculum and class schedule, particularly for Mathematics and Science subjects, which are interrelated, should be thoroughly reviewed in order to ensure that all concepts and skills are taught and learned in a timely and proper order. All required concepts and skills in those subject areas should be carefully checked and placed in the sequence that would match the needs of the students. For example, this study suggests that mathematics and science class periods should be rescheduled for the whole academic year. At the beginning of the semester, there should be more class periods for mathematics than for science. By doing so, the students

will have a chance to learn all necessary Mathematics concepts and skills needed for their science learning.

4) Student creativity is also an important factor in Science learning. Emphasis should be made on integrated activities that will foster and reinforce student creativity in all subjects across the curriculum. Schools should give students the opportunity to present their work to the community, a strategy aimed at helping students become public-minded.

For teachers

1) Teachers have to develop new teaching and learning processes. If not, this study suggests the '**LisT**' learning process, as an innovative integrated approach to ICT-mediated learning in science. Teachers can apply this learning process into their classes.

2) To improve student achievement, many active teaching and active learning strategies are introduced from various studies. Learning style is an important factor of student achievement. Being aware of the relationship between learning and teaching style, teachers are able to allow each student to have the opportunities to achieve the optimum academic performance. Thus, teachers have to understand the concepts of learning style and its application to teaching approaches. This also leads to the development of innovation in learning materials.

3) The study of the impact of genders or the impact of grouping technique identity on learning styles is significant not only as an assessment of teaching approach, but also as a means of assisting all students in developing their competence in science.

4) A useful active teaching technique is 'questioning'. Teachers should practice using questioning in class. Also, teachers should promote and encourage students to use questions to create new knowledge and exchange ideas.

5) The use of ICT affects students' achievement and students' creativity. Thus teachers should learn how to use modern ICT more frequently. Therefore, teachers have to provide the opportunity of using ICT for students by integrating ICT into lessons.

6) An active learning environment also effects students' achievement. It is the teacher who can promote an active learning environment by providing situations. The situations which promote an active learning environment are, for example: using ICT in exploring, using questioning, using group work, using group discussion, and using a sharing

technique.

For further studies

Most educators agree that effective learning involves the performance of learning management, a learning process that involves active learning methodology and the use of ICT. Evidence from various research and theories indicate that those techniques can promote students' achievements, attitudes, creativity, and learning atmosphere. Similarly, positive effects were found in this study. There are several recommendations for further studies suggested by the findings of this study.

1) The '**LisT**' learning model should be employed and its effectiveness further examined in other science content areas such as Biology, Chemistry or Earth Science.

2) Because the active learning environment is found especially in ICT-mediated classroom, an interesting question is how possibly science classrooms in Thailand can be shifted from traditional classrooms to science classrooms of the future?

3) When a wide range of ICT is integrated into science classrooms, what is the student's appreciation of this new technology? And how will the appreciation of new technology affect science achievement or creativity?

4) The positive effects of the use of ICT to support science learning have been confirmed in this study. Hence, efforts must be made in the design and development of high-quality educational software especially in the form of computer simulation.

5) As 'Questioning' has been proven to be effective and considered a contributing indicator for better performance in learning science, the use of questioning techniques by science teachers should be further explored.

6) The change in learning style is found; therefore, a further study of learning style shift is recommended. A study of a suitable learning style combination is also advised.

7) It was found that the creativity in scientific communication of students could be promoted by the use of ICT. Another finding was that the combination of learning style in groups also effects the creativity in scientific communication of students. Consequently, what is the best pattern of this combination that affects both creativity in scientific communication and achievement?

8) The study should be extended into a larger sample. This would allow results to

be generalized to the population. If the focus is on how lower or higher academic institutions utilize integrated ICT-mediated learning in Science, a larger representative sample of lower key stage or higher education will be preferable.

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APPENDIX

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Appendix 1

Related Persons and Schools in this study

1. Experienced persons for research instruments

- | | |
|--|---|
| 1.1 Assistant Professor Niramon Pitaniapalin | Srinakharinwirot University |
| 1.2 Assistant Professor Buncha Silskulsuk | Srinakharinwirot University |
| 1.3 Dr.Suphot Musiri | Srinakharinwirot University |
| 1.4 Dr.Kanitha Ruchirrote | Srinakharinwirot University |
| 1.5 Mr.Vinai Bourahong | Srinakharinwirot University |
| 1.6 Assistant Professor Surapan Yimmun | King Mongkut's Institute of
Technology North Bangkok |
| 1.7 Dr.Wichan Lertlop | Suan Sunandha Rajabhat
University |
| 1.8 Miss. Tusanaporn Gunprom | Triam Udom Suksa Pattanakarn
School |
| 1.9 Mr.Pinsak Chumkasean | Benjamarachalai School |
| 1.10 Mr.Somnuk Karukaraj | Klaeng Vitaya Satavorn School |

2. Teachers for trial this study

- | | |
|------------------------------|--|
| 2.1 Mr.Pinsak Chumkasean | Benjamarachalai School
(Pilot Study Phase) |
| 2.2 Miss. Tusanaporn Gunprom | Triam Udom Suksa Pattanakarn
School (Experimentation Phase) |

3. Schools used in this study

- | |
|--|
| 3.1 Benjamarachalai School on Pilot Study Phase |
| 3.2 Triam Udom Suksa Pattanakarn School on Experimentation Phase |

Appendix 3

Study Schedule

Date	Activity
Preparation Phase	
March 04	Preparing research instruments and the package of the integrated approach to ICT-mediated learning in Science
	Evaluating some research instruments and the package by experienced educators
	School meeting for the pilot study
	First trial with one student for writing the second version of the package of the integrated approach to ICT-mediated learning in Science
April 04	School meeting with experimental school
	Teacher meeting for using research instruments and selected ICT
	Evaluating some research instruments by experienced educators
	Editing all research instruments and approved by advisors
	Second trial with 8 students for writing the third version of the package
May 04	Preparing classrooms and documents for the third trial.
	Findings the validity and reliability of the research instruments
	Editing research instruments and approved by advisors
	Third trial with one classroom for writing the final version of the package
Experimentation Phase	
May 04	Beginning research at the school and doing pretests.
June 04 –	- Experimentation by using the final version of the package of the integrated
August 04	approach to ICT-mediated learning in Science with 2 classrooms of Year-10 at Key-Stage 4.
	- Doing post-test
November 04	Summary the research findings and discussions for this study

Appendix 3
Statistical Analysis

(a) Index of Item-objective consistency of the Tests

No	Experienced teachers' evaluation score					IOC
	1	2	3	4	5	
1	1	1	1	1	1	1.0
2	1	1	1	0	1	0.8
3	1	-1	1	-1	1	0.2
4	1	-1	1	1	1	0.6
5	1	1	1	0	1	0.8
6	1	-1	1	1	1	0.6
7	1	1	1	0	1	0.8
8	1	0	1	1	1	0.8
9	1	1	-1	1	1	0.6
10	1	1	1	1	1	1.0
11	1	1	1	0	1	0.8
12	1	1	1	1	1	1.0
13	1	1	1	0	1	0.8
14	1	0	1	1	1	0.8
15	1	1	1	1	1	1.0
16	1	1	1	1	1	1.0
17	1	0	0	1	1	0.6
18	1	-1	0	1	1	0.4
19	1	0	-1	1	1	0.4
20	1	1	1	1	1	1.0
21	1	1	1	1	1	1.0
22	1	1	1	1	1	1.0
23	1	0	0	1	1	0.6

No	Experienced teachers' evaluation score					IOC
	1	2	3	4	5	
24	1	1	1	0	1	0.8
25	1	1	-1	1	1	0.6
26	1	0	1	0	1	0.6
27	1	1	1	0	1	0.8
28	1	1	1	1	1	1.0
29	1	1	1	0	1	0.8
30	1	-1	0	0	1	0.2
31	1	0	0	1	1	0.6
32	1	1	1	0	1	0.8
33	1	1	1	1	1	1.0
34	1	-1	-1	-1	1	-0.2
35	1	0	1	0	1	0.6
36	1	0	0	1	1	0.6
37	1	1	1	0	1	0.8
38	1	1	1	0	1	0.8
39	1	0	0	0	1	0.4
40	1	1	1	0	1	0.8
41	1	1	0	1	1	0.8
42	1	1	1	0	1	0.8
43	1	1	1	0	1	0.8
44	1	-1	1	0	1	0.4
45	1	1	-1	0	1	0.4

(b) Data analysis from the first try-out of reliability of the Tests

No	Learning Outcomes by Bloom's Taxonomy						Unit	Difficulty (p) / Discrimination(r)		Significant	Used in this study
	K	C	A p	A	S	E		p	r		
1		X					1	0.62	0.40	✓	✓(1)
2		X					1	0.62	0.17	-	-
3			X				1	0.75	0.45	✓	✓(2)
4	X						1	0.63	0.34	✓	-
5	X						1	0.23	0.38	✓	✓(3)
6		X					1	0.19	0.08	-	-
7			X				1	0.74	0.46	✓	✓(4)
8		X					2	0.45	-0.06	-	-
9			X				1	0.52	0.29	✓	✓(7)
10			X				1	0.43	0.45	✓	
11			X				1	0.45	0.45	✓	✓(21)
12			X				1	0.33	0.30	✓	✓(6)
13		X					1	0.26	0.29	✓	✓(5)
14		X					1	0.42	0.51	✓	✓(8)
15	X						2	0.56	0.38	✓	✓(9)
16		X					2	0.72	0.45	✓	✓(11)
17		X					2	0.69	0.45	✓	✓(10)
18			X				2	0.21	0.38	✓	✓(12)
19			X				2	0.49	0.21	✓	-
20		X					2	0.12	0.17	-	-
21		X					2	0.56	0.38	✓	✓(13)
22	X						2	0.25	0.20	✓	✓(14)
23		X					3	0.45	0.40	✓	✓(15)
24		X					3	0.37	0.27	✓	✓(16)
25		X					3	0.18	0.17	-	-
26			X				3	0.21	0.47	✓	-
27			X				3	0.37	0.40	✓	✓(17)
28			X				3	0.35	0.24	✓	✓(22)
29			X				3	0.37	0.41	✓	-

No	Learning Outcomes by Bloom's Taxonomy						Unit	Difficulty (p) / Discrimination(r)		Significant	Used in this study
	K	C	A p	A	S	E		p	r		
30			X				3	0.37	0.24	✓	-
31		X					4	0.67	0.20	✓	✓(18)
32		X					4	0.24	0.19	✓	-
33		X					4	0.54	0.47	✓	✓(19)
34			X				4	0.20	0.23	✓	✓(23)
35		X					4	0.40	0.28	✓	✓(20)
36		X					4	0.23	0.09	-	-
37		X					4	0.30	0.03	-	-
38			X				4	0.21	-0.03	-	-
39			X				4	0.25	0.17	-	-
40			X				4	0.32	0.12	-	-

Denote: K = Knowledge, C=Comprehension, Ap=Application, A=Analysis, S=Synthesis, E=Evaluation

(c) Index of Item-objective consistency of the weight scheme for scoring the creativity in scientific communication

No	Criteria for measuring creativity in scientific communication	Weight	Experienced educators' evaluation score					IOC
			1	2	3	4	5	
1	Them	1	1	0	1	1	1	0.8
2	Communication	2	-1	1	1	1	1	0.6
3	Essay	2	1	1	1	1	0	0.8
4	Multimedia and Photographic design	1	1	1	1	1	1	1.0
5	Using ICT	1	1	1	1	1	0	0.8
6	Target group	2	-1	0	1	1	1	0.4

(d) Index of Item-objective consistency of the rubric scheme for the creativity in scientific communication

No	Criteria for measuring the creativity in scientific communication	Experienced educators' evaluation score					IOC
		1	2	3	4	5	
1	Them	1	1	1	1	1	1.0
2	Communication	0	1	1	1	1	0.8
3	Essay	1	1	1	1	1	1.0
4	Multimedia and Photographic design	1	0	1	1	1	0.8
5	Using ICT	1	1	1	1	1	1.0
6	Target group	1	0	1	1	1	0.8

(e) Index of Item-objective consistency of the observational learning environment questionnaire

No	Observed Question	Experienced educators' evaluation score					IOC
		1	2	3	4	5	
1	Students are totally involved in learning process.	1	1	1	1	1	1
2	Students interact with teacher and other students.	1	1	1	1	1	1
3	Students demonstrate their understanding in learning topic through acting and discussion.	1	1	1	1	1	1
4	Students enjoy with the activity.	1	1	1	1	1	1
5	Students actively pay attention in activity	1	1	1	1	1	1
6	Students post or reflect questions.	1	1	1	1	1	1
7	Teacher enjoys with this learning activity.	1	1	1	1	1	1
8	Teacher can well integrate learning process to the content.	1	0	1	1	-1	0.6
9	Students are totally involved in learning	1	-1	1	1	1	0.8

	process.						
10	Students interact with teacher and other students.	1	1	0	1	1	0.8

(f) Performance of the integrated approach to ICT-mediated learning in Science of the pilot study

Lesson	Tests of each learning unit		Performance
	Average score	Scale	
1	23.93	30	$E_1 = 79.78$
2	20.47	25	$E_1 = 81.87$
3	12.30	15	$E_1 = 82.00$
4	12.10	15	$E_1 = 80.67$
Mean of E_1			81.08
Tests	16.43	20	$E_2 = 82.17$

(g) Results from the Statistical Analysis Package: SPSS

1). Summative Achievement

Descriptives

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation	Variance
POSTTEST	82	17	51	34.79	7.83	61.352
PRETEST	82	4	35	15.02	6.43	41.283
Valid N (listwise)	82					

T-test**Paired Samples Statistics**

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	POSTTEST	34.79	82	7.83	.86
	PRETEST	15.02	82	6.43	.71

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	POSTTEST & PRETEST	82	.218	.049

Paired Samples Test

		Paired Differences				t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference			
					Lower Upper			
Pair 1	POSTTEST - PRETEST	19.77	8.98	.99	17.79 21.74	19.927	81	.000

2) Formative Achievement

Descriptives**Descriptive Statistics**

	N	Minimum	Maximum	Sum	Mean	Std. Deviation
Formative Practical work	82	29.00	42.00	2906.50	35.4451	3.8905
Formative Internet	82	10.00	23.00	1477.00	18.0122	3.6868
Formative Self Test	82	40.00	74.50	4895.50	59.7012	6.8100
acceleration	82	6.5	14.5	907.0	11.061	2.221
free fall	82	8.0	15.0	993.0	12.110	2.055
selftest1	82	12.0	28.0	1792.5	21.860	3.585
newton's law	82	9.0	14.0	1006.5	12.274	1.599
selftest2	82	9	20	1310	15.98	2.45
internet weight	82	4.0	15.0	814.0	9.927	3.074
selftest3	82	4	15	889	10.84	2.88
internet newton's law	82	3.0	11.0	663.0	8.085	1.476
selftest4	82	5	15	904	11.02	2.54
Valid N (listwise)	82					

3) Learning Style

Frequency Table

แบบการเรียนรู้ ก่อน

	Frequency	Percent	Valid Percent	Cumulative Percent
Valid 1	21	25.6	25.6	25.6
2	5	6.1	6.1	31.7
3	9	11.0	11.0	42.7
4	47	57.3	57.3	100.0
Total	82	100.0	100.0	

แบบการเรียนรู้ หลัง

	Frequency	Percent	Valid Percent	Cumulative Percent
Valid 1	16	19.5	19.5	19.5
2	24	29.3	29.3	48.8
3	17	20.7	20.7	69.5
4	25	30.5	30.5	100.0
Total	82	100.0	100.0	

Crosstabs

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
แบบการเรียนรู้ ก่อน *	82	100.0%	0	.0%	82	100.0%
แบบการเรียนรู้ หลัง						

แบบการเรียนรู้ ก่อน * แบบการเรียนรู้ หลัง Crosstabulation

Count

		แบบการเรียนรู้ หลัง				Total
		1	2	3	4	
แบบการเรียนรู้ ก่อน	1	4	5	7	5	21
	2	1	1	2	1	5
	3	3	3	2	1	9
	4	8	15	6	18	47
Total		16	24	17	25	82

Crosstabs

แบบการเรียนรู้ ก่อน * การเปลี่ยนแบบการเรียนรู้ Crosstabulation

Count

		การเปลี่ยนแบบการเรียนรู้		Total
		Change	Non-Change	
แบบการเรียนรู้ ก่อน	1	17	4	21
	2	4	1	5
	3	7	2	9
	4	29	18	47
Total		57	25	82

NPar Tests Chi-Square Test Frequencies

การเปลี่ยนแบบการเรียน

	Observed N	Expected N	Residual
Change	57	41.0	16.0
Non-Change	25	41.0	-16.0
Total	82		

Test Statistics

	การเปลี่ยนแบบการเรียน
Chi-Square ^a	12.488
df	1
Asymp. Sig.	.000

- a. 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 41.0.

การเปลี่ยนแบบการเรียน

	Observed N	Expected N	Residual
Change	17	10.5	6.5
Non-Change	4	10.5	-6.5
Total	21		

Test Statistics

	การเปลี่ยนแบบการเรียน
Chi-Square ^a	8.048
df	1
Asymp. Sig.	.005

- a. 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 10.5.

การเปลี่ยนแบบการเรียน

	Observed N	Expected N	Residual
Change	4	2.5	1.5
Non-Change	1	2.5	-1.5
Total	5		

Test Statistics

	การเปลี่ยนแบบการเรียน
Chi-Square ^a	1.800
df	1
Asymp. Sig.	.180

- a. 2 cells (100.0%) have expected frequencies less than 5. The minimum expected cell frequency is 2.5.

การเปลี่ยนแบบการเรียน

	Observed N	Expected N	Residual
Change	7	4.5	2.5
Non-Change	2	4.5	-2.5
Total	9		

Test Statistics

	การเปลี่ยนแบบการเรียน
Chi-Square ^a	2.778
df	1
Asymp. Sig.	.096

- a. 2 cells (100.0%) have expected frequencies less than 5. The minimum expected cell frequency is 4.5.

การเปลี่ยนแบบการเรียน

	Observed N	Expected N	Residual
Change	29	23.5	5.5
Non-Change	18	23.5	-5.5
Total	47		

Test Statistics

	การเปลี่ยนแบบการเรียน
Chi-Square ^a	2.574
df	1
Asymp. Sig.	.109

- a. 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 23.5.

การเปลี่ยนแบบการเรียน

	Observed N	Expected N	Residual
Change	12	12.0	.0
Total	12 ^a		

- a. This variable is constant. Chi-Square Test cannot be performed.

แบบการเรียน หลัง

	Observed N	Expected N	Residual
2	5	6.0	-1.0
3	7	6.0	1.0
Total	12		

แบบการเรียน ก่อน

	Observed N	Expected N	Residual
1	12	12.0	.0
Total	12 ^a		

- a. This variable is constant. Chi-Square Test cannot be performed.

แบบการเรียนรู้ หลัง

	Observed N	Expected N	Residual
2	5	5.0	.0
4	5	5.0	.0
Total	10		

Test Statistics

	แบบการเรียนรู้ หลัง
Chi-Square ^a	.000
df	1
Asymp. Sig.	1.000

a. 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 5.0.

แบบการเรียนรู้ ก่อน

	Observed N	Expected N	Residual
1	10	10.0	.0
Total	10 ^a		

a. This variable is constant. Chi-Square Test cannot be performed.

แบบการเรียนรู้ หลัง

	Observed N	Expected N	Residual
3	7	6.0	1.0
4	5	6.0	-1.0
Total	12		

Test Statistics

	แบบการเรียนรู้ หลัง
Chi-Square ^a	.333
df	1
Asymp. Sig.	.564

a. 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 6.0.

แบบการเรียนรู้ ก่อน

	Observed N	Expected N	Residual
1	12	12.0	.0
Total	12 ^a		

a. This variable is constant. Chi-Square Test cannot be performed.

แบบการเรียนรู้ หลัง

	Observed N	Expected N	Residual
1	1	1.5	-.5
3	2	1.5	.5
Total	3		

Test Statistics

	แบบการเรียนรู้ หลัง
Chi-Square ^a	.333
df	1
Asymp. Sig.	.564

a. 2 cells (100.0%) have expected frequencies less than 5. The minimum expected cell frequency is 1.5.

แบบการเรียนรู้ ก่อน

	Observed N	Expected N	Residual
2	3	3.0	.0
Total	3 ^a		

a. This variable is constant. Chi-Square Test cannot be performed.

แบบการเรียน หลัง

	Observed N	Expected N	Residual
1	1	1.0	.0
4	1	1.0	.0
Total	2		

Test Statistics

	แบบการเรียน หลัง
Chi-Square ^a	.000
df	1
Asymp. Sig.	1.000

a. 2 cells (100.0%) have expected frequencies less than
5. The minimum expected cell frequency is 1.0.

แบบการเรียน ก่อน

	Observed N	Expected N	Residual
2	2	2.0	.0
Total	2 ^a		

a. This variable is constant. Chi-Square Test
cannot be performed.

แบบการเรียน ก่อน

	Observed N	Expected N	Residual
2	3	3.0	.0
Total	3 ^a		

a. This variable is constant. Chi-Square Test
cannot be performed.

แบบการเรียน หลัง

	Observed N	Expected N	Residual
3	2	1.5	.5
4	1	1.5	-.5
Total	3		

Test Statistics

	แบบการเรียน หลัง
Chi-Square ^a	.333
df	1
Asymp. Sig.	.564

a. 2 cells (100.0%) have expected frequencies less than
5. The minimum expected cell frequency is 1.5.

แบบการเรียน ก่อน

	Observed N	Expected N	Residual
3	6	6.0	.0
Total	6 ^a		

a. This variable is constant. Chi-Square Test
cannot be performed.

แบบการเรียน หลัง

	Observed N	Expected N	Residual
1	3	3.0	.0
2	3	3.0	.0
Total	6		

Test Statistics

	แบบการเรียน หลัง
Chi-Square ^a	.000
df	1
Asymp. Sig.	1.000

a. 2 cells (100.0%) have expected frequencies less than
5. The minimum expected cell frequency is 3.0.

แบบการเรียนรู้ หลัง

	Observed N	Expected N	Residual
1	3	2.0	1.0
4	1	2.0	-1.0
Total	4		

Test Statistics

	แบบการเรียนรู้ หลัง
Chi-Square ^a	1.000
df	1
Asymp. Sig.	.317

- a. 2 cells (100.0%) have expected frequencies less than
5. The minimum expected cell frequency is 2.0.

แบบการเรียนรู้ ก่อน

	Observed N	Expected N	Residual
3	4	4.0	.0
Total	4 ^a		

- a. This variable is constant. Chi-Square Test cannot be performed.

แบบการเรียนรู้ หลัง

	Observed N	Expected N	Residual
2	3	2.0	1.0
4	1	2.0	-1.0
Total	4		

Test Statistics

	แบบการเรียนรู้ หลัง
Chi-Square ^a	1.000
df	1
Asymp. Sig.	.317

- a. 2 cells (100.0%) have expected frequencies less than
5. The minimum expected cell frequency is 2.0.

แบบการเรียนรู้ ก่อน

	Observed N	Expected N	Residual
3	4	4.0	.0
Total	4 ^a		

- a. This variable is constant. Chi-Square Test cannot be performed.

แบบการเรียนรู้ หลัง

	Observed N	Expected N	Residual
1	8	11.5	-3.5
2	15	11.5	3.5
Total	23		

Test Statistics

	แบบการเรียนรู้ หลัง
Chi-Square ^a	2.130
df	1
Asymp. Sig.	.144

- a. 0 cells (.0%) have expected frequencies less than
5. The minimum expected cell frequency is 11.5.

แบบการเรียนรู้ ก่อน

	Observed N	Expected N	Residual
4	23	23.0	.0
Total	23 ^a		

- a. This variable is constant. Chi-Square Test cannot be performed.

แบบการเรียนรู้ หลัง

	Observed N	Expected N	Residual
1	8	7.0	1.0
3	6	7.0	-1.0
Total	14		

แบบการเรียนรู้ ก่อน

	Observed N	Expected N	Residual
4	14	14.0	.0
Total	14 ^a		

a. This variable is constant. Chi-Square Test cannot be performed.

Test Statistics

	แบบการเรียนรู้ หลัง
Chi-Square ^a	.286
df	1
Asymp. Sig.	.593

a. 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 7.0.

แบบการเรียนรู้ หลัง

	Observed N	Expected N	Residual
2	15	10.5	4.5
3	6	10.5	-4.5
Total	21		

แบบการเรียนรู้ ก่อน

	Observed N	Expected N	Residual
4	21	21.0	.0
Total	21 ^a		

a. This variable is constant. Chi-Square Test cannot be performed.

Test Statistics

	แบบการเรียนรู้ หลัง
Chi-Square ^a	3.857
df	1
Asymp. Sig.	.050

a. 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 10.5.

Frequencies of a difference of learning style per group

จำนวน LSI per group

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	one LSI type	4	4.9	4.9	4.9
	two LSI type	36	43.9	43.9	48.8
	three LSI type	29	35.4	35.4	84.1
	four LSI type	13	15.9	15.9	100.0
	Total	82	100.0	100.0	

Statistics

จำนวน LSI per group		
N	Valid	82
	Missing	0

Oneway of summative posttest

ANOVA

POSTTEST

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	426.700	3	142.233	2.442	.070
Within Groups	4542.776	78	58.241		
Total	4969.476	81			

4) Creativity in scientific communication

Descriptives**Descriptive Statistics**

	N	Minimum	Maximum	Mean	Std. Deviation
Poster 1	82	7.00	25.00	15.5854	3.7117
Poster 2	82	7.00	30.00	19.9146	5.0288
Poster 3	82	15.00	30.00	25.0244	4.4499
Mean of 3 Posters	82	14.00	28.00	20.1748	3.2132
Valid N (listwise)	82				

NPar Tests Friedman Test**Test Statistics^a**

Ranks			
	Mean Rank	N	
Poster 1	1.19	82	
Poster 2	2.04	Chi-Square	107.473
Poster 3	2.77	df	2
		Asymp. Sig.	.000

a. Friedman Test

Poster 1 Poster 2 Poster 3 Mean of 3 Posters * จำนวน LSI per group
Means from the three posters of groups**Case Processing Summary**

	Cases					
	Included		Excluded		Total	
	N	Percent	N	Percent	N	Percent
MTOTAL * จำนวน LSI per group	82	100.0%	0	.0%	82	100.0%

Report**MTOTAL**

จำนวน LSI per group	Mean	N	Std. Deviation
one LSI type	58.0000	4	.0000
two LSI type	59.0000	36	6.8785
three LSI type	65.4138	29	9.8978
four LSI type	54.6154	13	12.4869
Total	60.5244	82	9.6395

ANOVA Table

		Sum of Squares	df	Mean Square	F	Sig.
MTOTAL * จำนวน LSI per group	Between Groups (Combined)	1256.340	3	418.780	5.210	.002
	Within Groups	6270.111	78	80.386		
	Total	7526.451	81			

Measures of Association

	Eta	Eta Squared
MTOTAL * จำนวน LSI per group	.409	.167

5). Learning Environment

Regression All Situation**Variables Entered/Removed^b**

Model	Variables Entered	Variables Removed	Method
1	INTERCODE	.	Enter

- a. All requested variables entered.
b. Dependent Variable: ATMOSPHERE

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.384 ^a	.147	.117	7.22

- a. Predictors: (Constant), INTERCODE

ANOVA^b

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	252.051	1	252.051	4.831	.036 ^a
	Residual	1460.915	28	52.176		
	Total	1712.967	29			

- a. Predictors: (Constant), INTERCODE
b. Dependent Variable: ATMOSPHERE

Coefficients^a

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	29.615	3.624		8.173	.000
	INTERCODE	3.903E-02	.018	.384	2.198	.036

- a. Dependent Variable: ATMOSPHERE

Regression with non ICT-Mediated Science Classroom**Variables Entered/Removed^b**

Model	Variables Entered	Variables Removed	Method
1	INTERCODE	.	Enter

- a. All requested variables entered.
b. Dependent Variable: ATMOSPHERE

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.186 ^a	.035	-.034	4.47

- a. Predictors: (Constant), INTERCODE

ANOVA^b

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	10.040	1	10.040	.503	.490 ^a
	Residual	279.710	14	19.979		
	Total	289.750	15			

- a. Predictors: (Constant), INTERCODE
b. Dependent Variable: ATMOSPHERE

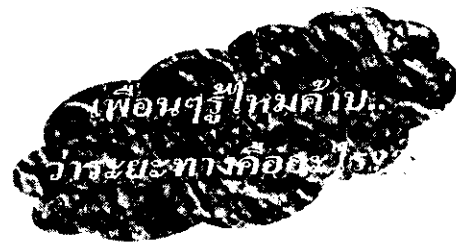
Coefficients^a

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	28.972	3.237		8.951	.000
	INTERCODE	1.433E-02	.020	.186	.709	.490

- a. Dependent Variable: ATMOSPHERE

Appendix 4

Examples of students' work



ถ้าไม่รู้ผมจะไขปัญหาให้เอง . . .

ระยะทาง นั้นก็หมายถึง เส้นทางที่วัตถุต่างๆ เคลื่อนที่ไปจริง อาจจะเป็นเส้นตรง หรือไม่เส้นตรงก็ได้ มีหน่วยเป็นเมตรหรือเซนติเมตร เป็นปริมาณสเกลาร์ ในการเดินทางไปที่ต่างๆของเราก็ถือว่าเป็นระยะทางเช่นกัน

เช่น ในการที่รถ



เคลื่อนที่ไปในสถานที่

ที่ต่างๆ เราควรรู้ระยะทางเพื่อคำนวณระยะเวลาในการเดินทาง



ม.4/1 กลุ่ม 9

น.ส.นันท์ชนก หาญตะคุ ม.4/1 เลขที่ 26

น.ส.อารดา ไตรศิริเวทวัฒน์ ม.4/1 เลขที่ 30

น.ส.ญานิกา คงมั่นวัฒนา ม.4/1 เลขที่ 31

น.ส.ฤชดา นันตะพานา ม.4/1 เลขที่ 33

กลุ่มที่ 7 ห้อง 4/3

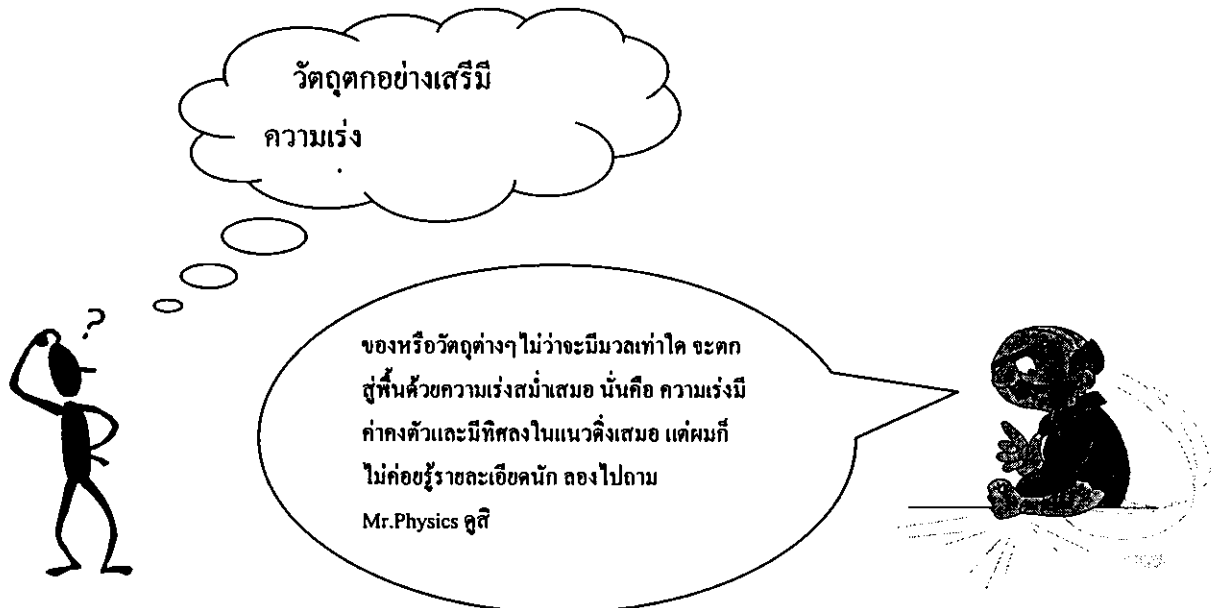
- ถ้าเราตอยหน้าเพื่อน ทำไมหน้าเพื่อนถึงเจ็บมากกว่ามือของเรา ทั้ง ๆ ที่ Action ขนาดของแรงจะเท่ากับ Reaction เสมอ



- เพราะว่า ใบหน้าคนเรามีความอ่อนตัวมากกว่า ในขณะที่มือของเรามีความแข็งแรงมากกว่า แต่ ยิ่งไงก็ตามแรง Action จะเท่ากับ Reaction เสมอ



ฟิสิกส์ในชีวิตประจำวัน

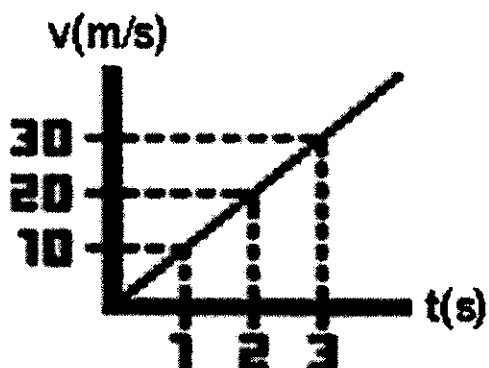


Mr.Physics →



การตกอย่างเสรี หมายถึง การตกโดยไม่มีสิ่งใดกีดขวางหรือกระทบ ความเร่งในการตกของ
วัตถุลงสู่พื้นโลก เรียกว่า ค่าความโน้มถ่วง ใช้สัญลักษณ์เป็น g ค่าเฉลี่ย g ทั่วโลก เป็นค่ามาตรฐาน
คือ 9.8065 m/s^2

ให้กราฟ v กับ t ในการปล่อยวัตถุลงในแนวดิ่ง เมื่อเวลาผ่านไป 3 วินาที วัตถุจะ
เคลื่อนที่ได้เป็นระยะทางเท่าใด



$$\text{ความเร่ง} = \text{slope} = \frac{v}{t} = \frac{30}{3} \text{ m/s} = 10 \text{ m/s}^2$$

$$\begin{aligned} \text{ระยะทาง} &= \text{พื้นที่ใต้กราฟ} \\ &= \frac{1}{2} \times 3 \times 30 = \frac{1}{2} \times 3 \text{ s} \times 30 \frac{\text{m}}{\text{s}} = 45 \text{ m} \end{aligned}$$

ความเร็ว

ความเร็ว คือ การเปลี่ยนตำแหน่งต่อ 1 หน่วยเวลา สำหรับช่วงเวลาที่ยาวสามารถหาได้จากสูตรนี้



$$\text{ความเร็ว} = \frac{\text{ระยะทาง}}{\text{เวลา}}$$

หรือ $V = \frac{S}{T}$

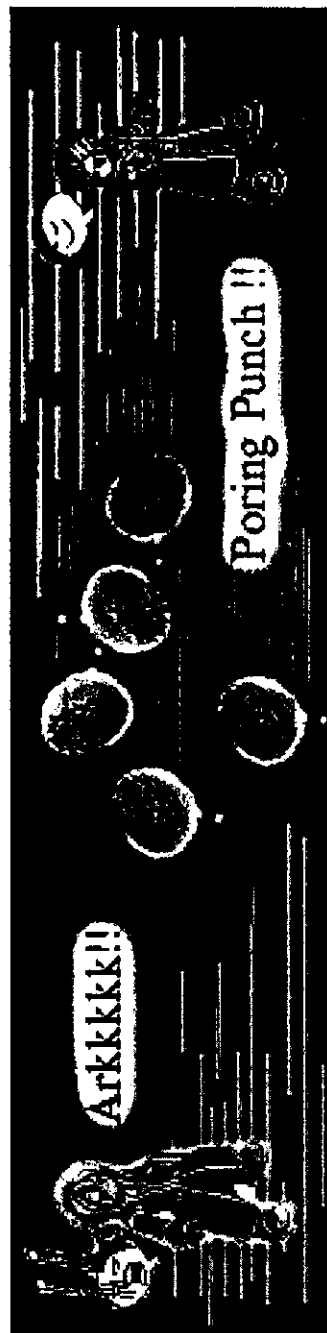
ตัวอย่างเช่น

การที่นักเทนนิสเลิฟลูเทนนิสออกไปแล้วนั้น จะเห็นได้ว่าจะมีจุดที่สามารถบอกความเร็วของลูกเทนนิสได้ทันที ซึ่งเป็นการวัดของเครื่องมือที่เรียกว่า Light Gate เป็นอุปกรณ์ที่ใช้แสงเข้ามาช่วยในการวัด และแสดงผลได้หลายรูปแบบ เช่น เป็นข้อมูลตัวเลขกราฟ แผนภูมิ ตาราง เป็นต้น ซึ่งที่เราเห็นในสนามเทนนิสนั้นเป็นการแสดงข้อมูลแบบตัวเลข



สมเด็จกลุ่ม	
1. มาชกา พวงลำไย	ม.4/4
2. พิศราภา ทุกเผือก	ม.4/4
3. รังสิยา รังษิธรรมปัญญา	ม.4/4

ถ้า Monk ต่อ Poring ทำไม่ Poring ถึงเจ็บมากกว่า Monk



อธิบายตัวอย่างการกระทำที่มีลักษณะเดียวกันข้างต้น

กฎข้อที่ 3 แรงกระทำกับแรงปฏิกิริยา แต่มิทิศทางตรงข้าม กล่าวที่ ถ้าวัตถุ A ให้แรงจำนวนหนึ่งแก่วัตถุ B วัตถุ B ก็ให้แรงจำนวนที่เท่ากันที่โต้รับมาส่งกลับให้วัตถุ A เช่น การที่เราออกแรงเตะไปตีลูกบอล (แรงกระทำ) ลูกบอลก็จะออกแรงเตะมาที่เท้าของเราเช่นกัน (แรงปฏิกิริยา) ซึ่งทำให้เราเจ็บเท้าได้ เราจำเป็นต้องสวมรองเท้าเพื่อไม่ให้เท้าเราเจ็บไปครับ

สรุป

การกระทำที่เกิดขึ้นจากการที่ Monk ต่อ Poring นั้น แรง action ที่ Monk ต่อ Poring ไปนั้น จึงมีขนาดเท่ากับแรง reaction แต่ที่ Poring เจ็บกว่า Monk นั้นอาจเป็นเพราะว่า พื้นที่รับการกระทบนั้นต่างกัน จึงทำให้การเจ็บที่เกิดขึ้นต่างกัน

รายชื่อผู้จัดทำ (กลุ่ม 6 ชั้น ม. 4/3)

1. นาย ฐานุตร์ ปิรมหัยวุฒิ เลขที่ 11
2. นาย ธรรมรัตน์ ใจชินวงศ์ เลขที่ 14
3. นาย ทรงพล อัครธรรมนาท เลขที่ 15
4. นาย พิรพงษ์ สมบูรณ์ เลขที่ 16

VITAE

VITAE

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C.3

**THE DEVELOPMENT OF AN INNOVATIVE INTEGRATED APPROACH
TO ICT-MEDIATED LEARNING IN SCIENCE**

ABSTRACT

BY

SIRINOOT TEANRUNGROJ

1 0 31.8. 2548

Presented in partial fulfillment of the requirements for the

Doctor of Education degree in Science Education

at Srinakharinwirot University

March 2005

Sirinoot Teanrungrroj. (2005). *The Development Of An Innovative Integrated Approach To ICT-mediated Learning In Science*. Dissertation, Ed.D. (Science Education). Bangkok: Graduate School, Srinakharinwirot University. Advisor Committee: Associate Professor Dr.Nason Phonpok, Associate Professor Somchit Savathanaphaibul, Dr.Pornpun Waitayangkoon.

The main idea behind this study was to investigate how the achievements of students could be improved by the use of ICT, a wide range of information and communication technologies with the active learning methodologies being integrated into the curriculum and classroom. The purposes of this study were as follows:

- 1) To develop an integrated approach to ICT-mediated learning in Science for the science curriculum entitled Force and Motion Module, which was designed based on active learning pedagogy for students in Year-10 (aged 14-15) at Key Stage 4 (Mathayom Suksa 4).
- 2) To investigate how the achievement of students could be improved.
- 3) To explore how ICT could change the learning style of students.
- 4) To investigate how the creativity in scientific communication of students could be improved.
- 5) To examine how ICT could change the classroom learning environment.

In order to achieve the purposes of this study, an integrated approach to ICT-mediated learning in Science was developed. A learning process, the **LisT** learning model, was developed for this approach. '**LisT**' is an abbreviation for 4 stages of learning episodes: Look and Listen; Investigate; Share and Tests. The 'Force and Motion' is the module for this study. Four different effects on students are examined: achievement; learning style; creativity in scientific communication and learning environment.

Five hypotheses of this study were as follows:

- 1) The performance of the integrated approach to ICT-mediated learning in Science is 80/80.
- 2) The achievement of students on the post-test would be higher than that of the pre-test.
- 3) The learning style of students is changed.
- 4) The creativity in scientific communication of students would be improved by the

5) The learning environment becomes an active learning environment enhanced by classroom interactions.

The subjects were 82 students from Year-10 level of the science program in the first semester of the academic year 2004. A research methodology for this study was research and development. Four steps of research methodology were followed to achieve the conclusions of this study. The first development phase aimed to set up conceptual framework, and research instruments: an integrated approach to ICT-mediated learning in Science, tests, a learning style questionnaire, a rubric score scheme for evaluating creativity in scientific communication, an CBI-computer-based interactions coding system, and an observational learning environment questionnaire. The second development phase aimed to find the validity and reliability of research instruments. The third development phase aimed to find the performance of the integrated approach to ICT-mediated learning in Science package. The fourth development phase aimed to achieve the conclusions of this study. Prior to the experiment, the subjects were given a pretest to measure achievements and learning styles. During the investigation, the ethnographic research methodology was performed using video recording to observe the learning environment. At the end of the study, the subjects were given a post-test on achievements and learning styles.

The findings were as follows:

- 1) The performance of the integrated approach to ICT-mediated learning in Science package was greater than 80/80.
- 2) The achievements of students on the post-test was higher than that of the pretest.
- 3) The learning style of students was changed.
- 4) The creativity in scientific communication of students was improved by the use of ICT.
- 5) The learning environment becomes an active learning environment enhanced by classroom interactions.

It was concluded that the integrated approach to ICT-mediated learning in Science package affected achievement, learning style, creativity in scientific communication and learning environment. Moreover, the findings from in-depth analysis indicated that the use of

ICT can support the study of science. The only students found statistically to have developed a new learning style were students who in the pretest had a divergent learning style. The different learning style combinations did not statistically affect achievements but they affected creativity in scientific communication. The uses of ICT enhanced the classroom learning environment especially in the ICT-mediated classroom.

การพัฒนานวัตกรรมบูรณาการเทคโนโลยีสารสนเทศเพื่อการเรียนรู้วิทยาศาสตร์

บทคัดย่อ
ของ
ศิรินุช เทียนรุ่งโรจน์

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ตามหลักสูตรปริญญาการศึกษาดุเชฎฐบัณฑิต สาขาวิทยาศาสตร์ศึกษา
มีนาคม 2548

ศิรินุช เทียนรุ่งโรจน์. (2548). *การพัฒนาวัตกรรมการบูรณาการเทคโนโลยีสารสนเทศเพื่อการเรียนรู้*

วิทยาศาสตร์. ปริญญาโท. กศ.ด.(วิทยาศาสตร์ศึกษา). กรุงเทพฯ: บัณฑิตศึกษา มหาวิทยาลัยศรีนครินทรวิโรฒ คณะกรรมการควบคุม: รองศาสตราจารย์ ดร.ณสรณ์ ผลโคก, รองศาสตราจารย์ สมจิต สวชนไพบูลย์, ดร.พรพรรณ ไวย่างกูร.

การวิจัยครั้งนี้มีจุดมุ่งหมายเพื่อพัฒนาวัตกรรมการบูรณาการเทคโนโลยีสารสนเทศเพื่อการเรียนรู้วิทยาศาสตร์ เพื่อให้บรรลุเป้าหมายของการวิจัยกระบวนการเรียนแบบ "ลิสท์ (LisT)" จึงถูกพัฒนาขึ้นและได้นำเสนอไว้ในเอกสารชุดการเรียนรู้วิทยาศาสตร์แบบบูรณาการเทคโนโลยีสารสนเทศภายใต้เนื้อหาากลุ่มสาระการเรียนรู้วิทยาศาสตร์และเทคโนโลยี สารที่ 4 เรื่องแรงและการเคลื่อนที่ สำหรับช่วงชั้นที่ 4 เพื่อศึกษาผลของการบูรณาการเทคโนโลยีสารสนเทศเพื่อการเรียนรู้วิทยาศาสตร์ในประเด็นต่าง ๆ ดังนี้ 1) ผลสัมฤทธิ์ทางการเรียนของนักเรียน (achievement) 2) แบบการเรียนรู้ของนักเรียน (learning style) 3) ความคิดสร้างสรรค์ในการสื่อสารข้อมูลทางวิทยาศาสตร์ (creativity in scientific communication) และ 4) บรรยากาศการเรียนรู้ (learning environment)

ผู้วิจัยได้พัฒนาชุดการเรียนรู้วิทยาศาสตร์แบบบูรณาการเทคโนโลยีสารสนเทศโดยครอบคลุมเนื้อหาสาระในเรื่อง การเคลื่อนที่ใน 1 มิติและกฎการเคลื่อนที่ของนิวตันจำนวน 4 หน่วยการเรียนรู้ และใช้ควบคู่กับหนังสือเรียนฟิสิกส์สำหรับชั้นมัธยมศึกษาปีที่ 4 ของกระทรวงศึกษาธิการ ใช้เวลาในการสอนทั้งหมด 34 ชั่วโมง เทคโนโลยีสารสนเทศที่นำมาบูรณาการในชุดการเรียนรู้ประกอบด้วย โปรแกรมจำลองด้วยคอมพิวเตอร์ (computer simulation software) โปรแกรมชุดการทดลองวิทยาศาสตร์ด้วยเครื่องมือเทคโนโลยีสารสนเทศ (Data logging) อินเทอร์เน็ต (Internet) และโปรแกรมใช้งานทั่วไป (generic software) งานวิจัยนี้ได้ทดลองภาคสนามกับนักเรียนชั้นมัธยมศึกษาปีที่ 4 จำนวน 2 ห้องเรียน รวมนักเรียนทั้งหมด 82 คน ในภาคเรียนที่ 1 ปีการศึกษา 2547 โดยใช้การทดสอบก่อนและหลังการเรียนรู้ด้วยชุดการเรียนรู้วิทยาศาสตร์แบบบูรณาการเทคโนโลยีสารสนเทศสำหรับแบบวัดผลสัมฤทธิ์ทางการเรียนของนักเรียน และแบบการเรียนรู้ของนักเรียน ใช้การเก็บข้อมูลแบบหลังจากใช้ชุดการเรียนรู้วิทยาศาสตร์แบบบูรณาการเทคโนโลยีสารสนเทศสำหรับความคิดสร้างสรรค์ในการสื่อสารข้อมูลทางวิทยาศาสตร์ และใช้การบันทึกเทปวิดีโอสำหรับบรรยากาศการเรียนรู้

ผลการทดลองพบว่า

1. ชุดการเรียนรู้วิทยาศาสตร์แบบบูรณาการเทคโนโลยีสารสนเทศมีคุณภาพ 80/80
2. ผลสัมฤทธิ์ทางการเรียนของนักเรียนหลังการเรียนรู้ด้วยชุดการเรียนรู้วิทยาศาสตร์แบบบูรณาการเทคโนโลยีสารสนเทศสูงกว่าก่อนเรียนด้วยชุดการเรียนรู้วิทยาศาสตร์แบบบูรณาการเทคโนโลยีสารสนเทศ
3. แบบการเรียนรู้ของนักเรียนเปลี่ยนหลังการเรียนรู้ด้วยชุดการเรียนรู้วิทยาศาสตร์แบบบูรณาการเทคโนโลยีสารสนเทศ

4. ความคิดสร้างสรรค์ในการสื่อสารข้อมูลทางวิทยาศาสตร์ของนักเรียนพัฒนาขึ้นหลังจากการเรียนรู้ด้วยชุดการเรียนรู้วิทยาศาสตร์แบบบูรณาการเทคโนโลยีสารสนเทศ

5. บรรยายการเรียนเปลี่ยนแปลงไปสู่บรรยากาศการเรียนรู้แบบกระตือรือร้นด้วยปฏิสัมพันธ์ในชั้นเรียน

สรุปผลงานวิจัยได้ว่า การบูรณาการเทคโนโลยีสารสนเทศเพื่อการเรียนรู้วิทยาศาสตร์ทำให้นักเรียนมีพัฒนาการที่ดีขึ้นในด้านผลสัมฤทธิ์ทางการเรียนและความคิดสร้างสรรค์ในการสื่อสารข้อมูลทางวิทยาศาสตร์ อีกทั้งยังส่งผลต่อการเปลี่ยนแปลงของแบบการเรียนรู้ของนักเรียน และทำให้บรรยากาศการเรียนรู้มีพัฒนาการไปสู่การเรียนรู้แบบกระตือรือร้น นอกจากนี้ยังพบว่าเทคโนโลยีสารสนเทศช่วยสนับสนุนการเรียนรู้วิทยาศาสตร์ การเปลี่ยนแปลงแบบการเรียนรู้ของนักเรียนเป็นผลมาจากนักเรียนที่มีแบบการเรียนรู้ก่อนการเรียนรู้ (pretest) เป็นแบบอ่อนก้นย (divergent learning style) ความแตกต่างของแบบการเรียนรู้ในกลุ่ม (learning style combination) ไม่ส่งผลต่อผลสัมฤทธิ์ทางการเรียนแต่กลับส่งผลดีต่อความคิดสร้างสรรค์ในการสื่อสารข้อมูลทางวิทยาศาสตร์ และพบว่าเทคโนโลยีสารสนเทศช่วยส่งเสริมบรรยากาศการเรียนรู้โดยเฉพาะอย่างยิ่งในห้องเรียนที่มีการบูรณาการเทคโนโลยีสารสนเทศ