CAUSAL FACTORS INFLUENCING SCIENTIFIC REASONING SKILLS OF THAI FOURTH-GRADE STUDENTS

A DISSERTATION

BY

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TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

Page

CHAPTER II REVIEW OF RELATED LITERATURE (continued)

TABLE OF CONTENTS (continued)

TABLE OF CONTENTS (continued)

LIST OF TABLES

LIST OF FIGURES

Figure **Page**

CHAPTER 1

INTRODUCTION

Background of the Problems

Thailand has faced many problems in science education. Success in the implementation of elementary school science is questionable (Pornsima. 1999a: 106). Soydhurum (2001a: 16) studied and summarized in his recent research on science education in Thailand and found that at the elementary level, national scores on learning achievement in science learning skills were rather low. The average score was 50 percent with rather high discrepancies. Fourth graders had an average score of 45.67 percent for science process skills. Furthermore, in the Third International Science Study (TIMSS. 1999) which was carried out in 1999, elementary science achievement compared with the other 24 participant countries at the third grade level and 26 countries at the fourth grade level,
Thai children had science scores lower than average. The international means for the third and the fourth grade level were 473 and 524, respectively. Thai third grades averaged 433 and the fourth grades 473. Pornsima (1999b: 105) claimed that the major reasons for such under achievements were as follows;

1. The incompetence of teachers. Most elementary school teachers did not have enough background in physical science education. A large number of them were trained in elementary education, early childhood education, and Thai language social studies. Only 7.7 percent of them graduated with degrees in science (Soydhurum. 2001b: 38). These background problems caused the teachers to lack confidence. Therefore, they focused on rote learning rather than the development of initiative and other desirable characteristics.

2. The lack of equipment and poor physical learning environment. There were few teachers who created and used physical learning outside their classrooms. Furthermore, it was found that most schools did not have adequate teaching-learning aids and equipment.

3. The entrance examination system. Parents valued university education. The limitation of seats in the university caused the students to have rote learning styles. Parents had to prepare their child for the entrance examination early enough so that he/she could compete with others. This entrance exam system together with multiple choice

oriented tests caused an imbalance in the development of skills with regard to scientific reasoning.

Therefore, many government officials are involved in designing and developing science curricula and assessments. The current education reform was launched by the Ministry of Education in 1996. This reform has been revised and amended with an eye towards mitigating or eliminating problems and enhancing the quality of education until academic excellence is achieved by the year 2007.

At present, the Institute for the Promotion of teaching Science and Technology (IPST), a government agency is responsible for modifying and revising the curricula for science, mathematics and computer science education in accordance with the principles and guidelines stated in the education policy. The science curricula, according to the new National Educational Act, should aim at making science curricula more applicable to the needs of modernized economy and advancement in the scientific and technological world (Boonklurb. 2003a : Online , Tantraporn. 2003a: 2). The objectives of the National science curricula, which were set up by the IPST, are:

1. To understand principles, concepts and theories of basic science,
2. To understand the nature of science,
3. To promote the process of learning science and research in science and technology,
4. To promote an open-minded, rigorous attitude towards science,
5. To understand the inter-relationship and impact of science, technology, humanity and the natural environment,
6. To demonstrate applications of science and technology in daily life and society (Boonklurb. 2003b: Online).

According to the National Education Act, the system of educational quality assurance should be provided in order to ensure the achievement of educational objectives. The quality assurance in education was for the first time introduced by the Ministry of Education. The Office of Educational Standards was established. The objectives of the office were to develop the criteria and method for external assessment and to use the assessment of the outcomes of educational provision for the evaluation of the educational institutions (Office of the National Education Standards and Quality Assurance. 2000: Online). In 2003, the first pilot project was carried out in 218 schools located in many parts of the country. The assessment contained 14 standards and 53 benchmarks. The 14 standards consisted of three aspects; learners, teachers, and administrators. The students' achievement on thinking abilities was only 67 percent. These thinking abilities included analytical, synthetical, creative, meditative, and visual thinking. The study group urged that learners should improve their thinking abilities, especially the analytical thinking which was the lowest level (only 9.6 percent) (Office of the national education standards and quality assurance. 2004: 30).

During this decade, there have been many Thai researchers emphasizing learners' qualities. Department of Educational Technique (1997: 97) studied potentiality of Thai sixth, ninth, and twelfth grade students. There were two phases in this study. In the first phase, they found that all of students had the lowest achievement of thinking abilities. In the second phase of the study (1999: 42), they improved the tests which were more appropriate than the first phase tests. The results of the study also showed that all students still had the lowest achievement in thinking abilities.

In a study of intelligence quotients in Thai children, Chuprapawan (2001: Online) studied the intelligence quotients of Thai children who were 1-18 years old and found that the average IQ of Thai children in fifth to ninth grade were only 92 in 1997. She did the follow-up study in the year 2002 and found that students' IQ scores decreased to 87. The thinking abilities such as problem-solving and decision-making were rather low. She claimed that the major reasons were the poor educational system and lack of parental support. Moreover, Ruengtragul; & Wongwanich (2004: 289) studied the evaluation of students' outcome based on the National Education Act in the sixth and the ninth graders from 5 provinces. The results indicated that the learners' science and thinking skills were not satisfactory.

The above results seem to suggest that, this is a crisis of Thai child education about which government sectors such as the department of education has to be concerned. In today's society, all students need to think scientifically, understand scientific concepts, generate and evaluate scientific arguments, and understand the manner in which scientific knowledge is generated (Lynn. 1999a: 6). Kuhn described the importance of scientific thinking and its connection to science education as:

> Scientific thinking tends to be compartmentalized, viewed as relevant and accessible only to the narrow segment of the population who pursue scientific careers. If science education is to be successful, it is essential to counter this view, establishing the place that scientific thinking has in the lives of students. A typical approach to that object has been to try to connect the content of science to phenomena familiar in students' everyday lives. An ultimately more powerful approach may be to connect the process of science to thinking process that figure in ordinary people's lives. (Kuhn.1993a: 333).

Scientific reasoning skills are cognitive activities characterized by precision, systematic approach, and awareness of logical things. They are not qualitatively different from everyday thinking. It adheres to more rigorous logical constrains, which could be taught formally (Kaselman. 2001a: 1; Pearsall. 1999a: 1). Scientific reasoning skills ability could occur within and across scientific disciplines and domain of knowledge and experience, yet there were few college level students could think scientifically in the realms of biology and physics, for example biologically and physically. Ability to study science well was to learn how to think scientifically (Nosich. 2004 : Online). The quality of learning science depended on an efficient level of reasoning in learner rather than the possession of an extensive declarative knowledge (Lawson. 1995: 708). If the students are given opportunities to think scientifically, the more effective learning may occur (Watters; & English. 1995: 1). Acknowledging the importance of scientific reasoning skills, many science education reform programs are built on this idea. For instance, the American Association Advancement of Science (AAAS) advocated standard-based programs to foster the development of complex scientific reasoning skills (Songer. 2003a : 4). This idea was also reflected in the vision of Thailand science curricula which stated that Thai students should develop their scientific reasoning skills (IPST. 2003a: 2). As a result, in recent years, a substantial amount of research has been conducted on scientific reasoning (Sodian; et al. 1991a: 753). From the theory of cognitive development, Piaget proposed his idea that cognitive development consisted of the development of logical competence, and that the development of this competence consists of four major stages:

1. Sensory-motor (birth-2 years old) During this stage, Piaget said that a child's cognitive system is limited to motor reflexes at birth, but the child builds on these reflexes to develop more sophisticated procedures, such as images, language, or symbols.

2. Pre-operational (2 – 7 years old) At this stage, children acquire representational skills in the areas of mental imaginary, and especially language. They can use these

representational skills only to view the world from their own perspective. In addition, they can develop the ability to think in a more logical manner.

3. Concrete operational (7-11 years old) Children in this stage are able to perform operations on concrete ideas and objects, but they cannot perform mental operations on abstract or hypothetical elements. They cannot yet perform on abstract problems; such as, they have difficulty understanding relationships among relationships.

4. Formal operational (12 years old to adults) Children in this stage can master sophisticated kind of thinking that is abstract, formal, logical, with multiple hypotheses, so they can use logic to solve problems (Kodat. 2002a: Online)

From Piaget's perspective, the movement from one stage to the next occurred when the child reached an appropriate level of maturation and was exposed to relevant types of experiences. Without experience, children were assumed incapable of reaching their highest cognitive ability. Some previous research underestimated children's ability. Recent studies, however, indicate that children possess an understanding of the distinction between hypotheses earlier than prior research had indicated. Children are not as illogical and concrete as Piaget claimed. Children as young as 6 or 7 are able to recognize an appropriate hypotheses-evidence relationship, given an appropriate context (Ruffman; et al., 1993a). Metz (1997a: 151) argued for using this developmental theory in designing elementary science curricula. She claimed that when children knew a great deal about domain specific knowledge, they could think abstractly and were not limited to the concrete. Believing in stage-based limitations in children's cognitive abilities could prevent teachers from paying attention to individual variability and from adapting their teaching.

Promboon (1993: 2) stated that scientific reasoning was a process of thinking critically and creatively about natural world based-on science and mathematics knowledge. She advocated that scientific reasoning skills are important skills which should be engaged at an early age. Therefore, elementary science teachers should promote scientific reasoning skills in children. Having sound scientific reasoning skills can help Thai people to access the knowledge.

According to Piaget's theory, Thai fourth-grade students are in the concrete operational stage where they begin to reason logically, and organize their thoughts coherently. In Thai educational system, the fourth-grade students are in the upper elementary level. A good academic achievement of this grade level will naturally effect the academic achievement of the higher level (Simson; & Troost. 1982a: 766). Elementary children must develop their cognitive skills, social skills, and emotional skills in order to prepare them are successful in secondary school. In order to help teachers recognize their students' cognitive ability, they need to construct tests to assess their students' abilities, such as thinking ability. Given the significance of the fourth-grade students' scientific reasoning skills, science educators should attempt to attract students' capabling of utilizing these skills to careers that require them. The understanding of the factors which influence students' thinking abilities will provide more details for the improvement of their academic achievement. As a science teacher for several years with the awareness of how important scientific reasoning skills are, the researcher is interested in studying in Thai fourth-grade students' scientific reasoning skills. The research focus on the characteristics of scientific reasoning skills in Thai children and the factors that are related to scientific reasoning skills will be focused in this study.

Research Objectives

1. To study the relationship between the causal factors and scientific reasoning skill of Thai fourth-grade students.
2. To test whether the hypothetical model (Figure 1) consistent with the empirical data of Thai fourth-grade students.
3. To study the causal factors influencing scientific reasoning skills of Thai fourth-grade students.

Significance of the Study

This research on developing the test for assessing students' scientific reasoning skills in the fourth-grade students is expected to yield two kinds of outcomes:

1. It should yield a quality tool for evaluating scientific reasoning skills.
2. It should yield answers to two research questions that are described below.

Research Questions

The specific questions to be addressed in this research are:

1. Are there any relationships between the causal factors and scientific reasoning skills? The causal factors involve children background; for instance democratic child-rearing practices, authoritarian child-rearing practices, laissez-faire child-rearing practices, home

educational support, quality of science teaching, primary mental abilities, creative thinking skills, previous science grade, attitude towards science.

2. Is the hypothetical model consistent with the empirical data?

3. Are there any of those causal factors influencing scientific reasoning skills of Thai fourth-grade students?

Delimitation of Research

Population and Sample

The population of this study consisted of the fourth-grade students who were studying in the first semester of the academic year 2005 in Bangkok and surroundings. Thirteen schools (seven public schools and six private schools) were selected by purposely-simple random sampling. These seven public schools were under difference jurisdiction: Bangkok Metropolitan; Office of the Basic Education Commission; and Commission of Higher Education. One classroom from each school was selected randomly as the sample. The sample size of this study was 430.

Variables of the Study

According to the research questions, the variables are as following;

Causal factors:

1. Democratic child-rearing practice
2. Authoritarian child-rearing practice
3. Laissez-faire child-rearing practice
4. Home educational support
5. Science teaching quality
6. Primary Mental Abilities
7. Scientific creativity
8. Previous science grade
9. Attitude towards science

Dependent variable

Scientific reasoning skills

Definition of Terms

1. **Scientific reasoning skills** refer to a process of performance for solving problems in the domain of both general knowledge and specific knowledge. Domain general knowledge involves strategies, heuristics, and procedures that apply regardless of the content to which they are being applied. Domain specific knowledge is based on scientific contents of national science curriculum which was developed by the IPST.

Scientific reasoning skills are composed of:

1.1 Ability to ask, or define good questions and point out problem.

1.2 Ability to come up with hypotheses.

1.3 Ability to design an experiment

1.3.1 Identifying variables

1.3.2 Understanding of control variables.

1.3.3 Designing experiment or investigation.

1.4 Ability to collecting data

1.4.1 Determining the relevance of data.

1.4.2 Analyzing data.

1.5 Ability to explain and conclude

1.5.1 Evaluating the quality of explanation.

1.5.2 Formulating scientific explanation using evidence.

2. **Causal factors** refer to set of independent variables which will effect to students' scientific reasoning skills. They are democratic child-rearing practice, authoritarian child-rearing practice, laissez-faire child-rearing practice, home educational support, quality of science teaching, primary mental abilities, scientific creativity, previous science grade, and attitude towards science.

The definition of each factors are as following,

2.1 Democratic child-rearing practice refers to the style of parents who treat children by considering both the child's needs and theirs. Parents allow lots of discussion and consider children's opinions before making a final decision. Principles of guidance and discipline are generally discussed by both parents and children. In addition, parents always use rational and logic when disciplining. This style of parents will influence children's thinking, decision making, problem solving, creative thinking, and high in self-competence.

(Prasertwong. 1996a: 194-195). To determine whether a child fit in the democratic child-rearing practice the researcher designed a questionnaire to assess the result.

2.2 Authoritarian child-rearing practice refers to the style of parents who take care of their children by deciding the rules, informing the child, and then enforcing. The parents show little or no flexibility in their handling of guidance or discipline. There is low or no discussion with children, punitive punishment, and no logic in discipline (Prasertwong. 1996b: 194-195). To determine whether a child fit in the authoritarian child-rearing practice the researcher designed a questionnaire to assess the result.

2.3 Laissez-Faire child-rearing practice refers to styles of parents who permit a wide range of behavior for their children. Parents set few specific rules and allow the children a lot of freedom and self expression. In addition to parents' rewards and punishment depend son parents' emotion rather than reason. This style of parent has an effects on children's personalities become a lazy, and indiscipline (Prasertwong. 1996c: 194-195). To determine whether a child fit in the laissez-faire child-rearing practice the researcher designed a questionnaire to assess the result.

2.4 Home educational support refers to objects or activities which parents provide for students at home or in their community in order to support or promote their science learning abilities and attitude towards science, such as books, encyclopedia, science games, video, computer, internet, visiting science museum, gardening and etc. Home educational support can be assessed by using home educational support questionnaires which are developed by the researcher.

2.5 Science teaching quality refers to the science learning teaching characters which is child-centered teaching model in order to promote students' learning abilities. Science teacher will organize many learning activities and authentic assessment in order that students can think, discuss, question, and argue. The students will be happy and have positive attitude towards science. Science teaching quality can be measured by using science teaching quality questionnaires developed by the researcher.

2.6 Primary Mental Abilities refer to capability of a student to learn things or to perform certain tasks individually. The primary mental abilities can be measured by using primary mental ability test of Kumpuan (2002: 125). The primary mental ability test comprises:

2.6.1 Verbal meaning ability is an ability of students' understanding in language, vocabulary, and meaning which can be measured by a verbal meaning test; antonym and vocabulary relation.

2.6.2 Number facility ability is student ability in calculating correctly and rapidly. His ability can be measured by using mathematically series and mathematical reasoning test.

2.6.3 Reasoning ability is students' ability in thinking, concerning, making decision, categorizing, analogy, and drawing conclusions. This ability can be measured by using reasoning test.

2.6.4 Spatial relations ability is students' ability in mental rotate a figure in two or three dimensions. In addition, it is a student's ability in searching for a complicate geometry figure which is hided. This ability can be measured by using hided and manipulate figure test.

2.6.5 Perceptual speed ability is students' ability in identifying and distinguishing pictures rapidly. This ability can be measured by using similarities and difference figure test.

2.7 Scientific creativity refers to the ability of student to think about or a variety of science knowledge, valuably, and innovatively which can be measured by scientific creativity test of Kumtae (1999: 94). The scientific creativity consists of

2.7.1 Fluency: refers to ability of student to answer quickly and correctly.

2.7.2 Flexibility: refers to ability of student to categorize their thinking in many domains.

2.7.3 Originality: refers to ability of student to think in different terms.

2.8 Previous science grade refers to the students' knowledge and ability in science subject learning. The grade points average of science in the academic year 2004 will be used as criteria of their science achievement.

2.9 Attitude towards science refers to opinions, feelings or thoughts of students toward science, such as a nature of science, an importance of science in daily life, a scientist's working, information science, belief and interest in science (IPST. 2000: 272). Students' attitude towards science can be measured by using attitude towards science questionnaires which are developed by the researcher.

3. Exogenous variables refer to the variables in a causal model whose value independent from the states of other variables in the model (Diamantopoulos; & Siguaw. 2000: 2).

4. Endogenous variables refer to the variables which are influenced by other variables in the model (Diamantopoulos; & Siguaw. 2000: 2).

Theoretical Framework

The development of science reasoning ability in individuals has been shown to be correlated with multitude of variables; Piaget's cognitive theory of development, prior knowledge, Intelligence, as well as a number of individual aptitudes, achievement, and personality factors that have all been found to influence the development of scientific reasoning. Many of these variables are pre-existing attributes that students learn when they are young and bring with them to their college careers (Rifkin, Tronie –Georgakakos; & Harry. 1996: Online). Due to my interest in scientific reasoning skills in elementary level, I will review the relevant literature in order to construct a theoretical framework. This theoretical framework is based on three theories; first, the concept of development of scientific reasoning skills, second, the theories of cognitive development in a child, and last, the learning and teaching process.

This study is grounded in a theoretical framework based on the concept of development of scientific reasoning. Zimmerman (2000a: 99) concluded that the development of scientific reasoning, in the context of science, incorporates knowledge and skills that are both conceptual and procedural. The literature on this topic could be described in three connotations based on a distinct set of questions and methods of investigation. First, the term scientific reasoning has been used to describe the acquisition and use of conceptual knowledge in various domains of science (e.g., physics, biology) to solve problems or make predictions (e.g., predict the trajectory of a falling object). Second, scientific reasoning could refer to the more domain-general set of reasoning and problem-solving skills that transcend the particular domain to which they were being applied (e.g., experimental design, evidence evaluation, coordination of theory and evidence), and the research focused on procedural skills, but in conjunction with conceptual knowledge. A third sense, often called scientific literacy, involves understanding and critically evaluating reports of scientific research that were pervasive in newspapers, magazines, television, and the internet. Another point of scientific reasoning ability originally comes from the concepts inherent in Piaget's formal operations stage. Steussy (1984: 41) stated that scientific reasoning is used to denote consistent, logical thought patterns which are employed during the process of scientific inquiry that enable individuals to propose relationships between observed phenomena; to design experiments which test hypotheses concerning the proposed relationships; to determine all possible alternatives and outcomes; to consider probabilities of occurrences; to predict logical consequences; to weight evidence, or proof; and to use a number of instances to justify a particular conclusion. This is shown that children's scientific reasoning skills related to their cognitive ability.

In order to understand more of scientific reasoning skills development in child, the theory of cognitive development of a child need to be discussed. An understanding of how children develop cognitively has been thoroughly researched. A child understands the world changes as a function of age and experience. Movement from one stage to the next occurs when the child reaches an appropriate level of maturation and is exposed to relevant types of experiences. Without experience, children are assumed incapable of reaching their highest cognitive abilities (Kodat. 2002b: Online). Emphasizing scientific reasoning skills in fourth grade is an important issue. There are many factors affecting child's cognitive development and scientific reasoning skills. Parent, first, was one of the crucial factors which developmental psychologists have been long interested in. Parents styles or child rearing including home educational support which prepared by parent were family factors in this study. Child - rearing practice has been found to predict child development in the domain of social competence, academic performance, psychological development, and problem behavior (Darling. 1999: Online). Belsky (1984: 84) stated that the determinants of parenting shaped child rearing, which in turn influence child development. Robin and Gamble (1984: 521) stated that the styles of child rearing that enable the developing person to acquire the capacity required for dealing effectively with the ecological, she or he will inhabit during childhood, adolescence, and adulthood. Interaction between parents and child in their daily activities could promote students' scientific reasoning skills (Gleason; & Schauble. 1999: 343; Gleason. 2000: 5; Crowley; et al. 2001: 712). Therefore, studying the theory based on child - rearing practice and home educational support should yield answers whether they affect scientific reasoning skills of Thai fourth-grade students.

The last issue grounded on this study is principle of learning and teaching science. Although Thai science curriculum emphasizes what students should learn, how science is taught and what students' attitude towards science should be recognized due to its importance. Effective learning often requires more than just making connections of new ideas to old ones; it sometimes requires that people restructure their thinking radically.

Science is more than a body of knowledge and a way of accumulating and validating that knowledge. It is also a social activity that incorporates certain human values. Being curious, having creativity, imagination, and high esteem is an essential part of science teaching (American Association for the Advancement of Science. 1990: Online). In learning science, students should encounter such of those as part of their experience. In addition, the appropriate assessment and evaluation should be included. How does a science instructor know whether students have scientific reasoning skills? How do students find out how they are doing, and can they use the skills and techniques more effectively? Would students be able to explain or describe what and how they are thinking? Good assessment yields good information about these questions. According to the objective of this study, scientific reasonings skill test is an important instrument. A valid and reliable test must be emphasized. The results of this assessment should be indicators how students are doing in terms of thinking and reasoning skills. Measuring thinking skills in the classroom, the basic method of assessment is presented: paper-and-pencil tests, and associated scoring rubrics that require students to make or do something knowledge can be observed and judged (Stiggins; Ruble; & Quellmalz. 1988a: 4). Another factor that may affect the fourth-grade students' reasoning skills is language barrier. Because of the subjects' age in this study, the test including in questionnaires is based on the cognitive abilities as mentioned above. To construct a scientific reasoning skills test, it has been demonstrated that Piaget's theory could be applied for paper and pencil test construction (Duszynska. n.d.: 1).

According to the literature review, and experience in science teaching, the researcher found that scientific reasoning skills are usually related to students' achievement, students' attitudes, parents, school, and teachers. Diagnosis of learning characteristics in terms of the level of reasoning ability is necessary for teachers and science educators to establish their teaching-learning process. By using a scientific reasoning skills test, teachers can assess students' progress and their instructional effectiveness. There were many researchers who have been interested in scientific reasoning abilities and developed the test to investigate child's abilities in different ages, and contexts. Therefore, results, implications and comments on this study will be evaluated and will reflect learners' qualities in elementary science education in Thailand. The result of the present research should encourage teachers and parents to promote students' scientific reasoning skills in the future. The hypothetical model of various factors and scientific reasoning skills in this study is shown in Figure 1.

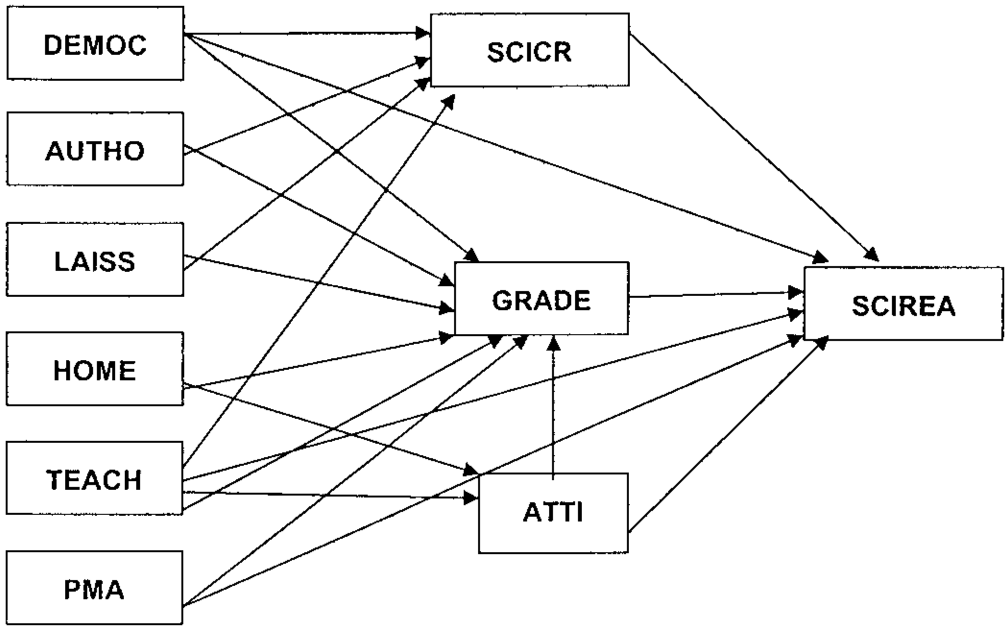

FIGURE 1 HYPOTHETICAL MODEL OF THE CAUSAL INFLUENCING SCIENTIFIC REASONING SKILLS OF THAI FOURTH-GRADE STUDENTS

NOTE left square means exogenous variables
middle square means endogenous variables
right square means dependent variable

Research Hypotheses

In the study of causal model of these factors, the research hypotheses are as follow:

1. There is a relationship between the causal factors and scientific reasoning skills. The causal factors are listed as democratic child-rearing practices, authoritarian child-rearing practices, laissez-faire child-rearing practices, home educational support, quality of science teaching, primary mental abilities, scientific creativity, previous science grade, attitude towards science.

2. The hypothetical model is consistent with the empirical data.

3. There are some causal factors influencing scientific reasoning skills. The research hypotheses from the hypothetical model are as follows:

3.1 Democratic child-rearing practice has a positive direct effect on scientific reasoning skill. It also has a positive indirect effect on scientific reasoning skills by mediating through previous science grade, and scientific creativity.

3.2 Authoritarian child-rearing practice has a negative indirect effect on scientific reasoning skills by mediating through previous science grade, and scientific creativity.

3.3 Laissez-Faire child-rearing practice has a negative indirect effect on scientific reasoning skills by mediating through previous science grade, and scientific creativity.

3.4 Home educational support has an indirect effect on scientific reasoning skills by mediating through previous science grade, and attitude towards science.

3.5 Science teaching quality has a direct effect on scientific reasoning skills It also has an indirect effect on scientific reasoning skills by mediating through scientific creativity, previous science grade, and attitude towards science.

3.6 Primary mental abilities have a direct effect on scientific reasoning skills. It also has an indirect effect on scientific reasoning skills by mediating through previous science grade.

3.7 Scientific creativity has a direct effect on scientific reasoning skills.

3.8 Previous science grade has a direct effect on scientific reasoning skills.

3.9 Attitude towards science has a direct effect on scientific reasoning skills. It also has an indirect effect on scientific reasoning skills by mediating through previous science grade.

CHAPTER 2

Review of Related Literature

The research literature will be described and divided into 5 sections.

1. Scientific reasoning skills
2. Creative thinking
3. Primary mental abilities
4. Child-rearing practice
5. Attitude toward science
6. Factors related to students achievement

1. Scientific reasoning skills

1.1 Definitions of scientific reasoning skills

What are scientific reasoning skills? The term of "reasoning" referred to the human capacity to draw conclusions or to make inferences on the basis of known or assumed rational rules (Bullock. 1996a: 297). Similarly, Voss (1996: 464) stated that reasoning was the process by which an individual, given particular information, inferred some other information from what had been given. Piaget's seminal work equated scientific reasoning with the ability to think about one's own thought (Peasall. 1996: 56; citing Inhelder; & Piaget. 1958). Schafersman (1997a: Online) and Glynn, Yeany, & Briton (1991a: 3) stated that scientific thinking and critical thinking were the same thing. Scientific thinking was practiced and used by scientists within the problem solving context of investigation, meanwhile critical thinking was used by layman. Scientific reasoning skills could be called by other words such as the process of science, scientific process, inquiry skills, scientific method or scientific thinking (Hugh. 1985a: Online). Paul (2003: 2) claimed that scientific thinking was the mode of thinking about science content, subject, or problem in which thinkers could improve their thinking abilities. In addition scientific reasoning was self-directed, self-disciplined, self-monitored, and self-corrective. It could entail the effectiveness of communication, problem solving, scientific skills, scientific abilities, and dispositions. Friedler, Navhmias, & Linn (1990a: 173) stated that scientific reasoning included the ability to

a) define a specific problem

b) state a hypothesis

c) design an experiment

d) observe, collect, analyze, and interpret data

e) apply the results

f) make prediction based on the results

In short, scientific reasoning might be assumed to include any or all of the following (Shauable. 2003a: 155):

a) conceptual development

b) hypothesis testing

c) control of variables

d) theory changing

e) correlation, contingency, induction, generation, and interpretation of evidence

f) visualization, design of experiments, data modeling, causality, representational tools and notations

g) a graph of relationships like uncertainly probability, necessity and sufficiency.

In terms of scientific reasoning, Hugh (1985b: Online) argued that scientific reasoning was promoted not only in science education literature but also in other subjects. Scientific reasoning was not different from everyday thinking, it was a cognitive activity distinguished by precision, asymptomatic approach, and attention to logical rules, problem solving, and induction thinking. It was, however, distinguished from scientific understanding, but it could be developed and led to scientific understanding (Keselman. 2001b: 45, Kuhn, Eric, & O'Laughlin. 1988a: 10).

Steussy (1989: 2) presented a definition of science reasoning, which stems from the concepts inherent in Piaget's formal operations stage. He stated that scientific reasoning skills were composed of:

a) Denoting consistent, logical thought patterns which are employed during the process of scientific inquiry that enable individuals to propose relationships between observed phenomena;

b) Designing experiments for testing hypotheses concerning the proposed relationships;

c) Thinking through all possible alternatives and outcomes;

d) Considering probabilities of occurrences;

e) Predicting the logical consequences;

f) Weighting evidence, or proof; and using a number of instances to justify a particular conclusion.

Dunbar (2004: Online) described that scientific thinking referred to the thought process that were used in science. This cognitive process involved the theory generation, experimental design, hypothesis testing, data interpretation, and scientific discovery. It has been investigated in many aspects such as induction, deduction, analogy, expertise, and problem solving.

Padilla (1991: 205) declared that the terms of scientific reasoning or scientific thinking has been used to refer to scientific process skills, which in turn have been also described as scientific method and/or critical thinking skills. These skills were defined as a set of broadly transferable skills, appropriate to many science disciplines reflecting the true behavior of the scientist. Driver (1985a: 145) mentioned that scientific reasoning skills were based on observable features in a problem situation.

In summary, the meaning of the term "scientific reasoning" in this study was derived from the above definitions as well as from a consideration of nature of science, and aims of science education. Here, science was viewed as the body of scientific knowledge and process. Aims of science education were viewed as an establishment of generalizations the nature of science and the thinking process (IPST. 2003b: 4).

Thus, in the context of Thai elementary students, scientific reasoning skills in this study are the ability of students to:

1. ask good questions and recognizing the problems
2. formulate hypotheses
3. design an experiment
4. collecting data
5. explain and conclude scientific relationship

1.2 The importance of scientific reasoning skills

Scientific reasoning skills were important to science education, as Kuhn stated that

> Scientific thinking tends to be compact mentalized and varied as relevant and accessible only to be the narrow segment of the population who pursue scientific careers. If science education is to be successful, it is essential to counter this event, establishing the place that scientific thinking has in the lives of students. A typical approach to this objective has been to try to connect the content of science to phenomena familiar in students' every life. An ultimately more powerful approach may be to connect the process of science to think process that figure in ordinary people's lives". (Kuhn. 1993b: 333).

Scientific thinking has been proven to be the most reliable and successful method of thinking in human history, and it was used in other human endeavors. Thus, the application of scientific thinking was taught in school in all areas, and it was reasonable to believe that students could possess scientific thinking skills in a science class (Schafersman. 1997b: Online). The development of scientific reasoning skills has been the goal of many reform efforts in science education and in the preparation of science teachers. Huge (1982: 3) declared that scientific reasoning skills were very important in science education; science education could fail if the class cover the matter of scientific thinking skill. There were many national organizations such as the American Association of the Advancement of Science (AAAS) that advocated standard-based curricula program to foster the development of complex reasoning in science (Songer. 2004a: 2). In addition, scientific reasoning was the most powerful of all types of thinking available in disciplines of knowledge (Huge. 1985c: Online).

Scientific reasoning was connected to everyday thinking and it was very important for science education, as Kuhn, Amsel, & O'Loughlin. (1988a: 233, 1993: 333) proposed that if science educators wanted to be successful in science education, it was essential for them to integrated scientific reasoning into lives of all students on a daily basis. A typical approach was to create the science contents, just to make students familiar with it in their everyday life and also to try to connect the process in science to thinking processes in ordinary people's lives. In this information technology ages, there was much scientific information, which related to people's daily life. Absorbing scientific information requires some conception of what science was all about and some special skills in evaluating the information one receives. Hence, scientific reasoning skills were necessary for people if they wanted to take full advantage from scientific information.

Everyone can think and it was in human nature to do so. The quality of life depended on the quality of thinking. Thinking and reasoning in science were associated with the intellectual achievement and success in high school, college, and everyday life. Having a set of scientific reasoning tools as students leave 12th grade would be optimal, even for those who did not pursue science education beyond high school (Williams; et al. 2004: 108).

There were science education reforms in many countries emphasized on scientific thinking (Songer. 2003b: 2). As a result, researchers found that science education in Thailand did not succeed because learners lack scientific reasoning process skills and the failure to develop analytical and critical thinking ability. Therefore, the achievement of scientific learning was low (Bhumirat; & ONEC Working Group. 2001: 9). To solve this problem, the new national science curriculum that puts an emphasis on scientific reasoning skills was designed. In today's society, the need for all students to be able think scientifically included a need for basic understanding of scientific concepts, an ability to generate and evaluate scientific arguments, and an understanding of the manner in which scientific knowledge was generated (Lynn. 1999b: Online). An improvement in thinking has many advantages. Swartz & Perkins (1989: 24) suggested that to achieve better thinking, there were six aspects which should be covered:

1. Awareness of one's own thinking
2. Investment of effort in one's thinking
3. Attitude toward thinking process
4. Organization of thinking process
5. Development of sub skills
6. Smoothness in the thinking process.

According to these claims, science educators have long been in agreement that science education ought to be fostering scientific reasoning skills, while teaching of thinking skill had become a topic of wide spread interest and concern. It was important to teach scientific concept and develop scientific reasoning skills. To develop scientific reasoning skills, science teachers need to teach methods to reason scientifically, rather than merely scientific knowledge or concepts. Science would fail, if it did not address the issue of how to think. This way of thinking has become increasingly popular. (Hugh. 1982: Online, Kuhn, Amsel, & O'Laoughlin. 1988b: 9). Unfortunately, there was a very limited body of research to identify the specific nature of such skills to approach scientific thinking (Shauable. 2003b: 155).

As there were more sophisticated theories and models of science phenomena, in the science classroom, teachers should emphasize the science process rather than just the content because students who understood the process were better prepared to acquire science content on their own. This means that the teacher should help their students' reason scientifically. In fact, teachers and students should become elaborative in the process of scientific reasoning.

How scientific reasoning process develops in students was described by a cognitive model of scientific reasoning. When reasoning in working memory about the science phenomenon, the students draw upon relevant facts, principles, and skills stored in long-term memory. These skills should include the basics and integrated science process skills routinely performed by scientists working in many disciplines. The basic skills included observation, classification, and communication, metric measurement, prediction, and inference. The integrated skills included identifying variables, acquiring and processing data, analyzing investigations, constructing hypotheses, defining variables operationally, designing investigations, and experimenting. The final products of student's scientific reasoning were theories and models (Glynn, Yeany, & Briton. 1991b: 25). This claim is proposed in Figure 2

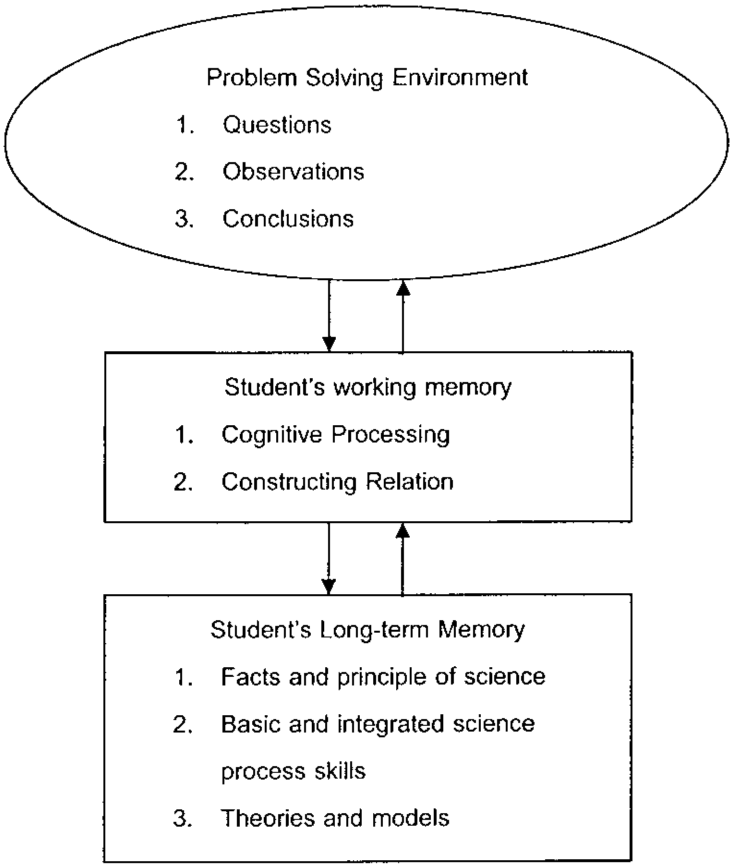

FIGURE 2 A COGNITIVE MODEL OF SCIENCTIFIC REASONING SKILLS
(Glynn, Yeany, & Briton. 1991c: 25)

Scientific reasoning skills were a process of special skills in evaluating information. These skills were necessary for taking a full advantage of the scientific information that was increasingly important for functioning effectively in professional and personal life (Driver; et al. 1996a: 17; citing Giere. 1991). Scientific reasoning skills were related to the nature of scientific knowledge. To understand the nature of scientific knowledge, Giere developed program for teaching scientific reasoning skills and developing an understanding of the nature of scientific knowledge by using the scientific reasoning model as described below.

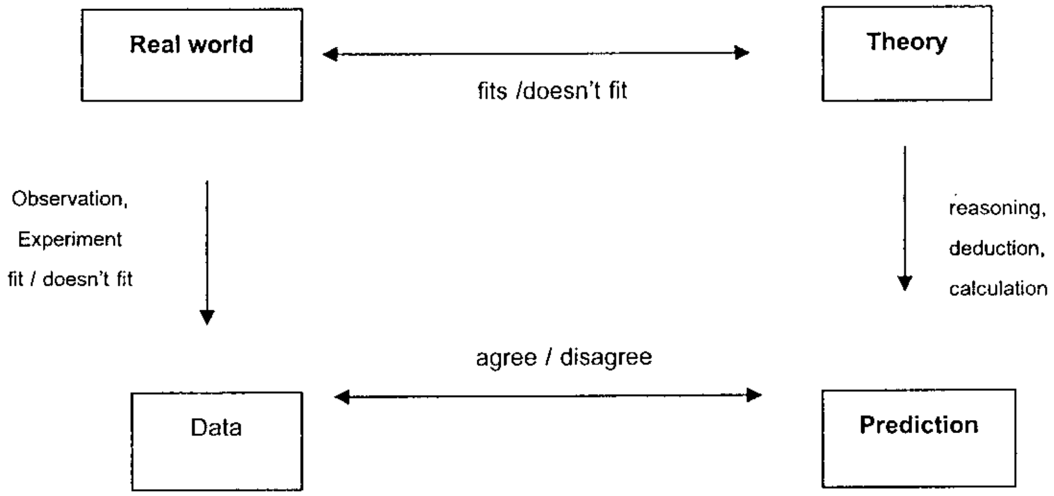

FIGURE 3 A MODEL OF SCIENTIFIC REASONING

(Driver; et al. 1996b: 17; citing Giere. 1991)

Scientific reasoning–both as it was studied by developmental psychologists and as it was taught by elementary school science teachers- could be classified along two dimensions: one representing the degree of domain specificity or domain generality, and the other responding the types of discovery processes, such as generality hypotheses, designing experiments, and evaluating evidence (Kalhr. 2000a: 123).

The need to develop scientific thinking skills was addressed in many researches. It was necessary for taking a full advantage of scientific information, which was increasingly important for functional efficiency in both academic performance and personal life. Teaching reasoning strategies per se has come to be seen as a narrow approach to science education. Scientific thinking was not a disembodied set of procedures that teachers could pass to students in a way that was disconnected to students' own thinking (Kuhn. 1993: 319).

1.3 Factors related to scientific reasoning skills.

Scientific reasoning was viewed as one kind of thinking which there were many factors relating to. Sternberg (1997a: 100) proposed his idea that there are 6 variables which effect to thinking.

1. Culture. In different cultures, there are different beliefs, which can take part in thinking ability. Different culture may use different languages. In the literature, there seems

to be an agreement among linguists that language does influence thought in various ways (Marlowe. 2004: Online).

2. Gender. Men and women can be socialized in ways that are so much as part of culture that people are hardly aware of how gender affected the way we think. Boy and girls babies; for instance, are treated differently from the time they are born. There has been a great deal of research conducted on gender differences and stereotypes of both regular and gifted students. Some studies have shown that at an early age, parents are the people who start the different treatment of males and females (Lynn. 1999c: Online). This might effect on student thinking and abilities.

3. Age. According to the study of Piaget, age is related to the stages of intellectual development. He concluded that young children think differently from older children and adults. However, later research has indicated that young children are not illogical and concrete in their thinking as Piaget claimed. Metz (1997b: 141) argued that children can think abstractly and are not limited to concreteness.

4. Parenting styles. What the parent encourages and rewards is likely to be reflected in the styles of the child. The parent exhibits a certain style, which the child is likely to emulate. The teaching role of the parent is unique and vital. Because parents are not classroom teachers, they have continuous opportunities to guide a child's intellectual growth. The earliest imprinting is attitude appreciation. The power of parent's supportive concidered as motivation for children immediate learning achievement has long been documented. Unfortunately, some of parents don't realize that science could be comfortably shared with the children (Harland; & Rivkin. 2000: 24).

5. School. Different schools give complements to different styles of thinking. Schools are socializing places, but it is surprisingly shown that a great deal of intellectual independence is not encouraged. At least it is not until the very highest levels of schooling, such as at a university level.

There are varieties of thinking. Sternberg (1997b: 19) claimed that people think in different ways. They have their own thinking styles. People who have styles that match what they expected in certain situations are judged by having higher level of abilities. The examples of thinking styles are:

1. Legislative styles. In this style, people like to come up with their own ways of doing things, and prefer to decide for themselves what they will do and how they will do it. Furthermore, they prefer to create their own rules and solve their own problems.

2. Executive styles. This style is opposite to legislative styles. In this style, people prefer to follow rules and problems that are pre-structure or prefabricated. In addition, they like to solve some given problems and apply rules to problems.

3. Judicial styles. People tend to evaluate rules and procedures, and prefer problems in which one can analyze and evaluate existing things and ideas.

4. Hierarchical styles. People tend to be complex and recognize the need to view problems from number of angles so they can set priorities correctly.

5. External individual styles. People tend to be extroverted, out going, and people oriented. They like working with other people whenever possible.

6. Internal individual styles. People tend to be introverted, and task oriented. They like to work alone, and apply their intelligence to things or idea isolated from other people.

In terms of schooling, methods of instruction are also concerned. Different methods of instruction work best for different styles or permit a wide range of behavior. Parents set few specific rules and allow the children much freedom and self expression. The instruction method which teachers always use in their classrooms could affect to students' thinking. This idea was concluded by Sternberg (1997c: 116)

1. Lecture Style. The lecture style is compatible with the hierarchical style in which students tend to be systematic and organized their solutions or problems before making a decision. As a result, students usually do not want to take everything that teachers say, but they tend to decide what the most important things that have been mentioned are.

2. Thought-based questions. The judicial and legislative styles of teaching can have an effect on students. They prefer to evaluate rules and procedures, judge things, as well as analyze and evaluate problems. Therefore, students whom are taught by this instruction method are more likely to compatible with thought based questions. However, it depends on the kinds and levels of questioning. If the questions require analysis and judgment, the questions are more likely to appeal to judicial students. If the questions require creative production, the questions are more likely to appeal to legislative students. This instruction method is commonly used in the classroom.

3. Cooperative learning. This method refers to learning as a group. It is likely to appeal considerably more to external than to internal students, because externals enjoy working in groups and actively seek them, whereas internals are likely to shy away from

groups and prefer to work individually. Therefore, the internal individual may find cooperative learning actually to be somewhat painful.

4. Project. It encourages students to express on their own in order to formulate their science experiments. It tends to be particularly welcomed by legislative students because of their interventions to the students who structure the task to be done by themselves.

5. Small group recitation. In the way, the teachers pose many types of questions to students. The students who are better in functioning with an executive manner will basically give the teacher expected answers and make them look better in a small or large group recitation. Shy students may be shy to speak out or assert themselves in front of the class. The teacher may misunderstand that students do not know the answers.

6. Small-group discussion. This method will be favored by the students who are willing to speak out in front of the group, and judicial students who like to analyze and discuss.

7. Reading. Actually, reading is not a style-free activity that flavors hierarchical students, because there is more to absorb in the material than the student can possibly remember. Therefore, the students need to decide selectively what materials are worth learning and what material is not. In addition, it will benefit either executive or judicial students, depending on the objective of the reading, which can be memorizing, or analyzing.

8. Memorization. It is largely the executive, local, and conservative activity. It is executive because students have to attempt to learn the material as presented. It is local because it involves committing to memorize the exact details. It is conservative because students have to absorb knowledge in the structure.

The importance of this analysis is that teachers have to concern themselves and need to use a variety of teaching methods to improve their students' thinking. The conclusions of the above ideas are summarized in table 1.

TABLE 1 THINKING STYLES AND METHODS OF INSTRUCTION
(Sternberg. 1997d: 116)

Method of Instruction	Style most compatible with each method of instruction
Lecture	Executive, Hierarchical
Thought-based questioning	Judicial, Legislative
Cooperative (group) learning	External
Problem solving of given problems	Executive
Projects	Legislative
Small group: Students answering factual questions	External, Executive
Small group: Students discussing	External, Judicial
Reading	Internal, Hierarchical

1.4 Assessing scientific reasoning skills

The call of thinking was evident in many education reforms. Since the attention of thinking is explicit in the late 1970s, with extensive accompanying research, educators have recognized that thinking can be assessed and then students' thinking abilities can be improved. By the 1990s, the call for higher level of thinking, particularly in the area of problem solving resounded from the workplace. The issue of all students working towards higher level of thinking was at the center of educational and political call for greater accountability to a higher set of standard (Kallick. 2001: 496). The question is that "What are the purposes for evaluating student's thinking?" Swartz & Perkins (1990b: 207) suggested that the purpose of measuring students' thinking abilities were:

1. Honoring and motivating achievement
2. Teacher assessment
3. School assessment
4. Help student recognize strength to preserve and weaknesses to repair.

5. Serve as basic for assigning different thinking activities or topics

6. Justification of the effectiveness of the particular methodology.

According to Beyer (1987: 217), there were 2 ways to assessing student thinking. Teacher could use paper and pencil test item, and observational techniques. Stiggins, Rubel, & Quellmalz (1988: 9) argued that the measurement of students' thinking ability could take many forms, some formal and informal, some individual and group, some standardized for all classroom and some for specific classroom context. Paper-pencils test, Oral questioning and performance test can be provided.

In terms of scientific reasoning skills which were similar to critical thinking, teacher can use critical thinking test to assess students' scientific reasoning skills. Mc Daniel (1994: 207) summarized the measurement of thinking which was based on everyday thinking. This belief proceeded from the way that provides an entirely new approach to the measurement of thinking. How we think was affected by what we were thinking about, and there appeared to be no substitute for expert knowledge in any given subject matter field. This point of view had implication on how thinking processes are measured. The examples of measurement thinking were standardized test of critical thinking. The two most commonly used thinking skill tests are:

1. Watson-Glaser Critical Thinking Appraisal. This is the oldest test and best-established measure of critical thinking. The manual shows a number of relatively high correlations with school ability and school achievement, but no direct evidence that the test is measuring thinking process.

2. Cornell Critical Thinking Test. This test is similar to Watson-Glaser Critical Thinking Appraisal. It can be used from grade four students through college sophomore students.

Paul (2003b: 10) clarified the universal intellectual standards which could be used for checking the quality of reasoning about problems, issues, or situations. He mentioned that to think scientifically entails having command of standardized criteria. The most significant standards areas shown in table 2:

TABLE 2 STANDARDS AND EXAMPLE OF THE QUESTION FOR CHECKING (Paul. 2003c: 10)

Standard	Examples of the question for checking
Clarity	Can students elaborate further on that point?
	Can students express that point in another way?
	Can students give the example?
Accuracy	Is that really true?
	How could students find out if that is true?
Precision	Could student give a more details?
	Could students give a specific point?
Relevance	How is that connecting to the question?
	How does that bear on the issue?
Depth	Is that dealing with the most significant factors?
	How does the answer reflect complexities in question?
Breadth	Do students need to consider another point of view?
	Is there another way to look at this question?
	What would this look like from the point of view, conflicting theory, hypothesis or conceptual scheme?
Logic	Does this really make sense?
	Does this follow from what has been mentioned?
Significance	Is this a central idea to focus on?
	Which set of data is the most important one?
Fairness	Are students misrepresenting a view with which student agree?

"How teachers choose the method of assessing student thinking" is an important issue. The method which teachers choose should be compatible with thinking styles and purpose of the assessment. Sternberg (1997e: 119) proposed various methods of assessing and main skills which were most compatible in Table 3.

TABLE 3 METHODS OF ASSESSMENT AND MAIN SKILLS TAPPED

Method of assessment	Main skills tapped
Short-answer and multiple choice test	Memory, Analysis, Time allocation, Working by self
Essay test	Memory, Macro analysis, Micro analysis, Creativity, Organization, Time allocation, Acceptance of teacher viewpoint, working by self
Project and portfolio	Analysis, Creativity, Teamwork, Working by self, Organization, High commitment
Interview	Social ease

1.5 Research related to scientific reasoning skills

The questions about human thinking ability were interesting as Klahr stated that

> The nature of human thinking is one of the "Big Questions" along with the nature of matter, the origin of the universe, and the nature of life. The behind of thinking we call "scientific" is of special interest, both for its' apparent complexity and for its products. Scientific thinking has enhanced our ability to understand, to predict, and control the natural force that shape our world. (Klahr. 2000b: 2)

The psychological research has produced opposing views of development of scientific reasoning skills with reasonable argument and supporting evidence on both sides.

On one hand were those who viewed the child as a scientist and on the other hand were those who viewed scientific thinking as a manifestation only in those with extraordinary mental skill and extensive formal view (Klahr. 2000c: 45).

The development of scientific reasoning skills encompassed two types of knowledge.

1. Domain-specific knowledge. It was about the natural world including substantive knowledge concerning particular domains (e.g. physics, biology and chemistry). One approach to studying the development of scientific reasoning has involved investigating the concepts that children and adults hold phenomena in various content domains in science such as biology, astronomy, and physics. The main focus has been on determining the naïve mental models or domain specific theories that children and adults hold about scientific phenomena and the progression of changes that these models undergo with experience instruction (Zimmerman. 2000b: 99).

2. Domain-general procedure for generating, assessing, and integrating knowledge including a complex set of cognitive skills used to support scientific discovery, the senses for hypotheses via induction, abduction, analogy, the design execution, and interpretation of experiments and the revision of hypotheses (Penner; & Klahr. 1996a: 2709, Klahr. 2000d: 46). They were involved in the discovery and modification of theory about categorical or casual relationships. These strategies included the general skills implicated in experimental design and evidence evaluation, where the focus was on the cognitive skills and strategies that transcend the particular content domain to which they were being applied. In these reviews of research, Voss, Riley, & Carretero (1995a: 155) classified scientific reasoning as a general intellectual skill. In this approach, scientific reasoning involved the application of the methods or principles of scientific inquiry to reasoning or problem solving situations (Koslowski. 1996: 45). In addition, this approach had historical roots in experimental psychology, in the body of research on reasoning and problem solving (Zimmerman. 2000c: 110).

Research on scientific reasoning used many different methodologies. Hence, most developmental scientific reasoning research had focused on one or the other components as shown in the Figure 4 (Klahr. 2000e: 55).

	Generating Hypotheses	Designing and executing experiments	Evaluating evidence
Domain specific knowledge	A	B	C
Domain general knowledge	D	E	F

FIGURE 4 DEVELOPMENTAL SCIENTIFIC REASONING SKILLS RESEARCH (Klahr. 2000f: 95)

Klahr (2000g: 95) also presented some examples of the investigation which were shown in various cells in table 4.

TABLE 4 AN EXAMPLE OF INVESTIGATION LAOCATED IN VARIOUS CELLS. (Klahr. 2000h: 95)

Cell(s) from FIGURE 4	Focus of Study	Reference
A	Domain-specific hypothesis generation. Participants are asked to make predictions or give explanations in a specific domain in order to reveal their intuitive theories of mechanical or biological phenomena. They are not allowed to run experiments, and they are not presented with any evidence to evaluate.	Carey. 1985; McCloskey. 1983
B.	Domain-specific experimental design. Participants are asked to decide which of a set of prespecified experiments will provide the most informative test of a prespecified hypothesis. There is no search of the hypothesis space and the experiment space search is limited to choosing from among the given experiments, rather than generating them.	Tschirgi. 1980.
E	Domain-general experimental design. People are asked to design factorial experiments in relatively sparse contexts. The use of domain-specific knowledge is minimized as is search in the hypothesis space and the evidence evaluation process.	Case. 1974; Kuhn; & Angelev. 1976; Siegler; & Liebert. 1975.
C & F	Domain-specific and domain-general evidence evaluation. Studies in this category focus on people's ability to decide which of several hypotheses is supported by evidence. Typically, participants are presented tables of covariation data, and asked to decide which of several hypotheses is supported or refuted by the data. In some cases, the factors are abstract and arbitrary—in which case we would classify the studies in Cell F—and in others, they refer to real world factors, such as studies that present data on plant growth in the context of different amounts of sunlight and water.	Amsel; & Brock. 1996; Bullock, Ziegler; & Martin. 1993; Ruffman, Perner, Olson, & Doherty. 1993; Shaklee; & Paszek. 1985.

TABLE 4 AN EXAMPLE OF INVESTIGATION LAOCATED IN VARIOUS CELLS.
(Klahrl. 2000h: 95) (Continued)

Cell(s) from FIGURE 4	Focus of Study	Reference
A&C	Domain-specific hypothesis generation and evidence evaluation. Children are asked to integrate a variety of forms of existing evidence in order to produce a theory that is consistent with that evidence. They do not have the opportunity to generate new evidence via experimentation, and the context of their search in the hypothesis space is highly domain specific.	Vosniadou; & Brewer. 1992.
A, C, & F	Domain-specific hypothesis generation and domain-specific and domain-general evidence evaluation.	Koslowski. 1996; Koslowski; & Okagaki. 1986; Koslowski, Okagki, Lorenz, & Umbach. 1989.
D,E, & F	In these studies, participants are presented with a complex mixture of covariation data, possible causal mechanisms, analogous effects, sampling procedures, and alternative hypotheses from which they are asked to make a decision about a potentially causal factor. People are given the opportunity to go beyond just the covariation data—that is, to use both their domain-specific knowledge as well as other domain-general features, such as sample size, in making their decisions	Bruner, Goodnow, & Austin. 1956 ; Wason. 1960

1.5.1 Scientific reasoning skills and age

Children could be compared to scientist because they were born with an ability to learn the way that scientists found out ability the world was found in the study of Driver (1985i: 15) and Brewer; & Samarapugavan. (1991: 6) and Samalapugavan (1992: 3). In Samarapugavan's study, she carried out two experiments to study children's use of four criteria for their own theory choice. The participants were students in the first, the third and the fifth grade. There were two experiments; the first experiment examined the use of three criteria (range, empirical consistency, and logical consistency) as bases for theory choice. In this experiment student was tested with three set of materials (two sets from the domain of astronomy and one from chemistry). In second experiment, they examined the use of the non-ad hocness criterion. The research suggested that children could evaluate explanations on metaconceptual criteria that played an important role in scientific reasoning. This ability could successfully be applied and could increase in age. In addition, the results supported the view that children could use the same kinds of metaconceptual criteria to evaluate ideas as scientists did in selecting among competing theories.

In a complex scientific concept such as density, sinking and floating objects, the proportional reasoning may be required to gain a full understanding of the concept. In the study of preschools' reasoning about density, Kohn (1993a: 1637) developed a buoyancy prediction task to access preschoolers' understanding of density, because the preschoolers were used to play with objects in water. The participants were 3, 4, 5 years old and adults. She concluded that 4 - 5 year old children had some conception of density. Children as young as 3 years old could show a mean proportion of correct performance. Both adults and children had a common sense on understanding of density.

In the same abstract concept of sinking objects, Penner; & Klahr (1996b: 2703) who studied in 10, 12, and 14 year old students. The goals of this study were to investigate developmental differences in the interaction between children's prior domain beliefs and experimental strategies. The context of the sinking object was used in this study. The object set consisted of eight objects designed in various long three dimensional shapes (cube or sphere), size (large or small), and material (stainless steel or white Teflon). There were four-phase structured interviews in the experiment; initial questions and probes, sinking predictions, experimentation, and consolidation and summary. The results in this study were similar to Kohn's study. They found a growing ability with age to hold prior beliefs in abeyance in order to determine the effects of all attributes. That is, younger children could construe experimentation as a request to demonstrate the correctness of their initial belief. The older children attempted to investigate the effects of attributes other than those implicated in their initial beliefs. These results of the study were not in line with Piaget's Child development theory who claimed that the density concept was a difficult concept. The children could not truly understand this concept until the stage of formal operation (Kohn. 1993b: 648).

Another abstract scientific concept which was studied in order to investigate scientific reasoning skills was the concept of interaction of force (vectors). Puaen (1996: 2782) studied the advance understanding of movements caused by more than one physical force. In this concept, children must learn to combine force vectors. In order to test the hypotheses "Children consider information as only one aspect", 160 elementary school students and 31 adults judged the effect of two forces pulling at one object simultaneously. She founded that the performance generally improved along with age. This result paralleled the finding of earlier studies in children use of multidimensional information in different areas of reasoning.

In a similar study, Bullock (1985b: 1) studied the second and the forth grade students. There were two goals of this study. First, to investigate how children performed on task that taps two components of scientific reasoning: constructing an empirical test, and interpreting evidence, and how the components change in the school years. The second goal was to identify the sources of individual differences. In improving the students' scientific reasoning skills, the story about making the later was introduced as a problem solving situation with pictures and texts. These hypotheses were tested through card choice task in which children were asked to choose a set of objects that would provide a critical test. And the last hypothesis involved testing an ability to formulate hypothetical perspective. For this, children were asked to contrast how outcome would vary where the focal dimension did or did not make a difference. She found that at least the fourth grade students had a conceptual understanding of what an experimental test entails. They also adopted hypothetical perspective to discuss how outcome would vary. In first grade students they understood some requirement for an experimental test, prepared a contrastive empirical test and used information for testing. Moreover, logical skills were related to performance in the second grade students and the performance level additionally related to intelligence quotient (I.Q).

Studies in the field of learning often use the cognitive visual conflict to study the effectiveness in encouraging conflict situation and cognitive change. The effectiveness of cognitive kinetics conflict on developing of thinking is rooted in Piaget's Theory. Druyan (1997b: 1083) conducted her study with two groups of students aged 4.5-5.5 years old and 5-15 years old in order to investigate the effect of the kinesthetic conflict. Concept of balance was conducted in 5-6 year old students and the final concepts, concept of speed, was conducted with sixth grade students. Pre-test and post-test one group design was the research design in this study. The results support Piaget's theory which determined that scientific thinking began with the sensomotoric experience of the physical surrounding.

In an analogous result, Shrempp; & Sodian (1999: Online) studied scientific reasoning in elementary school age children which involved the ability to test hypotheses and evaluate evidence. The finding indicated developmental progress during this age and this knowledge rich domain offer a new outlook on evaluating the "child as a scientist" metaphor. Kuhn (1989: 45) has argued that the conceptualizations used by a child, a lay man, and the scientists were significantly different. The manner in which existing theories were coordinated with new evidence may not be the same in the child as it was in the adult or in the scientist.

In children, Sodian; et al. (1991b: 753) studied whether young elementary school learners could distinguish between the notion of hypothetical belief and evidence. Two experiments were carried out in 20 first grade students and 14-second grade students.

In the first study, students were read a story about a boy and a mouse, and then followed with the questions. The answers were classified into five response patterns in order to assess children's ability to choose between alternative hypotheses in an artificially contrived world. In the second study, the children were posed with a genuine scientific problem. The results indicated that young elementary school learners in both first and second grade could distinguish between the notion of hypothetical belief and evidence. These results were similarly to Ruffman; et al. (1993b: 103) who examined children's understanding of the role of covariation evidence in a hypothesis formation. Three experiments were employed with different techniques. In the first experiment, hypothesis-evidence task was tested in 16-four year old students. In the second experiment, two purposes were designed, to rule out an alternative interpretation for the results in experiment 1, and to examine children' understanding of imperfect evidence. In the last experiment, there were four purposes; to rule out an alternative interpretation for the results in experiment 1and 2, to concern the relation between false belief tasks and fake evidence task, to directly compare the differences between the way children's understanding of the hypothesis evidence relation in experiment 1 and 2, and to ensure that students in both experiment 1 and 2 really did understand the way in which exposure to a particular state of evidence would lead to the formation of particular hypothesis. The results pointed out that by as early as 6 years of age; children could possess some understanding of a very basic prerequisite that was needed to properly understand much of science. In addition, the children had metacognitive abilities to allow them to form hypotheses from the evidence given in a appropriate context. In contrast with these results, Kuhn (1989: 674) argued that young children had limited metaconceptual understanding and lack the fundamental differentiation between the notion of theory and evidence.

Vassniadou; & Brewer (1994: 123) investigated elementary school children's explanation of the day and night cycle in order to answer the question whether children could form initial mental models which provided explanations of everyday experience (day/night cycle), The participants were the first, the third, and the fifth grade students. The students were asked to explain the certain phenomena, such as the disappearance of the sun during the night, the disappearance of the star during the day, the apparent movement of the moon, and the alteration of the day and the night. The results demonstrated that the younger children could form initial mental model to provide an explanation. The older children could even construct a synthetic mental model.

According to the above research, we can conclude that scientific reasoning skills were frequently studied in young children such as, preschool students and elementary school students. Scientific reasoning skills could be improved along with age. Most of the results were in lined with Piaget's study. Moreover, there are other factors that related to scientific reasoning skills. Gender considered as one of the factors will be focused in the next section.

1.5.2 Scientific reasoning skills and gender

Gender has been regarded as an important aspect of scientific reasoning (Voss, Riley, & Carretero (1995b: 160). This topic was studied by Burbules; & Linn (1988: 65). The 13 and 14 years old students were participants in this study. The scientific concept of water displace volume was used in order to examine how students remember their scientific ideas. They found that cognitive restructuring in relation to specific evidential input apparently varies as a function of a number of factors. They were also concluded that girls should be encouraged to use analogical reasoning processes to improve their making prediction skills. Moreover, by using analogous tasks in training sessions, four and five years old children were able to construct the concept from working experience (Klahr; & Zhen. 2003: 1280).

Gender was one of the significant the variables of students' achievement including scientific reasoning skills. Science and mathematics were the most subjects affected by gender. There were many science educations researched studied on this topic, and found that girls' achievement in science is less than those of boys', so that there was few girls taking courses in science when they were at higher education level (The International Study Center. 2004: Online).

1.5.3 Scientific reasoning skills and teaching approach

The idea that science educators ought to teach methods of scientific thinking, rather than merely scientific knowledge or concept, has become increasingly popular (Kuhn, Amsel, & O'Loughlin. 1988c: 15). Lehrer; & Schauble (1998: 4) conducted their experiments in the second and the fifth grade students. In order to examine their scientific reasoning skills, the students were interviewed about how gear is shifted and work. The older students could formulate their reasoning into more general rule, formal and mathematical.

A context based-on technology and design was a fruitful way to develop students' scientific reasoning, testing, and revising hypothesis. Strategies and specific knowledge context were important elements in the development of scientific reasoning skills (Schauble. 1996: 105, Schauble; et al. 1994a: 142). These findings wee in line with the studies of Kuhn; et al. (1992a: 523) who studied two domains. Pre-tested subjects in each of the two domains were tested in order to understand the scientific reasoning process during self directed investigation of the fourth, fifth, and sixth grade students. This study also identified reasoning strategies across content domain. Doing exercising and appropriate teaching approach could develop students' scientific reasoning skills. Scientific reasoning skills could also be developed from a domain-specific content in which they were situated (Kuhn; et al. (1992b: 523). Thus, science educators should encourage their students to think scientifically as Kuhn stated that

> While the teaching of thinking skills has become a topic of wide spread interest and concern, science educators have long been in agreement that a major goal of science education ought to be fostering skills of scientific reasoning" (Kuhn, Amsel, & O'Loughlin. 1988d: 125; Kuhn. 1993d: 86).

The experiment played a central role in both popular and philosophical views of scientific practice. It occupied a center stage in framing expectations about student activity and reasoning in a science classroom. Moreover, experimentation in a complex form of argument was deeply embedded within domain-specific practice of modeling, representation, and material of world (Lehrer; & Petrosino. 2001: 44). Bullock; & Ziegler (1993: 5) studied whether students in the second – the fifth grade had a conceptual understanding of experimental control. To address this issue, three tasks were presented; story task, spring task, and forest task. In each of the three tasks, students were asked for two measures. Firstly, for production measure, in this task children were asked to test potential causal relation in a multivariable situation. Secondly, for choice / evaluation measures, children were asked to choose or evaluate tests made by hypothetical. They found that although students posed the conceptual ability to construct control test, they didn't engage this understanding in their own product. This meant that children acquired a conceptual understanding of the logic of experimental control during the grade school years, but could not apply this understanding when actively producing experiments. After training, they could improve their performance.

To study the transfer of scientific reasoning skills, Kuhn; et al. (1992: 288) studied the scientific reasoning process during self directed investigation and identification of reasoning strategies across content domain in the fourth through the sixth grade students. The specific goal was to identify reasoning strategies across content domains and to examine to the extent in which development takes place across domains. The pre–test of both problem domains (boat and car domain) was tested. Then, they were followed by problem solving sessions for a period of nine weeks. The final assessment was provided after the instructions. The findings indicated that learning occurred in both domains. Exercise and appropriate instruction (facilitator) could develop scientific reasoning skills. In other words, scientific reasoning skills could develop from a specific content in which they were situated. The instruction would be more effective if opportunities are provided in the classroom. By doing so, it can help foster complex thinking, understanding, and scientific reasoning. The teachers should teach scientific process skills in the context of curricula, as well. Without changing the curriculum, there were substantial opportunities for teachers to provide instructions about experimentation (Shauable; et al. 1994b: 145).

Other intervention studies have demonstrated that this facilitates in scientific reasoning. The previous two approaches have used different types of tasks that emphasized either conceptual knowledge or experimental strategies. Since science could be recognized as both a product and a process. Klahr; & Dunbar (Zimmerman 2000c: 101; citing Klahr; & Dunbar 1988) recognized the importance of both product (concept formation) and process (experimental design or evidence evaluation skills). They developed an integrated model to incorporate domain-general strategies with domain specific knowledge. This was called scientific discovery dual space model (SDDS model). In this model, Klahr; & Dunbar perceived scientific reasoning as a problem-solving skill that is characterized as a guided search and information gathering task. It was also a complex activity that requires the coordination of several higher level cognitive skills, including heuristic search through problem spaces, inductive reasoning, and deductive logic. In their experiments, they used undergraduate students with and without programming experience to search both hypothesis space and experimental space while solving a problem, and explained how the search in one space affected the search in the other. They asked the subjects to formulate hypothesis about how a new function (repeat key) of a computer-controlled robot tank (call Big Track) worked and then performed the actual experiment (program), in order to find out how the new device key exactly represented the repetition command. The use of a thinking-aloud method allowed the researchers to analyze the interaction between the hypothesis-formation and experimental-design phases of the problem-solving process. They found that the subjects who tested hypotheses performed a learning task better.

Klahr; & Zhen (1999: 1098) conducted the study, which addressed an important issue in scientific reasoning and cognitive development. The questions of this study were how children acquire a domain-general processing strategy (Control of variable strategy) and generalize it across various contexts. They used three conditions; explicit instruction and probing questions, probing questions with no explicit instruction, no probing questions, in second, the third and the forth grade students. The pre-and post test performances were analyzed. The finding indicated that with appropriate instructions, elementary school children are capable of understanding, learning, and transferring the basic strategy when designing and evaluating a simple test. Strategies also facilitated the acquisition of domain specific knowledge. The power of this approach depended on the learning context, children's age and initial knowledge.

The recent study of Klahr; & Zhen (2003b: 1275) confirmed these results. The objectives of this study were to examine whether and how four and five years olds learn to distinguish determinate from indeterminate evidence. The participants were four – five years old. Children were asked to decide whether various patterns of evidence were sufficient to reach unambiguous conclusion. Two experiments were conducted in this study. The first experiment was to determine whether preschoolers' use of the positive-capture strategy could be reduced by embedding indeterminacy problems in pragmatic contexts.

The second experiment was to investigate children's performance on a particularly difficult acquisition. The first experiment demonstrated that the positive-captured strategy was deeply entrenched, even in a meaningful, pragmatic context. The second experiment revealed that young children are capable of replacing the positive-capture strategy with a correct strategy when they are exposed to various analogous tasks in several training sessions. According to both of these experimentations, they concluded that with structured experience and instruction, even five years old can master fundamental concept of impertinency. They favored rich and varied content, in early science rather than a consistent underlying structure.

When students studied science, not only were they distinguished by varieties of conceptual knowledge and reasoning skills, but also by differences in the conditions or contexts in which reasoning occurs (Wong. 1996: 1). Wong studied in sixteen of seventh and eight grade students for 18 weeks. These students were identified by their teachers as severely disruptive, and academically at risk. He used the nontraditional ways to encourage the students to generate, elaborate, share, evaluate, and modify their own ideas. He examined the students' in the context of their prior knowledge and the available empirical data complicated by the traditional distinction between students' and scientists' explanations. He concluded that learning particular discipline might not always benefit individuals in situation outside the scientific community. Since the students did not go on to become scientists, the challenge to science educators was to examine closely the nature of scientific reasoning as it does and possibilities to occur in other context.

Teacher guide discussion was also an important pattern of promoting scientific reasoning. Hogan, Nastasi, & Pressley (1999: 379) studied discourse patterns and peer collaboration in scientific reasoning and teacher-guided discussions. In this study, they examined the discourse components, interaction patterns, and reasoning complexity of 4 groups of 12 of the eighth grade students in 2 science classrooms as they constructed mental models of the nature of matter, both on their own and with teacher guidance. Interactions within peer and teacher-guided small group discussions were videotaped and audiotaped, then transcribed, and analyzed in a variety of ways. The key act of participants in both peer and teacher-guided groups was working with weak or incomplete ideas until they are improved. The accomplishment somewhat depended on the presence or absence of a teacher in the discussion. Teachers acted as a catalyst in discussions, prompting students to expand and clarify their thinking without providing direct information. Teacher-guided discussions were a more efficient means of attaining higher levels of reasoning and higher quality explanations, but peer discussions tended to be more generative and exploratory. Students' discourse was more varied within peer groups, and some peer groups attained higher levels of reasoning on their own.

Friedler, Nachmias, & Linn (1990b: 173) studied learning scientific reasoning skills in microcomputer-based laboratories. In this study, the definitions of scientific reasoning skills were the abilities of define scientific problems, state hypotheses, design an experiment, collect data, apply results, and make prediction. The study was to investigate the impact of enhanced observation or enhance of prediction on scientific reasoning about heat energy and temperature problems. The participants were eighth grade students. A microcomputer-based laboratory curriculum was designed to develop scientific reasoning skills. They found those equal gains for the observation and prediction conditions on (a) subject matter knowledge, and (b) ability to use scientific reasoning skills to solve problems. Using learning cycle for teaching science was often found in science education research. The learning cycle was implemented in order to promote scientific reasoning skills of the ninth-grade physical science in a Midwestern city (Westbrook & Roger: 1994: 65). The study was designed in order to test the hypotheses that descriptive learning cycles are neither sufficient to stimulate students to reason at a formal operation level nor to encourage a level of comfort with the process of scientific investigation. A six week long investigation unit on a simple machine was provided. There were three instructional groups; descriptive group, question design group, and hypotheses testing group. The effect of the treatment was assessed in pretest-posttest format using Lawson's Seven Logic Task, the Test of Integrated Process Skills, and Lawson's Revised Classroom Test of Scientific Reasoning. The results indicated that the hypotheses testing group exhibited a significant increase on the test of integrated process skills and on the task of the seven logic tasks.

The further study of Keys (2000: 676) focused on laboratory report writing. This study examined the thinking processes used by 16 eighth grade science writers during laboratory report writing and explored the possibility that writing could contribute directly to science learning. Using Bereiter and Scardamalia's knowledge-transformation model of writing as a theoretical lens, the study characterized a specific content and rhetorical thinking which are engaged in by the students using think-aloud protocols and qualitative data analysis methodologies. Thinking aloud was also related to the quality of the students' written products. She found that 5 out of the 16 students exhibited no mental reflection during writing, recording information straight from memory into the composition. Two students engaged primarily in rhetorical planning, specifying the sequencing and organization of their writing in advance. Nine students demonstrated scientific problem solving skills such as forming hypothesis and giving evidence, examining generization in the data, and making general knowledge claims in response to the need to generate content for writing. This indicates that the act of report writing could directly stimulate science learning however, thinking during writing was not necessary to compose a report that contained hypotheses and supporting evidence.

Science teaching was a complex activity that is a key to the vision of science education. To improve student achievement in science, educators must engage students in a deeper understanding of science concepts. The question that needs to be raised is that "What kind of teaching can improve student conceptual understanding of science as well as their basic skills" was an important question.

It becomes an issue that educators should try to develop their science teaching skills and engage their students to learn science by doing science (Cain. 2002a: 10). A growing amount of research mentioned suggested some types of teaching can improve students' scientific reasoning skills. To attain the vision of science education as described, appropriate teaching styles are needed in the entire system.

1.5.6 Scientific reasoning skills and peers

Developing a student's skill was an important part of elementary education, and teaching science could make a contribution to this in several ways. First, science instruction could help students develop domain general knowledge of scientific reasoning skills. Second, when the students used laboratory equipments, they developed psychomotor skills. Third, science experiences could contribute to the development of other skills: mathematical, reading and communicative skills. Development of scientific thinking skills are a major goal for science education. Hence, science instruction should develop the ability of constructing understanding and evaluating ideas, rather than passively accepting scientific information (Bybee; et al. 1989a: 9; Hogan. 1999a: 1085). Such increasing instruction approach as inquiry-based learning, problem-based learning, interdisciplinary approach, including the interaction among students, peer collaborations, and kinesthetic-conflict required the entire system to develop scientific understanding and scientific reasoning (Druyan. 1977b: 1083; Hogan 1999b: 1089; Teasley. 1995a: 207).

An intervention stressing the metacognitive and strategy aspect of knowledge co-construction, called Think Aloud Together, was embedded within 12- week science unit on building mental models of the nature of matter in four classes of eight grade students. Pre-post test, one group design was conducted. Four classes of eighth graders received the intervention, and four served as control groups for quantitative analyses. In addition, the interactions of 24 students in eight focal groups were profiled qualitatively, and 12 of those students were interviewed twice. Students who received the intervention gained metacognitive knowledge about collaborative reasoning and ability to move their collaborative reasoning processes than those in comparison to students in control classrooms, as hypothesized. However, the treatment and control students did not differ either in their abilities to apply their conceptual knowledge or in their on-line collaborative reasoning behaviors in ways that were attributable to the intervention. Thus, there was a gap between students' metacognitive knowledge about collaborative cognition and their use of collaborative reasoning skills. The results indicated that students who received the intervention gained more metacognitive knowledge about reasoning in comparison to students in the control classroom (Hogan. 1999c: 1085).

In recent years, there has been a great deal of discussion about the most effective and efficient ways to group students in order to raise their levels of achievement. Moreover, teachers recognized that learning increases when students are encouraged to interact with their peer by asking questions, sharing ideas, and working together to investigate meaningful science questions (Bybee et al. 1989b : 16; Gega. 1991: 9; Suknandan. 2000: 123; Cain. 2002b: 8). The role of talking in children's peer collaboration using a computer-based scientific reasoning task was investigated in study of Teasley (1995b: 209). Seventy of fourth grade students were assigned to work alone or with a same sex partner during a 120- unit session. Significant performance differences between the two groups were found.

Similarly, peer discussion could facilitate students' ability to acquire concepts and scientific reasoning. Collaborative writing and laboratory reports could develop scientific reasoning skills. This claim has been inquired in six ninth-grade general science students by Keys (1994: 1003). Ten laboratory reports over a 4.5 month period were written for evidence of the use of scientific reasoning skills and document qualitative change in reasoning skills. The results indicated that most improvement in their writing reflected the reasoning skills. Collaborative writing encouraged students to construct their own understanding of science concepts by creating an environment in which thinking reasoning and discussion were valued.

In summary, the values of peers can play an important role in students' educational experiences and outcomes. The findings summarized above were based-on scientific reasoning skills. To achieve any improvement in both scientific reasoning skills and science concept, motivation of peer relationship among students in science classroom has to be concerned.

1.5.7 Scientific reasoning skills and student's achievement background

The strategies and specific knowledge could develop scientific reasoning. It means that the appropriate knowledge could support the selection of approval experimental design strategies and valid experimentation could also support the development of more accurate and complete knowledge (Shauable. 1996: 67). Hence, some of the researchers both in psychological and science education fields have demonstrated which interaction in order to facilitate students in scientific reasoning. Shauable; et al. (1991: 201) has demonstrated that strong and weak learners use different strategies in solving electrical circuit problem. The participants, 22 undergraduate students with no formal college instruction in physics work individually on an initial problem to access their conceptual models of circuits and in subsequent sessions on an open-ended experimentation with the computer laboratory, attempted to rediscover the laws of electric. Relations were found between students' causal models and their learning gaining in the computer laboratory. The results showed that the good learner were superior in the planning and the control of variables than the weak ones. In addition, they were able to generate hypotheses, in which a greater proportion was correct, and they were better at data management.

In conclusion, scientific reasoning skills are the same as other skills, which can be improved by a good science content background. Moreover, scientific reasoning skills are not different from everyday thinking as Kuhn's study observed. Improvement on students' achievement in other subjects can improve scientific reasoning skills, as well.

1.5.8 Scientific reasoning skills and science curricula

While many science curricula interventions focused on fostering scientific inquiry, much research in science education and the sciences learning suggested that the inquiry skills and complex reasoning science required a longer amount of time than many science education reforms. In most countries are developed through nation science curriculum which emphasized on scientific thinking and content knowledge. Even strong curricular programs, research diagnosing students' scientific thinking revealed that students' understanding was incomplete (Songer. 2003c: 3). The Biokids: Kids' Inquiry of Diverse Species, curricula units were developed by Songer in order to foster student's complex reasoning skills among 5-8 grade students. The topics of biodiversity, weather, and motion were provided in this curricular. In this eight-week unit, particular inquiry thinking skills such as the development of hypothesizing were fostered through a carefully scaffolding activity sequence. The research results demonstrated that an assessment system that was sensitive to the development of students' complex reasoning with complex reasoning.

Another example of developing science curricula in order to promote scientific reasoning skills was belonged to the project of The Cornell Institute for research on children science education program. A new educational program was developed by the Cornell Institute for Research on Children (CIRC), a research and outreach center funded by the National Science Foundation. Thinking Like a Scientist targets students from a group of people who historically underrepresented in science (i.e., girls, people of color, and people from disadvantaged backgrounds). They are trained individually to reason scientifically about everyday problems. This contradicts programs such that was content based which relies on disciplinary concepts and vocabulary within a specific domain of science (e.g., biology), Thinking like a Scientist was domain-general and it attempts to promote the scientific reasoning. The test did not focus on the specific content of science lessons; it rather aimed at measuring scientific reasoning skills. The full evaluation will be reported later (Wiliams; et al. 2004: 107).

In conclusion, there are many institutes concerning about science curricula. Development of science curricula for fostering thinking skills and reasoning skills could be founded in many countries including Thai science education. To achieve the objectives of science teaching and to improve higher order thinking skills, it is important for teacher to know how to design the test. The factors that related to scientific reasoning skills are not only student and schools factors, but also parents' factor which will be focused in the next section.

1.5.9 Scientific reasoning skills and parents

The technique that researchers should use to capture explanatory conversation is to observe families in a setting that provide motivation for parents and children to talk about scientific events Gleason; & Schauble (1999: 343) studied parents' assistance given to children while conversing scientific reasoning. In this study, 20 dyads of parents and their preadolescent children spent 45 min solving a scientific reasoning problem that entailed generating and interpreting a series of experimental trials to understand the causal structure of a moderately complex system. As the dyads worked, the researchers tracked their experimentation strategies, patterns of interaction, and changes in their domain-specific beliefs about the system. In comparison to solo participants observed in previous research, the dyads performed well on strategies for generating and interpreting evidence. However, parents assumed that there are many of the difficult conceptual tasks, including recording data and making inferences, and delegated the logistical roles-the actual manual operation of the equipment-to the children. Parents did not cede the conceptual roles to children as the session progressed. On the positive side, parents shared control of the problem solving and engaged in collaborative discussions with their children. Parents also provided valuable assistance of many kinds, usually during the evidence-generation phase of the trials. They missed key opportunities for helping children interpret evidence, and as a result, children failed to achieve the gains of understanding that the parents did. The beliefs of parents and children did not come into closer alignment over the course of the study. In summary, especially as children reach school age, parents who wished to assist their children's learning may increasingly need to understand how their children think-not just in general, but specific kinds of problems and content domains.

Crowley; et al. (2001: 712) studied parents-child interaction in a child museum which emphasized the role of parent in structuring children's everyday scientific reasoning and in facilitating the construction of children's everyday scientific theories. The participants were 91 families with children between 4- and 8- years old. Data were collected on four separated days. Video camera and wireless microphone were use to collecting data. The research focused on each child's ability in integrating data collection and evaluation of evidence with the creation of theories to explain the evidence. The result demonstrated that parents shaped and supported children's scientific thinking in everyday, nonobligatory activity. When children engaged in an exhibition with parents, their explorations of evidence were observed to be longer, broader, and more focused on relevant comparisons than those who did so without their parents. Parents were observed too while talking to children about how to select and encode appropriate evidence and how to make direct comparisons between the most informative kinds of evidence and parents also sometimes assumed the role of explainer. Children's experience was casted in causal terms. This experience was also connected to prior knowledge, and was introduced abstract principles. The findings were discussed with respect to two dimensions of children's scientific thinking: developments in evidence collection and developments in theory construction. The findings also indicated that parents who provided children with informal scientific activities develop an engagement of students not only in learning science but also in practicing scientific reasoning.

In the same year, Crowley; et al. (2001: 258) studied whether parents explained more often to boys than to girls while using interactive science exhibitions in a museum. Explanation included causal relations, analogies, and scientific principles. This study was motivated by the previous research showing that when children, undergraduates, or professional scientists focus on building explanations during scientific thinking, they developed more coherent theories, and were better at interpreting evidence and at applying knowledge to solve new problem. The participants were 298 interactions which came from different families. Of the 185 families, the youngest boy was involved 1-3 years old in 88 families, 4 -5 years old in 66 families, and 6-8 years old in 31 families. Of the 113 families with girls, the youngest girls was 1-3 years old in 43 families, 4-5 years old in 41 families, and 6-8 years old in 29 families. Video camera and wireless microphone wireless were used at 18 interactive science exhibitions in California children museum. It was shown that, in the exhibition, the content from biology, physics, geography, or engineering could be manipulated by a single child. Data was collected in 26 days. The results showed that parents were three times more likely to explain science to boys than to girls while using interactive science exhibited in museum. The findings also suggested that parents engaged informal science activities with their children may be unintentionally contributing to a gender gap in children scientific literacy well before children encounter formal science instruction in grade school.

Gleason (2000: 5) provided the further study, which focused on parent child interactions. Three different treatment conditions were applied to help parents effectively assist their children's learning. Together, parent-child dyads solved a moderately complex problem -- a scientific experimentation task -- less than one of three different treatment conditions (13 dyads in each condition). These conditions were enhanced versions of the three common approaches to helping parents effectively assist their preadolescent children's learning: (a) providing opportunities and encouragement for an involvement, (b) giving specific directions for completing an activity with the child, and (c) helping parents learn how a child typically reasons about the problem to be solved. The three interventions were provided via a brief letter and three short video clips that exemplified the main points of each letter. Problem solving strategies forms dyadic interaction, and categories of parental assistance were recorded for each group. Dyads in the "models of children's thinking" intervention were more likely use advanced problem solving strategies than those in the other two groups and to interact in a way that encourage children's learning, and to provide a variety and forms of assistance. Further, these parents apparently carried over the advice into the second, similar task, because the "models group" maintained their advantages over the other two groups in a second task. These results implied that educators who wanted to help parents assist their children should help parents understand basic ideas about children's domain-specific thinking, because this kind of information helped parents to tailor their assistance to their children's thoughts and focused parents on children's learning rather than their mere performance.

The two aims of science conceptual development and reasoning process are controversial in science education. Science education did not clearly answer the question about the appropriate relative emphasis on learning scientific concepts versus acquiring reasoning skills and strategies (Shauble. 2003c: 155). Developing scientific reasoning skills and scientific concept were interlinked. The point of science education was to enable students to understand the world around them and to enable them to be able to adapt to a rapidly changing world. Although the contents of the subject had changed, teaching methods had developed a little in response to the new understanding about what students have learned and new technology has become vital and available to support both teachers and students, the teaching yet remained emphasizing on knowledge and concepts of academic subjects.

In brief, parents affect students' life and learning. Interaction between parents and child in their daily activities can promote students' scientific reasoning skills. Scientific knowledge is cumulative. So, it's important that the child should start learning early—and at home. According to the research, a good way for parents, to begin the learning process is by sharing their own interests in science. How parents view and talk about science can influence child's scientific reasoning skills.

Learning science is something they should do, not something that has to be done to them. By letting students experience a practical work for themselves, they gain experience in coping with problems, coming up with ideas and developing their scientific reasoning skills. (Shauble. 2003d: 157). How can teachers be aware of students' performance? How can teachers implement assessment strategies which are appropriate to the learning context and students? These are questions which teachers should be concerned. Science teachers should devise and develop techniques to assess student achievement in science such as their use of scientific reasoning skills. To achieve this aim, the researcher is interested in developing scientific reasoning skills test for Thai fourth grade students in the context of Thai culture and classroom environment.

2. Creative thinking

The psychology of creative thinking was first researched in the 1950s. In 1950, The American psychologist Guildford, J.P gave a lecture on creative thinking or creativity to the congress of The America Psychological Association which stimulated interest in this aspect (Duric. 1989a: 102).

2.1 Definition of creative thinking

Since the 1950s psychologists have been concentrating on the question of creativity, hence, there were many definitions of creative thinking.

Puccio; & Murdock (2001: 5) declared that the terms of creative thinking were different from creativity. They were conceptual related but not identical. Creativity was an umbrella construct that subsumes creative thinking.

Torrance's classic definition of creative thinking also provided a clear description of some behaviors that were illustrative of creativity. Torrance (1969: 16) defined creativity broadly as the process of sensing a problem, searching for possible solutions, formulating, testing and evaluating, and communicating the results to others. In addition, he added that the process includes original ideas, different point of view, breaking out of the mold, recombining ideas or seeing through new relationships among ideas.

Guilford (Benjamin. 1984a: Online; citing Guildford. 1973) established his idea about creative thinking process. He explained that the creative thinking stages were not necessarily distinct and usually involved complex recycling. The 5 stages were:

1. Preparation is the stage of acquiring skills, background information, resources, recognizing and defining a problem.

2. Concentration refers to the stage of focusing intensely on the problem to the exclusion of other demands such as a trial and error phase that includes false starts and frustration.

3. Incubation is a stage of withdrawing from the problem; sorting, integrating, and clarifying at an unconscious level; often includes reverie, relaxation, and solitude.

4. Illumination refers to "The Aha! Stage", which often sudden, involving the emergence of an image, idea, or perspective that suggests a solution or direction for further work.

5. Verification and elaboration are the last stage which refers to the stage of testing out the idea, evaluating, developing, implementing, convincing others about the ideas.

Rawlinson (1981a: 8) mentioned that creative thinking was the relating of things or ideas which were previously unrelated. In addition, he concluded that other technical terms used to describe creative thinking was "bio-creative thinking", which means imagages of a manager tackling a problem moving around on a plane or matrix. The example for this meaning was in the field of scientific discovery by the scientists.

Weisberg (1986a: 6) proposes that creativity could be defined by the novel use of tools to solve problems or novel problem solving. Creative thinking could be both problem solving and problem finding. The formulation of a problem was just an important a part of creativity thinking skill just as the solving one.

Torrance; & Goff (1990: Online) defined that academic creativity was a way of thinking about learning, and producing information in school subjects such as science, mathematics, and history.

Harris (1998: Online) proposed his idea about creative thinking in 3 dimensions:

1. Creativity was ability. Creativity was the ability to imagine or invent something new. This ability for generating new ideas could be developed by combining, changing, or reapplying existing ideas.

2. Creativity was an attitude. Creativity was also an attitude. It was an ability to accept change and newness, a willingness to play with ideas and possibilities, and a flexibility of outlook.

3. Creativity was a process. It refers to a process in a way that creativity needs a period of time to create something. For instance, creative people worked hard and continually improved ideas and solutions, by making gradual alterations and refinements to their works. Thus, there were few creative people that can work in such a short period.

Lamp (2004: Online) concluded that creative thinking involved creating something new or original. It involved the skills of flexibility, originality, fluency, elaboration, brainstorming, modification, imagery, associative thinking, attribute listing, metaphorical thinking, and forced relationships. The aim of creative thinking was to stimulate curiosity and promote divergence.

Saskatchewan Education (2004: Online) proposed the definition of creativity that creative thinking was generally considered to be involved with the creation or generation of ideas, processes, experiences or objects.

In terms of creativity some educations proposed their ideas that it was close to imagination. The National Advisory Committee and Cultural Education (Craft. 2000a: 3; citing National Advisory Committee and Cultural Education. 1999) stated that creativity was imaginative activity fashioned so as to produce outcomes that were both original and valuable. Creative thinking was divergent thinking. It was different from analytical thinking, but they are linked because complements another. Analytical thinking consolidated ideas and practices, and must be followed by creative leaps when progress is made. Analytical thinking was convergent, narrowing down to a unique answer or small number of ideas which could be further analyzed and implemented. In contrast, creative thinking was divergent thinking starting from the description of the problem to giving many ideas to solve the problems (Rawlinson. 1981b: 4). In conclusion, the analytical thinking produce solution, and creative thinking produces the idea of which a large numbers could be selected. These ideas can be concluded in the Figure 5.

Analytical	**Creative**
Logic	Imagination
Unique (or few) answers	Many possible or answer ideas
CONVERGENT	DIVERGENT
VERTICAL	LATERAL

FIGURE 5 TWO SORTS OF THINKING

(Rawlinson. 1981c: 5)

Craft (2000b: 33) argued that creative thinking involves a cycle as shown in the following figure:

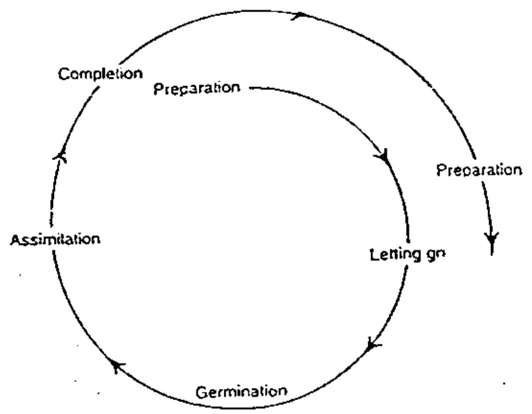

FIGURE 6 THE CREATIVITY CYCLE

(Craft. 2000c: 33).

First, the preparation was the stage of getting into an appropriated place for being creative.

Second, letting go was a period of passivity, emptiness, lack of direction and loss, where the main activity was about letting go, and surrendering control.

Then, Germination was a period of the idea was conceived which was often accompanied by a greater burst of energy.

Assimilation was a period of acquiring time for taking place.

The last stage, completion was the stage of bringing fruition to the idea which involved the capacity to receive as well as to create.

Bellis (2004: Online) proposed that creative thinking was described as making connections and communicating providing alter native possibilities; a variety way of thinking and experience and come up with different points of view; thinking of new and unusual possibilities; and guiding in generating and selecting alternatives.

There were many Thai educators who were interested in creative thinking. Wongyai (1980: 4) summarized that creative thinking comprised 4 steps:

1. Step of sensory problem
2. Step of formulating hypotheses
3. Step of testing guess.
4. Step of communicating the results

Rungsinun (1989: 29) concluded that creative thinking was thinking abilities which had 3 characters:

1. Originally refers to creating something new or differently from others.
2. Fluency refers to the variety of thinking abilities which are appropriate and correct. They are composed of:
    2.1 Word fluency
    2.2 Associational fluency
    2.3 Expressional fluency
    2.4 Ideational fluency
3. Flexibility refers to the thinking abilities which easily adapt to new condition or different circumstances. They consisted of:
    3.1 Spontaneous flexibility
    3.2 Adaptive flexibility

Above of all, the definition of creative thinking can be summarized in a process of thinking for creating a new idea or another perspective of an old idea. The creative thinking is one of the most important skills children could acquire and develop whilst in the early years. Without creative manner, children would be unimaginative (Wheeler, Waite, & Bromfield. 2001a: Online).

2.2 The purpose of developing creativity thinking

Duric (1989b: 101) stated that it was important for teachers to develop creative thinking in the classroom. The basic principle of this idea was:

1. Every mentally health individual disposed a certain level of creative thinking which level was differing.

2. Creative thinking could be developed by doing activities. In school, the main activity was learning, so that students could develop their creativity thinking by learning activities under the guidance of teachers or educators.

3. Inculcating creative thinking in students formed an integral part of shaping the whole personality.

4. The objective of creative thinking in education should conform to the general education objectives.

5. The global objective of developing creative thinking was represented by forming a creative personality in order to work in an efficient manner.

6. The person who is in charge of creative thinking development in students should be teacher or educators who have been trained.

2.3 The characteristics of creative abilities

Guildford (Duric: 1989c: 102; citing Guildford. 1973) proposed the basic facilities of creative thinking characteristics that were composed of 6 facets as follows:

1. Fluency meant the ability to form with facility as many psychological products as possible such as words, ideas, figures, symbols, etc. in a given time.

2. Flexibility meant the ability to come with various solutions, problems and to overcome rigidity in thinking.

3. Originally meant the ability to form clever, ingenious, unusual, extraordinary ideas, and yet hint at a distance connection.

4. Sensitivity was the ability to notice and perceive the problems before others recognize.

5. Redefinition meant the ability to transform the purpose of objects or their parts, to use them in different ways, to free oneself from customary ways of problem solving.

6. Elaboration was conceived as the ability to propose elements of solutions to complete a certain whole.

According to the most extensive research in this field, creative people possessed in quantity the abilities identified by Torrance as follows

1. Sensitivity to problems and deficiencies;

2. Ability to flesh them out;

3. Ability to perceive in a way different from the traditional or established method (Benjamin. 1984b: Online citing; Torrance. 1969).

In addition, highly creative people shared the following traits: flexibility rather than rigidity, openness to new ideas and experiences, tolerance of ambiguity, a wide range of interests, curiosity, enthusiasm and energy vivid imaginations, playfulness, commitment and concentration, comfort with change, capacity for hard work, persistence, divergent thinking. In addition, because creativity involved new approaches and the production of something new and untried, it also involved the risk of failure. The other two characteristics of the creative person were particularly significant were self-confidence, based on a strong self-concept, and independence, the strength to hold fast against disagreement or resistance by others and the courage to persist when others may be threatened by a new idea or discovery (Wheeler, Waite, & Bromfield. 2001b: Online).

2.4 Scientific Creativity

Scientific Creativity has been of central concern to all who work on creativity and was a topic that has been tackled by almost every major area in psychology. Most of psychiatrists were interested in the creativity of scientists because scientists spoke of their research and discoveries in the same terms that were used by other creative thinkers such as poets and artists. The other reason for the vast interest in scientific creativity was that science was highly regarded in society and by discovering the key components of scientific creativity it should be possible to foster scientific discovery. Most researchers agreed that scientific creativity as being composed of the same mental processes that guide all other forms of creativity. The difference between science and other subjects was that there was a vast theoretical, technical and experimental knowledge that creative scientific ideas must either extend or more rarely supplant. Furthermore there were sets of norms and scientific practices that any new scientific discovery must abide by before it was accepted by other scientists as being a discovery (Dunbar. 1999: 1379).

Oyama (2004: Online) stated that problem solving could be considered as involving three phases; a creative phase, a decision phase, and an application phase. In the creative phase, ideas were developed, and a person adopts the role of an "artist." In the decision phase the ideas developed in the creative phase were evaluated, and a person adopts the role of a "judge." Finally, in the application phase, the ideas were brought into action, and the person takes on the role of a "warrior."

The world needs creative scientists who produce useful, innovative solutions to our problems. Weisberg (1986b: 15) asserted that creative scientists differ from noncreative scientists in at least two distinct ways. First, creative scientists need to be free of rules in order to exercise flexible thinking. This flexibility made them more likely than others to know when to abandon nonproductive efforts and change approaches to problem solving. Second, creative scientists also seem to be more open to experience, making them more sensitive to problems than their noncreative colleagues. It appeared that they know when to expend effort on a problem and recognize apotential for significant breakthroughs. They wasted little time on simple solutions or on problems for which the solutions would have little impact. The creative scientist might also recognize a problem that others miss, and thus, possessed great potential for producing original research.

Scientific creativity thinking was a process of solving problem which emphasized on a new idea and product outcome. Scientific creativity thinkers were persons who are able to;

1. Recognize the problem,
2. Create new ideas,
3. Organize ideas, and
4. Evaluate that ideas or outcomes (Piltz; & Sund. 1968: 4).

Recently, Gabora (Dickhut. 2003: Online; citing Gabora. 2002) asserted that the creative process requires a thought shift from associative thinking to cause and effecting thinking. Associative thinking might reveal some correlation or relationship between two things, but this correlation might not provide a solution and might not be appropriate. This replaced the preparation and incubation stages of creativity. There was then a shift to cause and effect thinking which was analytical and searches for a direct solution and for appropriateness. This replaces the illumination and verification stages.

There were some Thai researchers who were interested in scientific creative thinking and define its meaning. Scientific creative thinking referred to an ability to originate a new idea that was flexibility, fluency in order to solve some problems. This thinking process employed scientific process skills such as hypothesis skills and experimental skills

(Prukcholatan. 1974: 56; Kanchanachatri. 1982: 6; Chaichankul. 1983: 9; Boontaem. 1983: 3).

Savathanapaiboon (1984: 7) also defined scientific creative thinking in terms of thinking process and science products which were valuable products reflect in of society. The scientific creative thinking was divergent thinking. The compositions of scientific creative thinking were developed from the idea of creative thinking of Guildford. Therefore, scientific creativity comprised fluency, flexibility, originally, and elaboration.

According to the definition of creative thinking, scientific creative thinking, and scientific creativity, scientific creative thinking is defined as ability that a person can provide some new efficiency ideas or improve an old idea. Scientific creative thinking employs scientific process skills and composes of ability to think fluently, flexibly, and differently.

2.5 Science classroom and creative thinking

Children learned about scientific principles through discovery, investigation, and used the process skills in order to develop a basic scientific understanding. Even though students would not all become scientists, it was important to initiate creative thinking within academic content, By doing so, teachers help maximize the potential of those who did choose this profession. Additionally, all students who learned to think creatively, while engaging in scientific endeavors, they are capable of applying the skill to other contents. Elementary teachers could set the stage for discovery and investigation by creating an atmosphere in which students can encounter appropriate stimulation, ignite their sense of wonder and encourage them to ask questions. Teachers might use their authorities role and differentiated lessons and schools for encouraging and promoting their creative thinking in science classroom (Meador. 2003: 1).

The creative thinking was connecting directly to students by learning. This means, it was important for students to learn a modified and special form. These conditions were connected to students' and teachers' personalities, learning process, and learning materials. Creative thinking is involved several subjects in school. Science was one of the subjects that use a lot of creative thinking. The notion of a scientist as an inventor seemed to be conceptualized by children and adults when they think of science. A crucial part of science was the process of investigation using scientific method which started from the ability to define a problem, making prediction, and so on. In the process of science, all science started with observation; of phenomena, properties of object or living things.

Therefore, it was plausible for teachers to engage the creative thinking in their learning activities (Craft. 2000d: 82). The creativity thinking can be presented in a lessen as follows:

1. Asking questions
2. Giving an analysis
3. Being assertive
4. Being controversial.

In the classroom, it was essential that teachers should know how their students' creative thinking ability was. The assessment played an important role in this issue. Torrance (Benjamin 1984b: Online; citing Torrance. 1969) described four components by which individual creativity could be assessed:

1. Fluency: the ability to produce a large number of ideas.
2. Flexibility: the ability to produce a large variety of ideas.
3. Elaboration: the ability to develop, embellish, or fill out an idea.
4. Originality: the ability to produce ideas that are unusual, statistically infrequent, not banal or obvious.

Because of creative thinking could be both a product and a process, so the assessment process should base on both of them. Teachers need to facilitate learning by providing sufficient opportunities to develop true scientific understanding, science process skills, and corresponding creative thinking skills. As primary teachers provided students' opportunities for experimentation and discovery at a young age, they are likely to become a scientific genius or a problem solver. In this learning process, teacher could involve the assessment process. Paper-pencil test was one of the test that teacher could use in their classroom. The questions in the tests should include some examples of question types that they teachers could integrate those into other curriculum contents to help develop the skill with their students (Langrehr. 2004: Online).

There were some researchers who developed tests for assessing creative thinking skill which were suitable for different ages. Torrance developed several test batteries, of which Torrance tests of creative thinking were probably the best known and most carefully researched that were used with pre-school to adult aged groups. Torrance Tests of Creative Thinking, the tests provided specific data about creative thinking, and were accompanied by reports describing a variety of appropriate uses. The norms were the most extensive of any creativity instrument. This test was used for kindergartens – graduate students. The abilities to be tested were creativity focusing on fluency, flexibility, originality, and elaboration. The

Torrance Tests of Creative Thinking were accompanied by separate Norms and Technical Manuals for both the Verbal and Figural forms (Torrance. 1970: 276).

Rangsinun (1989b: 173) proposed that creative thinking tests were a systematic test. By integrating creative thinking test along with behavior observation or creative thinking behavior observation forms in the assessment process, this data would be valid.

2.6 Research related to creative thinking and science education

Swami (1972: Online) assessed the effectiveness of Elementary Science Study (ESS) materials for developing creativity in children. The sample consisted of four third-grade classes in two elementary schools with heterogeneous populations. After the pre-test, two classrooms were selected as the experimental group and the remainder served as a control. Four ESS units were taught in the experimental classrooms over a period of eight weeks while regular instruction went on as usual in the control classrooms. The pre- and posttests were scored of nine different measures and analyzed using the one-way analysis of covariance. Result indicated that children who received ESS instruction would achieve higher scores on Torrance Tests of Creative Thinking (TTCT) Figural and Verbal, and on the investigator's test of Observation and Classification.

Schemp (1983: 91) assessed the consequences of allowing students to make decisions relevant to their learning. In particulars, the effect such as decision-making had on elementary children's creative thinking in a human movement program was investigated. The 201 students were grouped into two experimental groups and one control. The students in the Shared Decision-Making Approach (SDMA) group were allowed to share decisions during the process of their learning. Students in the teacher decision-making approach (TDMA) group had all decisions dominated by the teacher. The control group received no formal training program. Both of the experimental groups received respective treatments once per week, in 45 minute classes, for eight weeks. The units of treatment instruction included four weeks of fundamental motor skills and four weeks of gymnastics. This creative thinking test offered five non-verbal measures of a child's creative thinking: fluency, flexibility, originality, elaboration and activity. Results indicated that children who were allowed to make decisions regarding their learning had significantly higher scores than children who did not provide a chance to make such decisions. This presented that the teacher should enhance creative thinking because it did encourage the children to make well-thought decisions.

Foster; & Penick (1985: 89) studied creativity in a cooperative group setting with 111 of fifth- and sixth-grade students. The objective of the study was to determine whether small groups would stimulate creativity more than individualized learning environments. Results indicated that small groups were more creative with electrical circuits than this grouping format should be introduced in elementary classes.

Young (1986: Online) evaluated that, the effectiveness of an instructional model is derived from the research on learning styles, science curricula development, and the development of thinking skills. 125 males and 128 females of seventh-grade students were randomly assigned to the two treatments for a total of 24 weeks. Dependent variables included student mastery of science concepts, and creative thinking as measured by the Torrance Tests of Creative Thinking (TTCT). The study demonstrated that using a variety of instructional strategies in a preplanned sequence in science significantly affected student achievement of basic thinking skills, verbal creative thinking, and figural creative thinking.

Al-Sulaiman (1998: Online) investigated the relationships between the creative thinking abilities of originality, fluency, and flexibility, and specific characteristics of classroom environment as perceived by tenth grade female students and their Arabic teachers. Such factors included the degree of emphasis on higher /lower level thought processes, classroom climate, and classroom focus. The study found a significant relationship between students' perceptions of the lower level thought process of translation and the ability of fluency. Classroom focus and absence of lecture were significantly related to the abilities of originality and flexibility. Classroom climate, specifically the factor of less teacher talk, was correlated positively with all three creative thinking abilities. Also, the study results showed statistically significant differences between teachers' and students' perceptions of their classroom environment. Teachers reported more emphasis on both the higher and lower level thought processes and a more positive climate than did the students. The demographic variables of family income, school location, and student nationality were significantly related to the students' creative thinking abilities.

Fults (1998: Online) determined the effectiveness of an instructional program for developing creative thinking, a positive self-concept, and leadership among intellectually and academically gifted elementary students in grades four, five, and six. A total of 179 students from a suburban North Texas school district completed the study, three instruments were administered as pretests and posttests to measure performance change over a six-month period. The Torrance Tests of Creative Thinking, Figural Forms A and B, the Piers-Harris Self-Concept Scale for Children, and the Scales for Rating the Behavioral Characteristics of

Superior Students, Part IV, Leadership Characteristics were utilized. Results indicated that the instruction program was effective. Girls appeared to benefit more than boys from training in creativity. Fifth-grade students appeared to benefit the most from training in creativity

Chand; & Runco (1993: 155) studied problem finding skills as components in the creative process. They compared the impact of explicit and standard instructions on six tests of divergent thinking. Two of these tests assessed real-world divergent thinking; two tests assessed real-world problem generation; and the last two assessed a combination of problem generation and divergent thinking. Eighty college students were asked to give solutions for problems concerning both work and school situations. The results revealed significant differences among the various tests and differences between the explicit and standard instructional groups. Importantly, only the scores elicited by explicit instructions were significantly correlated with and predictive of creative activities and accomplishments.

Lawson (2001: 13) studied creative and critical thinking skills in college biology He presented his model of creative and critical thinking in which analogical reasoning was used to link lines of thought and generate ideas that were then tested by employing an "if/and/then" pattern of reasoning. Data suggested that such thinking skills could be developed first in familiar and observable contexts before they could be used in less familiar and unobservable contexts.

Liang (2002: Online) investigated the relationship between students' scientific creativity and selected variables including creativity, problem finding, formulating hypotheses, science achievement, the nature of science, and attitude towards science for finding significant predictors of eleventh grade students' scientific creativity. 130 male of eleventh-grade students in three biology classes participated in this study. The major findings suggested students' scientific creativity significantly correlated with attitude toward science, problem finding, formulating hypotheses, the nature of science, attitude toward science, problem finding, resistance to closure, and originality with scientific creativity; there were big differences between students with a higher and a lower degree of scientific creativity on the variables of family support, career images, and readings about science. In addition, the research results encouraged teachers to view scientific creativity as an ability that could be enhanced through various means in classroom science teaching

In order to develop creative thinking, Russ (1993a: 88) asserted that it was worthwhile to develop principles for child-rearing, school environments, work environments, and adult lifestyles that help individuals' abilities.

Home environment could affect the child's creative thinking development. Rogers (Russ. 1993b: 90; citing Rogers. 1954) stated that creativity in children was most likely to occur when three conditions were present: openness to experience, internal locus of evaluation, and ability to toy with elements and concepts. In additions, these three elements could be fostered by two external conditions-psychological safety and psychological freedom. Child-rearing could affect on creative thinking. Harrington et al. (Russ. 1993c: 90; citing Harrington; et al.1987) concluded their research which emphasized on the relation of child-rearing practice and creative thinking. He investigates between child-rearing practices of parents and creative potential index of the child as a preschooler and as a young adolescence. He asserted that home environment such as child-rearing practice could contribute significantly to adolescence creative potential score. These findings were consistent with the work of Csikszentmihalyi (Russ. 1993d: 91; citing Csikszentmihalyi. 1990). He reported on the results of a study of family context in his laboratory which investigated variables in the families of teenagers that promoted optimal experiences for creative functioning. Five major characteristics of the family context emerged:

1. Clarity on expectations

2. Centering- most of parents were interested in what the child is currently doing rather than focusing too much on the future.

3. Choice- The child could choose from a variety of alternatives.

4. Commitment- Trust and a secure environment the child should feel safe enough to set aside defenses

5. Challenge- Parents provide complex opportunities for action.

In a later year, they studied the relation of talented children and home environment and found that a home environment that combined both support and optimal challenge was essential for creative development. Other factors emerged in the literature as being important for creative development. Singer &Singer (Russ. 1993e: 92; citing Singer; &Singer. 1990) reported that preschoolers who were read to or had quality of times with their parents were more imaginative. Creative older children reported that parents had more times and could play with them. This study was followed in the study of home environment and parents factors. The results emerged that the imaginative child had parents who were more resourceful, adventuresome, and creative based on self-descriptions. They used inductive child-rearing skills and had clear rules. This study also found that parents of gifted children spent more time with them on school-related activities, and demonstrated unconditional love.

Michel; & Dudek (1991: 281) found that mothers of high creative 8 years old child were less emotionally involved with their child, less likely to be perceived as overprotective, and less likely to deny hostility toward the child.

Amabile (Russ. 1993f: 92; citing Amabile. 1983) listed the following characteristics of home environment which promoted children's creative thinking based on her literature:

1. Children should have a choice in how to perform a task.

2. Reward should be used in such a way that it leads to positive affect and create higher enjoyment in the task.

3. Play and fantasy should be encouraged

4. There should be sufficient distance between parents and children.

In addition, she recommended teachers how to promote creative thinking for their students based on her work and the literature.

1. Help the child look for cues in the environment.
2. Help develop the child's talents.
3. Help the child make positive constructive evaluations of his or her work.
4. Recognize and tolerate the unusual.
5. Help the child resist peer pressure toward conformity.
6. Give a lot of choice
7. Reduce the amount of evaluation

School environment also took part in developing students' creative thinking skills. The school environment was considered one of the factors that could foster creativity, inhibit creativity, or had no effect (Russ. 1993g: 98).

Getzel; & Jackson (Russ. 1993h: 95; citing Getzel; & Jackson. 1962) reported that creative children were often viewed as a bother by teachers. Boys were more likely to be viewed more creative by teachers than girls (Russ. 1993: 95 citing Evans. 1979).

Gardner (Russ. 1993i: 94; citing Gardner. 1991) encouraged society to think creatively about the school environment. He proposed that teacher should teach students in context and used approaches that helped students to see the reasons for learning. He suggested alternative teaching models, such as the apprenticeship model, and using places other than school for learning, such as children's museums as supplements to the school experience.

3. Primary mental ability

Thurstone (Plucker. 2004a: Online; citing Thurstone .nd) concluded that primary mental abilities were human intelligence. Thurstone believed that an understanding and analysis of intelligence must begin with people and their attempts to reach their goals. Instinctual responses and lower levels of intelligence were characterized by the tendency to act on impulses without reflection. Higher levels of intelligence provided a greater protection and its likely that individuals would eventually reach their goals by deflecting less than optimal impulses at earlier stages in the process of attempting to reach their goal. He saw intelligence as an inhibitory process. Therefore, intelligence was made up of several primary mental abilities rather than general specific factors. He was among the first to propose and demonstrate that there are numerous ways in which a person can be intelligent.

Thurstone's Multiple-factors theory identified the seven primary mental abilities, Thurstone's Multiple-factors theory, that were collectively called the "primary mental abilities" (PMA's). The specific skills were:

1. Verbal comprehension indicated by size of vocabulary, ability to read, and skill at understanding analogies and the meaning of proverbs

2. Verbal fluency refers to the ability to think of words quickly, when making rhymes or solving words puzzles.

3. Number is ability to solve arithmetic problems and to manipulate numbers.

4. Spatial visualization is an ability to visualize spatial relationships, as in recognizing a design after it has been placed in a new context.

5. Inductive reasoning is the skill at the kind of logical thinking.
The ability of memorizing quickly, as in learning a list of paired words.

6. Associative memory is the ability to memorize quickly, as in learning or paired words.

7. Perceptual speed is the ability to grasp visual details quickly and to observe similarities and differences between patterns and pictures (Kagan; & Segal 1995a: 361; Kruger, Saul,& Lin. 2004a: Online).

This theory has been used to construct intelligence tests that yield a profile of the individual's performance on each of the ability tests, rather than general intelligence tests that yield a single score such as I.Q. (Plucker. 2004b: Online; citing Thurstone. n.d.)

Intelligence might be defined broadly as a facility at solving problems. Clearly, such facility is related to the competencies described in cognitive social theory. The heritability of intelligence has been shown by many studies in behavior genetics.

Intelligence might be defined broadly as a facility at solving problems. Wechsler (Kagan; & Segal.1995b: 360; citing Wechsler. 1975) was one of the intelligence tests which widely used. He defined intelligence as a capacity to understand the world and the resourcefulness' to cope with its challenges. Common definitions of intelligence were "success in a problem solving, ability to learn, capacity for producing neogenetic solutions, understanding of complex instructions or simply all-round cognitive ability" (Paik 1998: Online; citing Eysenck. 1982).

3.1 Intelligence theory

Intelligence theories have evolved through a succession of paradigms which have tried to explain and define intelligence. The theories which could define and explain the nature of intelligence are psychometric theories, cognitive theories, cognitive-contextual theories, and biological theories.

3.1.1 Psychometric theories

In this theory, the understanding of the structure of intelligence: forms, categories, and compositions were explained. Underlying psychometric intelligence theory is a psychological model according to which intelligence is a combination of abilities that can be measured by mental testing. These tests often include analogies, classification or identification, and series completion. Each test score is equally weighted according to the evidence in each category. A famous psychologist in this theory is Charles E. Spearman. His theory noted that people who excelled on one mental ability test often did well on the others, and people who did poorly on one of them tended to do poorly on the others. Based on his theory, he created a technique of statistical analysis that examined patterns of individual differences in test scores. This analysis explained about the two sources of the individual difference. They were the general factor (g factor) which is general intellectual ability and a test-specific factor (s factor) (Kagan; & Segal. 1995c: 361)

3.1.2 Cognitive theories

Cognitive approach to intelligence was the assumption that intelligence comprised a set of mental representations of information, and a set of processes that operate the mental representations. It was assumed that a more intelligent person represents information better, and operates more quickly on these representations than does a less intelligent person. There were many psychologists who explained intelligence based-on cognitive theory, such as Earl Hunt, Nancy Frost, and Clifford Lunneborg, and Sternberg. By using cognitive intelligence theories, a major problem remains regarding the nature of intelligence. Cognitive theories did not take into an account that the description of intelligence might differ from one cultural group to another. Even within mainstream cultures, it was well known that conventional tests did not reliably predict performance (Kagan; & Segal.1995d: 361).

3.1.3 Cognitive - contextual

Cognitive-contextual addressed the way cognitive processes operate. The two major cognitive-contextual theories were of Howard Gardner and Sternberg. Gardner proposed a theory of "multiple intelligences", arguing that there is no single intelligence. He identified what he believed to be the seven minimal intelligences, some of which were similar to the abilities proposed by psychometric theorists, but others not. Gardner devised his list of intelligences from a variety of sources, including studies of cognitive processing, brain damage, exceptional individuals, and cognition between cultures. He suggested that whereas most concepts of intelligence had been ethnocentric and culturally biased, his was universal (Krueger, Saul, & Lin. 2004b: Online)

Sternberg's "triarchic" theory of intelligence agreed with Gardner in terms of the conventional notions of intelligence being too narrow. However, he disagreed as to how to go beyond traditional notions. Sternberg proposed that intelligence has three aspects - not multiple intelligences, but independent aspects that related intelligence to internal and external factors and the media between the internal and external worlds (Kagan; & Segal. 1995c: 336).

3.1.4 Biological theories

Biological theories were radically different approaches to intelligence, seeking to understand intelligence in terms of its biological basis instead of hypothetical factors or abilities. Biological theories argued that they only sought to describe the fundamental behavior behind intelligence, not explain it. However, those in favor of these theories believed that understanding the biological basis of intelligence would compliment other investigations into intelligence (Aiken. 1991: 231).

3.2 Development of Intelligence

Many studies have investigated the development of intelligence. Psychometric theorists have sought to understand how intelligence develops in terms of changes over time, and changes in the amount of certain abilities children have. For example, "mental age" was a popular concept during the first half of the twentieth century. Mental age represented the average child's level of mental functioning for that given age. Intellectual development and ability were based upon the role of the social environment. This viewpoint is similar to Vygotsky, which suggested that intellectual development may be largely influenced by a child's social interactions. Thus, intelligence in children could be decreased or increased by social or environmental. A child saw others thinking and behaving differently, they would then imitated what he observed. Social interaction was an example of the factors of those parents mediated the environment for their child, and through this mediation the child learned to understand and interpreted the world. A healthy lifestyle could also affect their intellectual ability (Krueger, Saul, & Lin. 2004c: Online)

There was a statement signed by 52 psychologists, published in the December 14, 1994 Wall Street Journal stated about intelligence that;

1. Intelligence exists as a very general mental capability involving ability to reason, plan, solve problems, think abstractly, comprehend complex ideas, learn quickly and learn from experience. The brain processes involved were little understood.

2. Intelligence can be measured, and IQ tests measure it well. Nonverbal tests can be used where language skills were weak.

3. IQ tests were not culturally biased.

4. IQ is more strongly related than any other measurable human trait to educational, occupational, economic, and social outcomes. Whatever it is that IQ tests measure, it is very important

5. Genetics plays a bigger role than environmental intelligence, but environment has a strong effect.

6. Individuals were not born with an unchangeable IQ, but it gradually stabilizes during childhood and changes little thereafter (Gottfredson; et al. 1994: Online).

3.3 Measuring Intelligence

Both in education and psychology, testing is an attempt to measure a person's knowledge, intelligence, or learning. There are many types of tests;

1. Academic Achievement Test: standardized tests; non-standardized tests, norm and criterion-referenced test

2. Psychological Test: measurement requirements; assessment procedures

3. Criticisms of testing (Krueger, Saul, & Lin. 2004d: Online)

3.4 Research related to primary mental abilities and students' science achievement.

Visual-spatial abilities have been associated with the rendering of drawings and the comprehension of three-dimensional fields in science. In the study of Siefert (1998: Online), the relation between drawing three-dimensional forms and understanding earth motion diagrams were investigated. The consideration was the relations of art and earth science achievements with the Otis-Lennon School Abilities Test, and three subtests from the Differential Aptitude Test battery: mechanical reasoning, spatial relations and abstract reasoning. The study was conducted with ninth grade students taking art and earth science. The findings indicated that the abilities to imagine relative motion and to visualize from different points of view within a three-dimensional field were important components in understanding concepts related to earth motions. Some of the same abilities appeared to be utilized in the rendering of perspective drawings. Scholastic aptitude played a significant part. These findings suggested that science teachers should consider students' abilities in spatial and mechanical reasoning when teaching concepts relying on three-dimensional visualization. In addition, teachers were encouraged to include the drawing of three-dimensional fields in science classes.

The question arise was that "How did aptitude, instruction, and psychological environments affect on science interest and achievement?" In order to answer this question, Pittman (1992: Online) studied the effect of educational productivity factors on eighth-grade students interest and in science achievement. These factors of ability, development, and motivation or self-concept were included in the category of aptitude. Instruction was consisted of quantity and quality instruction. The psychological environments included home, social or classroom, peer group outside of school, and out-of-school factors.

The sample includes approximately 5,162 eighth grade students. Student and teacher responses to survey questions and students' science achievement scores were used in this study. Factors of aptitude, instruction, and the psychological environment were found to influence science interest and achievement.

Vahala (1990: Online) investigated the effects of learning style, institutional type, subject matter, and academic aptitude on college students' perceptions in their classroom environment. Two instruments were used to explore the hypotheses: Learning-Style Inventory and the College Classroom Environment Scales. Data were collected from five institutions: a large, public university; two non-residential, two-year public colleges; and two small, private colleges. Students perceived differences in their classroom environments based on institutional type. In general, students at the private colleges tended to perceive their classes as having a higher relationship-orientation than did the students at the university or the two-year colleges. Successful course achievement for all students was predicted by academic aptitude and perceived value, structure, and academic rigor of the course. For laboratory science, successful course achievement was predicted by academic aptitude and the perceived value, affiliation, and inimical ambience of the class. In the behavioral sciences, successful course achievement was predicted by academic aptitude and the perceived professorial concern and academic rigor.

Jeong (1987: Online) designed the study to examine the relationship between ninth grade achievement and tenth and eleventh grade science achievement in Korea. The influences of another variable, intelligence and aptitude, on the dependent variables were also investigated. The results indicated that the intelligence and aptitude could predict the students' science achievement.

4. Child-rearing practices

Developmental psychologists have been interested in how parents influence the development of children's social and instrumental competence since at least the 1920s. One of the most robust approaches to this area was the study on the topic of parenting styles or child - rearing practices. Parenting is a complex activity that includes many specific behaviors that work individually and together to influence children's outcomes. There are two dimensions along which parenting might vary. One was parental warmth –the amount of support, affection, and encouragement the parent provides. The dimension of parental warmth generally associated with positive child outcomes. The second dimension is parental control-the degree to which the child is monitored, disciplined, and regulated, as opposed to being left largely unsupervised. The most influential conceptualization of parenting styles was developed by Baumrind (Vasta, Miller, & Ellis. 2004: 607). The construct of parenting styles was used to capture normal variations in parents' attempts to control and socialize their children (Baumrind. 1991a: 56).

Parenting styles or child - rearing practice referred to describe normal variations in parenting. In other words, although parents might differ in how they try to control or socialize their children and to the extent in which they did so, it was assumed that the primary role of all parents was to influence, teach, and control their children (Darling. 1999 a: Online).

Child-rearing practice were defined as children's perception of their parents' attitude toward them, based on their experience of parental behaviors and influenced by their own developmental history. Thus, parenting styles were described as a relationship quality, reflecting characteristics of both parent and child, rather than a quality of the parent (Darling, Flaherty, & Dwyer. 1997: Online).

Child-rearing practice was done in a particular way, which parent consistently behaves toward children. The styles included the expectations that one has on his/her children and the manner in which one treats them. It also included the types of rules established for children and the method by which the rules were made and enforced (Hildebrand. 1994a:106).

Baumrind (1991b: 57) analyzed that there were two factors that emerged in parenting styles.

1. Demand. This related to the demands that the parents require from the child to be part of the family, their expectations for mature behavior, the discipline and supervision they provided, and their willingness to confront behavioral problems

2. Responsiveness. This related to fostering individuality, self-assertion, and regulation, as well as being responsive to special needs and demands.

According to the above, she categorized parents and created a model of parenting styles or child - rearing practice. There were four parenting styles.

1. Permissive/Laissez-faire- The parents make fewer demands, and allow the children to regulate themselves for the most part, using little discipline. They are higher on responsiveness but lower on demand, requiring little maturity and conventionalism, and avoid confrontation of problematic behavior. The children are less assertive, and less cognitively competent. Their children were often smarter but less achievement oriented,

showed less self-regulation and social responsibility, and were more likely to use drugs than the previous two. Only children from rejecting and neglecting homes are more likely to use drugs. More single parent homes were categorized in this group than the Authoritative or Authoritarian types.

2. Authoritarian- The parents are highly demanding and directive, but not responsive. They are obedience- and status-oriented, and expect their orders to be obeyed without explanation. These parents provide well-ordered and structured environments with clearly stated rules.

3. Authoritative- The parents are both demanding and responsive. The parents monitor and impart clear standards for their children's conduct. They are assertive, but not intrusive and restrictive. Their disciplinary methods are supportive, rather than punitive. They want their children to be assertive as well as socially responsible, and self-regulated as well as cooperative.

4. Rejecting/Neglecting- The parents are low on both demand and responsiveness; they do not structure, organize, discipline, attend and supervise, and may actively reject or neglect their children. The children demands are cope with the worst, and the least competent of the four groups. Their children are antisocial, lack self-regulation, have more internalizing and externalizing problems, lower scores on cognitive tests, are more immature and reject their parents as role models. They are most likely to use drugs and alcohol. More single parent homes fell in this group than the Authoritative or Authoritarian types (Baumrind. 1991c: 57; Vasta, Miller, & Ellis. 2004b: 607).

One key difference between authoritarian and authoritative parenting is in the dimension of psychological control. Both authoritarian and authoritative parents place high demands on their children and expect their children to behave appropriately and obey parental rules. Authoritarian parents, however, also expect their children to accept their judgments, values, and goals without questioning. In contrast, authoritative parents are more open to give and take with their children and make greater use of explanations. Thus, although authoritative and authoritarian parents are equally high in behavioral control, authoritative parents tend to be low in psychological control, while authoritarian parents tend to high (Baumrind. 1991d: 57) Hildebrand (1994b: 107) concluded that there were three child - rearing practices.

1. Authoritarian-The characteristic of this style where parents decided the rules, informed the children, and then enforced them. The parents' behaviors were predictable. Therefore, the children could expect their parents to respond in about the same way to

similar situations. In addition, parents showed little or no flexibility in their handing of guidance or discipline. They required their children to conform to their directions and expectations.

2. Democratic-The parents considered both the child's needs and their own point of view when making a decision. This style also called authoritative. Parents and children always worked together to set up rules. Children were expected to conform to these rules. Principles of guidance and discipline were generally discussed by parents and children. Both children and parents could suggest changes that may be needed according to changing circumstances. Thus, parents viewed their children as important people who have contributions to the family.

3. Permissive (Laissez Faire)-Generally parents permitted a wide range of behavior. Parents set few specific rules and allowed the children much freedom and self expression. Parents pattern were somewhat difficult to predict. They might change their guidance to meet particular situations.

Child - rearing practices have been found to predict child well-being in the domains of social competence, academic performance, psychosocial development, and problem behavior. The research based on parent interviews, child reports, and parent observations. The findings were consensus that:

1. Children and adolescence whose parents were authoritative rate themselves and were rated by objective measure as more socially and instrumentally competent than those whose parents are non-authoritative (Baumrind. 1991d: 52; Weiss; & Schwarz. 1996: 2101, Miller; et al. 1993: Online)

2. Children and adolescents whose parents were uninvolved perform most poorly in all domains (Darling. 1999b: Online).

5. Attitude towards science

An attitude was a learned predisposition to respond positively or negatively to a certain object, situation, institution, or person. It consists of cognitive (knowledge or intellective), affective (emotional and motivational), and performance (behavioral or action) components (Aiken. 2001: 303). Dalgety ,Coll, & Jones (2003a: 649) concluded the definitions of attitude toward science and scientific attitude. Researchers in science education were little confused attitude with belief, value, or opinion. Attitude was composed of three parts, which is called three-part attitude trilogy (affection, cognition, and conation). Each part was related to the definition of attitude to a certain degree. Affection was equivalent to evaluative quality, cognition was backdrop to attitude, and behavioral intention may replace conation (Shrigley, Koballa, & Simpson. 1988a: 659). This trilogy could be translated as follows:

Cognition: belief-unbelief

Affection: like-dislike

Conation: behavior (Shrigley, Koballa, & Simpson. 1988b: 672 citing Hollander. 1976).

Mager (River; & Ganaden. 2001a: Online; citing Mager. 1968) contended that development of positive attitudes toward school subjects was fundamental for three reasons. First, attitude seemed to be related to achievement and might actually enhance cognitive development. Second, students who had positive attitude toward a subject were more likely to want to extend their learning skills in both formally and informally in that subject after the direct influence of the teacher have ended. Third, attitude was often communicated to peers in a variety of ways throughout life. A negative attitude might result in lack of support for science and decreased resources for scientific study of society's problems. Therefore, it was desirable to promote the development of positive attitudes toward science as an important objective for education.

Attitude toward science and scientific attitude were different concepts and each contains dimensions that were distinct from each other. Attitude as it related to science is divided into two areas-scientific attitude and attitude toward science. Scientific attitude referred to a particular approach that a person assumes for solving problems, for assessing ideas and information, and for making decisions. It included such scientific methods and predispositions of objectivity, suspended judgment, critical evaluation, and skepticism (Germann. 1988a: 690; citing Gauld. 1982; Munby. 1983). Attitude towards science addressed scientific attitudes, scientists, scientific careers, method of teaching science, scientific interests, parts of curricula, or the subject of science in the classroom (Germann. 1988b: 690; citing Blosser. 1984). It may refer to belief about the processes, theoretical products, technological products, or the science technology relationship (Germann. 1988c: 690). The attitude towards science could be categorized as below:

1. Scientific attitudes
   1.1 Scientific attitudes
   1.2 Scientific process

1.3 Scientific curiosity

2. Attitudes to science instruction

    2.1 Teaching science

    2.2 Science subject preference

    2.3 Science interests/activities

    2.4 Science in school

3. Attitudes to science itself

4. Attitudes to science careers

    4.1 Career preference

    4.2 Occupational interests

    4.3 Energy research

    4.4 Reclaimed water

The difference between like-sounding terms such as attitude toward science and scientific attitude were sometimes very subtle and discretion was needed when comparing data findings. For example, SAI II measures scientific attitude, which was a slightly different concept from attitude-toward-science- the differences are best illustrated with examples. According to the literature, scientific attitude was a response to statements such as: "Scientists discover laws that tell us exactly what is going on in nature." In other words scientific attitude was what we think science could do. In contrast, an attitude toward science was a response to statement such as: "Working in a science job would be fun." In this case an attitude towards science was to do with what we think of science such as fun, boring, difficult, etc (Shrigley, Koballa, & Simpson.1988c : 661).

5.1 Attitude towards science inventory

Students' attitude toward science, as reported in the science education literature, was usually measured using purpose-designed questionnaires (more commonly infer to instrument). The two most widely used instruments employed to measure attitude toward science are the Scientific Attitude Inventory II (SAI II) and the test of Science Relates Attitude (TOSRA) (Shrigley, Koballa, & Simpson. 1988d: 661).

5.1.1 Scientific Attitude Inventory (SAI)

The development of the SAI was reported in the journal of research in science teaching over 30 years ago (Moore; & Foy. 1977: 328; citing Moore; & Sutman. 1970). The SAI was translated in Hebrew and Thai. According to Moore (Price, Ehle, & Belk. 2004: Online; citing Moore. 1969), the author of the Scientific Attitude Inventory (SAI), scientific attitude could be defined as "an opinion or position taken with respect to a psychological object in the field of science." "An attitude inventory in which the universe of content is scientific attitude is a scientific attitude inventory". In the 60-item SAI there were four subdivisions of scientific attitude. These included the following:

1. Positive intellectual attitude,
2. Negative intellectual attitude,
3. Positive emotional attitude,
4. Negative emotional attitude (Moore. 1969: unpaged)

All the positive responses were recorded in the "A" scale and the negative responses in the "B" scale. The responses were weighted in the following manner: Agree Strongly, A=3, B=0; Agree Mildly, A=2, B=1; Disagree Mildly, A=1, B=2; Disagree Strongly, A=0, B=3. No response or error received 1.5. The SAI constructed validity and a test, re-test reliability coefficient of 0.93 (Price, Ehle, & Belk. 2004b: Online; citing Moore; & Sutman. 1970).

The SAI II has been criticized extensively in the literature for its lack of theoritical grounding and lack of validity (Dalgety, Coll, & Jones. 2003b: 649; citing Munby. 1983).

In 1997, Moore; & Foy (1997b: 327) revised the Scientific Attitude Inventory (SAI) which was developed and field tested 25 years ago. The revision retained the original position statements of attitudes and assessed the original attitude statements with changes made only to improve readability and to eliminate gender-biased language. The SAI II used a five-response Likert Scale. The new version was shorter than the original, which included 40 items instead of 60. The SAI II was field tested with 557 students in Grades 6, 9, and 12. They claimed that the revision of SAI II would be a good instrument of attitude measurement.

5.1.2 Test of Science-Related Attitude (TOSRA)

The Test of Science Related Attitude (TOSRA) was a 70-item self-report instrument that was designed to obtain information about a person's attitude toward science. There were seven dimensions that TOSRA investigated. For each dimension, students responded to a set of 10 statements. The respondent answers on a 5-point Lickert scale -Strongly Agree instrument half the statements were reversed. Therefore, some statements strongly agree with indicative or a positive attitude toward science while in others strongly disagree indicated a positive attitude. For the purpose of clarity, all items have been adjusted so that a higher mean score (mean scores could range between 1 and 5) was indicative of a more positive view of science (Ward; & Linerode. 2000: Online).

The TOSRA instrument was considered to possess better than SAI II, but it was based on a secondary school context. Thus, it was less appropriate for each context. Some statements were appropriate for undergraduate students, for example statements in TOSRA regarding the term lesson could be taken to mean lecture, laboratory, or tutorial in the university environment. Therefore, a tertiary level study TOSRA required major revision to fit in different context (Dalgety, Cole, & Jones. 2002c; citing Wong & Fraser. 1996).

5.2 Research related to attitude toward science and science achievement

Keeves (1975: 455) used path model to study relationships and interactions between attitude and achievement in mathematics and science. A number of variables in the educational environment; for instance, home structure, attitudes and process of classroom structure and peer group structure were considered. He found that initial achievement was the major influence on final science achievement on a summative knowledge instrument. Contributions to final achievements were also made by attitudes and life style, structural characteristics of classroom, and interaction between teacher and students. The students' attitude toward science was not a significant contributor toward science achievement. Achievement in science, on the other hand, substantially affected attitude toward science.

Haladyna; & Shaughnessy (1982: 547) indicated that learning environment variables were the most influential predictors of attitude toward science. They recommended that because the researcher could not do much to change student variables, science educators should concentrate on examining the teacher and learning environment variables, which were mainly controlled by the teacher. This type of research of this nature may help science educators to have a better understanding how these variables might have an effect on increasing students' positive attitudes toward science. They concluded the result of meta-analysis of 49 students on attitudes toward science and reported that there was a small significant difference in attitude towards science between boys and girls. The effect of instructional programs on attitudes towards science is generally positive, but available; the teacher and the classroom environment played an important role in affecting attitude.

Mcgarity (1981: Online) examined relationships among teachers, classroom management behavior, student engagement and student achievement of middle and high school science students. These variables were investigated across varying levels of academic aptitude. The relationships found were between student engagement and achievement, student aptitude and achievement, and student aptitude and engagement.

Beall (1984: Online) pointed out the variation in science achievement which may be related to attitude toward science, interest in science, science curiosity, verbal aptitude, quantitative aptitude, and nonverbal aptitude. The investigation of differences among levels of science achievement on these dimensions was also included in the study. The subjects were 683 sixth grade students. Analysis of variance was employed to determine differences among study participants classified as high achievers, normal achievers and low achievers in science with respect to attitude toward science, interest in science curiosity, verbal aptitude, quantitative and nonverbal aptitude. The results indicated that verbal aptitude, quantitative aptitude, attitude toward science and nonverbal aptitude were found to have significant influences on science achievement.

Baker (1985: 109) used the Scientific Attitude Inventory (SAI), and found that middle school students who have A and B grades in science had negative attitudes toward science. Those who have C and D grades had a more positive attitude. He suggested that there are two possible reasons in these unexpected results. First, higher ability in middle school students may have found science boring and this adversely affected their attitudes. Second, the SAI may not be a valid measurement to examined attitudes toward science in school.

Cannon; & Simpson (1985: 130) found that attitudes toward science are an important factor related to science achievement. They used the Simpson-Troost Attitude Questionnaire to measure attitude toward science. Science achievement was measured by using summative assessment. In the middle year, ability of grouping was accounted for 17 percent of the variance achievement, while attitude was accounted less than 1 percent. At the end of the year, ability of grouping was accounted to 10 percent, and attitude was contributed 5 percent.

Talton; & Simpson (1987: 520) investigated relationships of attitude toward the classroom environment, attitude toward science, and achievement in science among tenth-grade biology students. They used Simpson-Troost Attitude Questionnaire to measure attitude toward science. They found that 56 percent to 61 percent of the variance in attitude toward science could be accounted for by the students' attitude toward science and attitudes toward classroom environment. The achievement was accounted for by both attitudes toward classroom environment and attitudes toward science. The achievement could be predicted by attitude towards science and attitudes toward classroom environment.

Germann (1988b: 700) studied relationship between attitudes toward science and science achievement in seventh to tenth grade students. He found that attitudes toward science correlated with achievement. A possible explanation was that students with more positive attitudes paid more attention to classroom instruction, lab exercises, studying, and homework than students who had less positive attitudes.

Marie (1996: Online) investigated Science self-efficacy, attributions and attitude towards science among high school students. She conducted her study in order to examine a structural equation model which estimated and tested relationships among the latent variables general aptitude, science self-efficacy, science attribution and attitude toward science for a nationwide sample of 411 high school students. Research has shown that attitude towards science correlated with achievement, selection of courses in high school and college and pursuing science as a career. With respect to science attitude differences between males and females, males showed more positive attitude toward careers in science and were more open minded than females, but females had more positive attitude about the normality of scientists. For females and minorities, in particular, college educators need to work at fostering their self-efficacy and improving their attitudes in order to keep themselves interested in the sciences.

Freedman (1997: 343) investigated the use of a hand-on laboratory program as a means of improving student attitude toward science and increasing student achievement levels in science knowledge. The research design was a posttest-only control group design. The findings showed that there was a positive correlation (r = .406) between their attitude toward science and their achievement. It was concluded that laboratory instruction influenced, in a positive direction, the students' attitude toward science, and influenced their achievement in science knowledge. It was recommended that science instruction include a regular laboratory experience as a demonstrated viable and effective instructional method for science teachers.

Science content and an interaction between students and teachers were therefore significant. If students successfully learned science in the classroom, and if they found science interesting and relevant to their lives, they were likely to become committed to learning science in next level (Simson; & Troost. 1982 b: 766). Therefore, it was an important factor for science teachers to assess students' attitude toward science in order to achieve the goal of science education.

6. Factors relate to science achievement

6.1 Parents

One of the important factors related to students' achievements is the parent. There were many educational researches studied on this topic because parents are the first educators of children. Recent research indicated that parental factor effect on children's achievement and attitude. The parental factor usually involves in educational level. Echevarria (2003: 3) analyzed student science achievement scores in hands-on reform versus traditional classrooms in 3,667 students of the third to sixth grade. These parameters were included in his study; gender, ethnicity, free or reduced lunch status, parent education, and level of English proficiency. He examined whether these subgroups performed better or worse in reform classrooms. The result showed that parent education was significantly related to higher achievement for boys only in reform classrooms. This finding was in line with the study of National Assessment of Educational Progress (NAEP) (1996: Online). This research assessment gathered detailed information about the science knowledge and skills of the nation's fourth-, eighth-, and twelfth-grade students. The national results indicated that parents' highest education level affected on all three grades. The higher level of parental education was associated with attainment of higher achievement levels.

In a meta-analysis of factors influencing achievement in science, Debaze (1994: Online) found a correlation between science achievement and environment, ability, attitude, and home factors. The study also analyzed parents' education, educational facilities at home, numbers of hours spent on homework per week. The results indicated that the educational level of parents influenced the students' achievement. There was a positive relationship between facilities at home and students' achievement. It also appeared that students with good past learning had more positive attitude towards science and science learning achievement.

According to the mentioned research, some of researchers suggested parents timing are important. Parents should take an advantage of starting early. Family structure turned out to be the most important students' level variable for science achievement. This assertion was studied by Ma (2001: 108). She analyzed Canadian data from The Third International Mathematics and Science Study and found that the parent immigrant status could effect the students' achievement in science and mathematics. The other parental factors which could predict students' achievements were family income, parental education, and family structures which associated with higher levels of achievement (Redd, Brooks, & McGarvey. 2004: Online).

Parental involvement is another interesting issue of parental factors related to students' achievement and scientific attitude. Parental involvements were ranged from interaction between parents and school regarding schoolwork, parents' expectation, students' perception, school activities, and perception of parents and students.(George & Kaplan. 1998a: 95). Many researches on parental involvement had focused on students' achievements as outcome of interest and had examined parental involvement in the context of home. However, parental involvement could be studied in other contexts as well, such as community, and school. George & Kaplan (1998b: 95) studied a structural model of parent and teacher influencing on science attitude to eight graders. They used data from the National Educational Longitudinal Study of 1988. The results indicated that the availability of science facilities had a significantly and direct effect on science experiments. Parental involvement had significant direct and indirect effects on science attitude mediated through science activities. Library/museum visits and science activities also had a significant direct effect on science attitude. This study suggested that improving the quality of science instruction and science activities in schools would have implications on science education in schools and this will, in turn, indirectly affect the science attitude of students. More importantly, the findings of this study provided concrete empirical evidence that parents played a very important role in the development of science attitude of students.

National Science Teachers Association (NSTA. 1994a: Online) strongly advocated parent involvement in science education. Parents played an essential role in the success of students in schools. In addition, parents who encouraged a daily use of science concepts and process skills enhance their child's ability to learn the skills necessary for success. In order to be succeeding in science, there were many activities which parents could do, for instance;

1. Doing science together with children.
2. Let children take the lead, and then build on his or her interests.
3. Listen to their explanations instead of answering.
4. Encourage children to work on science activities at home or in the community.
5. Develop a resource such as library at home. (NSTA.b: 1994; National PTA. 2001: 93).

Ash (2004: Online) studied reflective scientific sense-making dialogue in two languages; the science in the dialogue and the dialogue in the science. Spanish was chosen to be studied. She argued that family collaborative dialogues in nonschool settings could be the foundations for scientific ways of thinking. Frances & Cheryl (1998: 111) indicated that relationship of family could support an ethnic minority students' achievement in science and mathematics. They examined the relationship of the mother's support and participation to the eighth grade ethnic minority child's score on standardized tests, particularly mathematics and science. Mothers of 80 students responded via telephone to 63 questions on their behaviors, on the physical environment of the home, on their attitude towards science and mathematics, including four demographic questions. The results pointed out that students had higher test scores if parents helped them to see the importance of taking advanced science and mathematics courses. This result emphasized on an importance of mathematics in today's careers.

Hall; & Schaverien (2001: 454) studied how families could engage with young children's science and technology learning at home. The participants were kindergarten and one-year old children. The findings showed that families engaged children in inquiry at home in many ways - by providing resources, having conversation, and investigating collaboratively with children. Moreover, when families pursued inquiries together and when children conducted their own sustained intellectual searches, children's ideas were deepened. Moreover, such evidence of the educational significance of what families did suggested that early science and technology education were found to be more effective if it were aligned with the ways people learn together outside formal institutions that those who learned in a formal setting.

The effect of parental factor was also studied in adolescence and higher education. Tenenbaum; & Leaper (2003: 34) investigated the family predominantly middle-income European American backgrounds gender differences and science achievement. Adolescents at the age of 11 and 13 years old participated with their mothers and fathers on separate occasions; families were from predominantly middle-income European American backgrounds. Questionnaires measured the parents' and the child's attitude. Each parent also engaged his or her child in 4 structured teaching activities (including science and nonscience tasks). They found that parents were more likely to believe that science was less interesting and more difficult for daughters than sons. In addition, parents' beliefs significantly predicted children's interest and self-efficacy in science. When parents' teaching style was examined, fathers tended to use more cognitively demand speech with sons than with daughters during one of the science tasks.

The structural model of Walberg's theory of educational productivity (Reynolds; & Walberg. 1991: 97) was tested with a national probability in the sample of 2,535 10th graders for science achievement and attitude (Reynolds; & Walberg, 1992d: 371). Data from the Longitudinal Study of American Youth, the 3-wave design incorporated information gathered from students, teachers, and parents were used. Results indicated that the variables including prior achievement, home environment, exposure to mass media through reading, and instructional time had the greatest total effects on science achievement. Prior attitude, home environment, motivation, and prior achievement were the greatest total contributions to science attitude.

The results of study on family policies and academic achievement by children and single-parent families in TIMSS study was studied by Pong, Dronkers, & Thompson (2002: Online). They investigated the differences in the degree of academic achievement in third and fourth graders living with single-parent from 11 countries. They found that single-parenthood was more determinable for academic achievement than two-parent families. Single-parents were associated with lower math and science achievement than their counterparts in two-parent families. These findings were noted in other 11 countries, as well.

Gorman; & Yu (2004: Online) examined the relationship between student's home environment and achievement in science. Data from the 1985-1986 National Assessment of Educational Progress were used. Science achievement and background data of 3, 7 and 11 graders were also collected. The home environment variables included (1) parental characteristics; (2) students' use of free time; (3) educational support of students at home; and (4) indicators of interest in reading at home. The results supported previous findings that the educational attainment of parents is related to the educational achievement of students. The data suggested that the more television that White students view, the lower their science achievement was. This finding was not accurate for Black and Hispanic students. Problems with the use of some of the background questions were identified. In addition, it was concluded that the percentage correct metric was not sensitive enough to compare the relationship of several variables to performance on the science assessment.

There were several reasons to study science attitude. For example, positive attitude could enhance cognitive development; increased the learning of the subject both formally and informally after class. In addition, science attitude could increase enrollment in science courses, and influence science achievement, and interest in scientific career (George; & Kaplan. 1998b: 96). Reynolds and Walberg (1992b: 929) studied science achievement and attitude among eleventh graders. They found that prior achievement, attitude, home environment, and motivation were some of the factors that influenced science attitude. Moreover, their results indicated that science achievement influenced science attitude but not reverse.

In conclusion, parental factors were very important in students' achievement and attitude. The studies of family such as parents-children interactions, family structures and home environment were important in science education, as well. The most important of science education outcome indicator was student achievement. A second outcome was the development of positive attitude toward science (Carey; & Shaverson. 1988: 147). Attitudes were inferred from behaviors. It was important to gather information about students' behaviors so that science educators could integrate the results to help achieve the goals of science education. The variables of home and family factors including other intervention of teaching were often studied in other general education more than in science education (Schibeci. 1989: 13). Hence, it is interesting to study parental factors which effect on students' science achievement, attitude, and scientific reasoning skills.

The family is a major influence upon students' learning. The daily interaction of the family, such as watching science programs on television, going to museums, visiting zoos, or taking trips to the ocean or mountains, are models for a child's actions. These activities could influence the students' science performance. Therefore, the family variables should not be overlooked in order to examine the child's science achievement (Simson; & Troost. 1982 b: 767).

6.2 School

School is another variable which could effect student achievement. Goldstein, Kaufman, & Sedlacek (1992: Online) studied school factors which affected educational achievement in mathematics and science by using data from 1985-1986 National Assessment of Educational Progress. The National Assessment of Educational Progress collected data on school characteristics. This study investigated relationship between science and mathematics achievement in the third, seventh, and eleventh grades and two types of explanatory variables at different two levels. They were student and school level variables. Student level variables included gender, race/ethnicity, and socioeconomic status while school level variable focused on student body composition, fiscal and physical characteristics of the school, school program structure, school academic standards, and principal and teacher characteristics. The research indicated that differences among schools could affect student achievement. In addition, it indicated that tailored classroom practices could be made to address differences in ability. Home background was one of the reasons for school achievement.

The effects of school size on student learning, dropout and transfer rates were studied by Rumberger; & Palardy (2004: Unpaged). Data from the National Education Longitudinal Survey of 1988 were used in this study. Questionnaires were administered to about 25 students per school and their parents, to the principal of each school and approximately five teachers per school who taught courses to the sampled students. This study used approximately 14,200 student cases that completed the questionnaire. The information about students, parents, teachers, and principals were used to construct a comprehensive set of independent variables that measure various aspects of students' family and educational background, as well as teacher and school characteristics. The national data set was divided into four groups based on school size (small, medium, large, and extra large). They indicated that school size had on affect on students' achievement.

Cotton (1996: Online) studied the effect of school size and school climate on student performance. She concluded that academic achievement in small schools was at least equal and often superior to that of large schools. Levels of extra curricula participation were much higher and more varied in small schools than large ones, and students in small schools were satisfied more from their extra curricula participation. Student attendance was higher in small schools than that of in large ones. A smaller percentage of students dropped out from small schools than that from large ones. Moreover, students in small schools took more responsibilities for their own learning; their learning activities were more often individualized, experiential, and relevant to the world outside of school; classes were generally smaller; and scheduling was much more flexible.

In the year of 2001, Sadjapod, Thathong, & Suwannoi (2001: Online) studied the causal variables affecting learning achievement in chemistry of Matayomsuksa 5 students in Khon Kaen University demonstration school. The samples were 99 Matayomsuksa 5 students. The independent variables were student's characteristic and parent involvement. The student's characteristic were defined in terms of fundamental knowledge, achievement motivation, chemistry attitude, study habit, additional study time, critical thinking, science process skills, and numerical scholastic aptitude. The parental involvement was parental support and parental expectation. The fundamental knowledge and achievement motivation could make a prediction on student chemistry achievement.

In Thailand, Klainil (2004: 9) the leader of research committee in IPST studied the evaluation of students' achievement in science and mathematic literacy of students who graduated from national foundation curricula. In this study, they used the criteria Program for International Student Assessment (PISA) which emphasized on literacy skills. Scientific literacy was defined in terms of processes, concepts and content, as well as knowledge application. Earth, environment, life and health science including science in technology were investigated in this study. The finding indicated that there were significantly different achievements in science and mathematics among under different school jurisdiction authority. The students of demonstration schools of universities have the most achievement in science and mathematics when compared with students of school under jurisdiction authority of Office of Private Education Commission (OPEC) and Office of National Elementary education Commission (ONPEC), respectively. In addition, Students in Bangkok Metropolitans had the most achievement in science and mathematic when they compare with the northern part, the southern part, and the northeastern parts of Thailand, respectively. These results signified that Thai science and mathematics educators should concern more in improving students' achievement in the future.

In conclusion, a variety of factors affecting students' success in science were studied. The review of literatures emphasized on scientific reasoning skills, science achievement, attitude towards science, child-rearing practices, home educational support, creative thinking, primary mental abilities, school science program, and school jurisdiction authority. These crucial variables are included in the study. The next chapter focused on the research methodology.

CHAPTER 3

RESEARCH METHODOLOGY

In the previous chapters, the researcher has claimed that scientific reasoning skills are important to students. The acquisition of these skills will promote students' future understandings of advanced concepts of science. In this chapter, the researcher will focus on the research methodology related to scientific reasoning skills in the fourth-grade students. The research methodology consists of 2 phases as follows:

Phase 1 Research instrumental development

Phase 2 Data collection and data analysis

Phase 1 Research instrument development

Because this study is concerned with fourth-grade students' scientific reasoning skills and the related factors, the quality of test and questionnaire is the researcher's major concern in the study. The steps of research instruments development in this study were;

1. Developing research instrument the research instruments are composed of;

1.1. Scientific reasoning skills test: This test was developed for a dependent variable.

1.2. Questionnaires: These questionnaires were developed for independent variables. There were 4 questionnaires;

1.2.1 Child-rearing practices questionnaire

1.2.2 Attitudes towards science questionnaire

1.2.3 Home educational support questionnaire

1.2.4 Science teaching quality questionnaire

1.3. Cognitive tests: These tests were developed for independent variables. These tests consist of:

1.3.1 Scientific creativity test

1.3.2 Primary mental abilities test

2. Examining and interpreting data

1. Developing research instrument

1.1. Scientific reasoning skills test

For the purpose of the study, the researcher regards a scientific reasoning skills test as a necessary tool for assessing students' scientific reasoning skills. Presenting a problem in a context is used as a technique to find out what students were thinking. Scientific reasoning skills test was developed by the researcher based on the three concepts of development of scientific reasoning, first, the acquisition and use of a conceptual knowledge in various domains of science in solving problems or making predictions. Second, the domain-general set of reasoning and problem-solving skills, and third, scientific literacy. The steps for designing a problem situation for developing scientific reasoning test are as follows:

1. Review of the literature. The literature on scientific reasoning skills, test construction, National Science Standard and benchmark, child development, psychology theory, and rubric scoring were reviewed. Then, the definitions of terms were also addressed.

2. Test construction

2.1 Writing out the first draft. In this step on the essay test items were constructed as the first draft.

2.2 Try out (I) Ten students who had different abilities conducted on the test. The students were fourth-grade students of 2 schools; Srinakharinwirot University Prasanmitr Demonstration School (Elementary) and Sawasdee Vidhaya School.

2.3 Correcting students' answer sheet. In this step, the researcher corrected the answer and interviewed the first group of students. This step provided more understanding of their abilities, and helps determine whether the test was suitable. These data were useful to develop the second draft of the test.

2.4 Develop the second draft. The second draft of essay test items was developed. This test provided some clues and prompts so that the students understood and could answer concisely and correctly.

2.5 Try out (II) One classroom students of Srinakharinwirot University Prasanmitr Demonstration School (Elementary) and Sawasdee Vidhaya School who were not the samples of this study performed on this test.

2.6 Correcting students' answer sheet. The answer sheet was corrected. The results provided more understanding for a construction of a rubric score and for deciding whether this test was suitable, such as difficulty level, and language used in the test. The outcome from this stage was useful for developing the final draft.

2.7 Develop the final draft. This test composed of two parts. The first part was a multiple-choice test with 4 items, 20 questions. Students chose the best answer. The second part was a short essay, 4 questions. The student answered and described their reason. In addition, a checking guide which based on rubric scoring was developed in this step.

3. Revision and improvement of the tests.

3.1 First revision. The questions were reviewed by five experts; science experts, educational assessment experts, psychology development experts, and national science teachers. Science content and language structure were checked. Then, the method "index item of the objective congruence" (IOC) will be used to evaluate these items. The result from this step was used to improve the test item.

3.2 Revise the test. The researcher revised and corrected the test according to the experts' suggestion.

3.3 Second revision. The same group of experts rechecked and criticized this test in order to improve the test and checking guide.

4 Try out (III). The researcher administered this test with fourth-grade students who were not the sample group of the study. One classroom of fourth-grade students from each school: Wat Thammongkol School, Wat Chonglom School, Satit Bangna, Assumption Thonburi, and Srinakharinwirot University Prasanmitr Demonstration School (Elementary) performed on the test. Then, the quality of research instrument was investigated.

4.1 Construct validity by using known group technique.

4.2 Item difficulty (p) by using 50% technique.

4.3. Item discrimination (r) by using 50% technique.

4.4 Reliability (r_{tt}) by using Cronbach method.

Scientific reasoning skills test had 2 parts;

Part I was multiple choice items, consisted of 17 items. The reliability was 0.8646. The item difficulty (p) and Item discrimination (r) of each item were between 0.28 - 0.75, and 0.25 - 0.82, respectively.

Part II was essay items, consisted of 4 items. The reliability was .8216. The item difficulty (p) and Item discrimination (r) of each item were between 0.38 - 0.49, and 0.38 - 0.82

The summary of scientific reasoning skills test construction described was shown in the following figure.

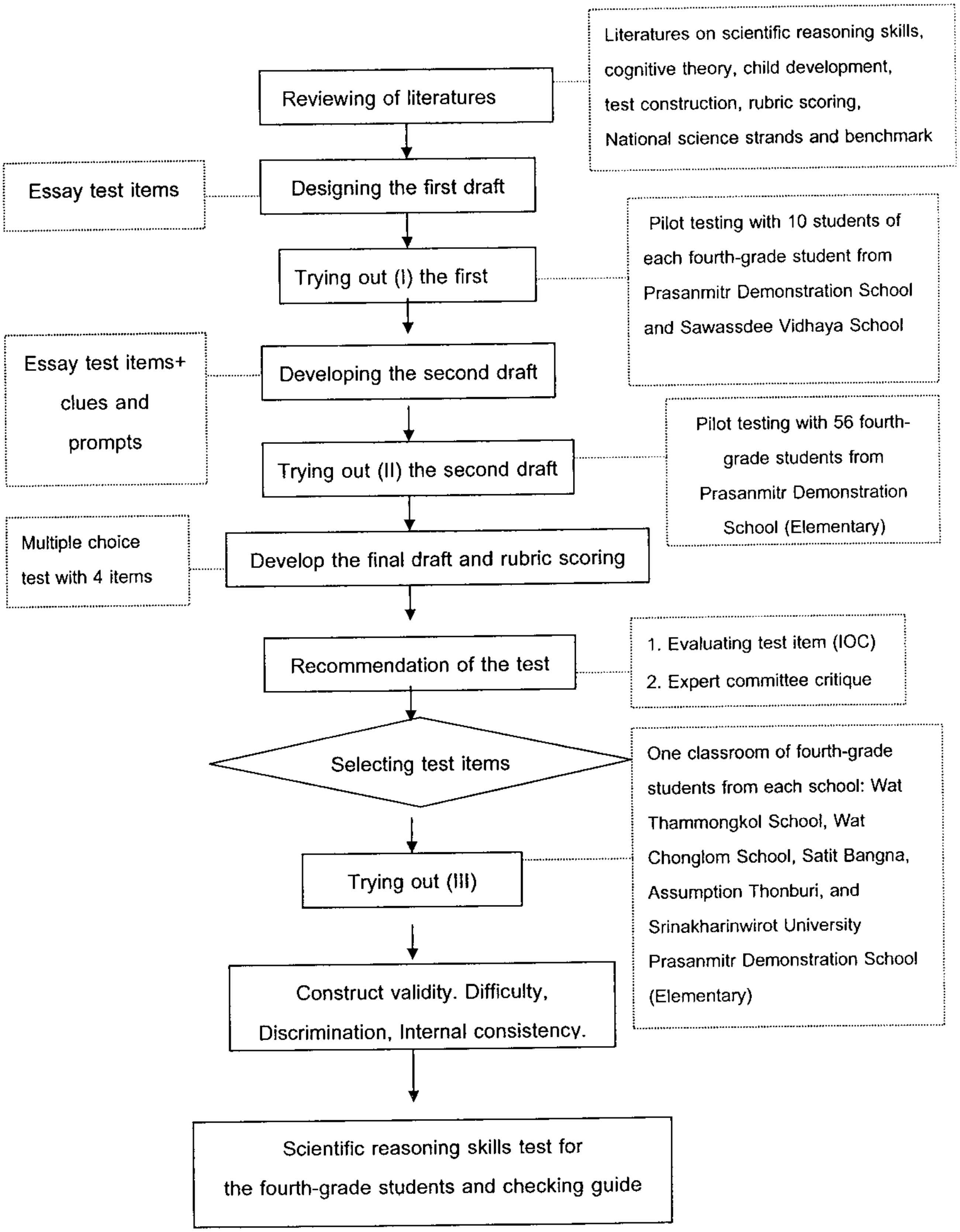

FIGURE 7 STEPS OF DEVELOPING A SCIENTIFIC REASONING SKILLS TEST

The examples of scientific reasoning skills test are as follows:

Examples

Read this statement carefully and answer question item No. (0) and No. (00)

"According to the science and technology development, there are many fruits having no seed. Tui believes that in the future these fruits may extinct because there are no seeds for propagation."

(0) Is Tui's statement true or false?

a. True

b. False (The correct answer is b.)

(00). What is your reason for answering the question 0)?

a. Because every plants need seed for propagating.

b. Because only some plants need seed for propagating.

c. Because some plant can use other parts for propagating.

d. Because propagating is an essential qualification of plants.

(The correct answer is c.)

The student who answered correctly will gain 1 point/ item.

1.2. Questionnaires

There were four questionnaires developed by the researcher; child-rearing practices, home educational support, science teaching quality, and attitude towards science questionnaire. These four questionnaires constructed by the researcher had the 5-point, and 3-point rating scale. The steps of development were as following;

1. Studying and reviewing the related literature to construct the questionnaires.

2. Developing 5-point and 3-point rating scale type questionnaires.

3. Recommendation of questionnaires: The experts checked the appropriateness of each item statement of the questionnaires by using the index item of the objective congruence (IOC) which indicated the consistency of these questionnaires (IOC > 0.5).

4. Revising the questionnaires according to the experts' suggestions.

5. Trying out: The questionnaires were provided to fourth-grade students in five schools which were not the sample of the study: Wat Thammongkol School, Wat Chonglom School, Satit Bangna, Assumption Thonburi, and Srinakharinwirot University Prasanmitr Then, the Cronbach Alpha coefficient of reliability of the questionnaires were established.

The details of each questionnaire were as follows:

1.2.1 Child-rearing practices questionnaire. This questionnaire assesses parental styles how parents take care of their children, which can be categorized into 3 groups.

1 Democratic child-rearing practice refers to the styles of parents who treat children by considering both the child's needs and their own points of view. Principles of guidance and discipline are generally discussed by parents and children.

2 Authoritarian child-rearing practice refers to the styles of parents who take care of their children by deciding rules, informing the child, and then enforcing those rules. The parents show little or no flexibility in their handling of guidance and discipline.

3 Laissez-Faire child-rearing refers to styles of parents who permit a wide range of behavior for their children. Parents set few specific rules and allow the children much freedom and self-expression.

There was 30 items, 5-point rating scale and the reliability of child rearing practice questionnaire was 0.9326,

Example of child rearing practice questionnaires

Item	Strongly agree	Agree	Not sure	Disagree	Strongly disagree
1. Parents give you some help when you have problem or are in trouble.					
2. You are punished without any explanation.					
3. You can do whatever you want to.					

1.2.2. Home educational support. The questionnaire asked students about objects or activities which parents provide for them at home or in their community in order to support or promote their science learning abilities and attitude towards science, such as books, encyclopedia, science games, video, computer, internet, visiting science museum, gardening and etc. There were 25 items, 5-point rating scale and the reliability of child rearing practice questionnaire was 0.8989

Example of home educational support questionnaires

Item	Often	Sometimes	Not sure	Seldom	Never
1. Our family loves to have a scientific conversation.					
2. My parents are not interested in science news.					
3. My parents help me when I have a science homework or a science project.					

1.2.3 Science teaching quality. The questionnaire asked about students' opinions feelings or thoughts about teaching in science classroom during they were studying in first grade-third grade, such as learning activities, classroom instruction approach, learning materials and assessment. There were 25 items, 3-point rating scale and the reliability of child rearing practice questionnaire was 0.7214.

Example of science teaching quality questionnaires

Items	Often	Sometimes	Never
1. Teachers allow student to design an experiment			
2. Teachers use questions in order to encouraging students to think.			
3. Teachers use only paper and pencil test for science assessment.			

1.2.4 Attitude towards science. The questionnaire asked about students' opinions, feelings or thoughts of students toward science, such as nature of science, importance of science in daily life, scientist's working, information science, belief and interest in science. There were 20 items, 5-point rating scale, and the reliability was 0.8007.

Example of attitude towards science questionnaires

Item	Strongly agree	Agree	Not sure	Disagree	Strongly disagree
1. Science connects to our daily lives.					
2. Science knowledge can be changed.					
3. Scientists always solve problems for themselves.					

1.3. Cognitive tests

1.3.1 Scientific creativity test This test focuses on the ability of students to think or create science knowledge variously, valuably, and innovatively. The scientific creativity test of Kumpaun (2002: 95) was used in this study. There were two parts in the test; the first part focuses on causes of the problems, while the second part is on solving of the problems. The reliability of these tests was 0.8635.

1.3.2 Primary mental abilities test This test assessed the capability of a student to learn things or to perform certain tasks individually. The Primary Mental Abilities test of Kumtae (1999: 94) was used in this study. This test composes of 5 parts; verbal, number facility, reasoning, spatial relation, and perceptual speed. The reliabilities of these tests were 0.8635, 0.8963, 0.8820, 0.8209, and 0.9726, respectively.

2. Examining and interpreting data

For scoring and interpretation of the abilities tests; scientific reasoning skills test, scientific creativity test, and primary mental abilities test; the researcher used area transformation method. The steps of this method were as follows:

1. The Kolmogorow-Smirnov test was used in order to test whether the data was a normal distribution.

2. The raw scores were converted to a percentile and a non-linear T-score.

3. The T-score was grouping into 5 levels.

The average score of tests and questionnaires were examined and interpreted as follows:

Scientific reasoning skills test (21 items, 29 marks).

Mean	Interpretation
1 - 6	low
7 - 10	rather low
11 - 22	medium
23 - 26	rather high
27 - 29	high

Scientific creativity test (4 items, do not have total score)

Mean	Interpretation
0 - 10	low
11 - 35	rather low
36 - 99	medium
100 - 170	rather high
$\geq$ 171	high

Primary mental abilities (160 items, 160 marks)

Mean	Interpretation
1 - 50	low
51 - 80	rather low
81 - 125	medium
126 - 140	rather high
141 - 160	high

Previous science grade (criteria according to elementary school assessment and evaluation)

Mean	Interpretation
0 - 0.99	improve
1 - 1.99	fair
2 - 2.99	good
3 - 1.00	very good

Democratic child rearing practice (10 items, 50 marks)

Mean	Interpretation
10 .00 - 14.99	democratic child rearing based on students' perception is at the lowest level
15.00 - 24.99	democratic child rearing based on students' perception is at a low level
25.00 - 34.99	democratic child rearing based on students' perception is at a medium level
35.00 - 44.99	democratic child rearing based on students' perception is at a high level
45.00 - 50.00	democratic child rearing based on students' perception is at the highest level

Laissez-faire child rearing practice (10 items, 50 marks)

Mean	Interpretation
10 .00 - 14.99	laissez-faire child rearing based on students' perception is at the lowest level
15.00 - 24.99	laissez-faire child rearing based on students' perception is at a low level
25.00 - 34.99	laissez-faire child rearing based on students' perception is at a medium level
35.00 - 44.99	laissez-faire child rearing based on students' perception is at a high level
45.00 - 50.00	laissez-faire child rearing based on students' perception is at the highest level

Authoritarian child rearing practice (10 items, 50 marks)

Mean	Interpretation
10 .00 - 14.99	authoritarian child rearing based on students' perception is a the lowest level
15.00 - 24.99	authoritarian child rearing based on students' perception is at a low level
25.00 - 34.99	authoritarian child rearing based on students' perception is at a medium level
35.00 - 44.99	authoritarian child rearing based on students' perception is at a high level
45.00 - 50.00	authoritarian child rearing based on students' perception is at the highest level

Home educational support (25 items, 125 marks)

Mean	Interpretation
25 .00 - 37.49	students have the lowest level of home education support
37.50 - 62.49	students have a low level of home education support
62.50 - 87.49	students have a medium level of home education support
87.50 - 112.49	students have a high level of home education support
112.50 - 125.00	students have the highest level of home education support

Science teaching quality (25 items, 75 marks)

Mean	Interpretation
25.00 - 39.99	science teaching quality based on students' perception is at a low level
37.51 - 62.50	science teaching quality based on students' perception is at a medium level
62.51 - 75.00	science teaching quality based on students' perception is at a high level

Attitude towards science (20 items, 100 marks)

Mean	Interpretation
20 .00 - 30.00	students have the lowest level of attitude towards science
30.01 - 50.00	students have a low level of attitude towards science
50.01 - 70.00	students have a medium level of attitude towards science
70.01 - 90.00	students have a high level of attitude towards science
90.01 - 100.00	students have the highest level of attitude towards science

Phase 2 Data collection and data analysis

2.1 Data collection

2.1.1 Population

The population of this study was the fourth-grade students in the first semester of the academic year 2005 from school located in Bangkok and surroundings. Theses schools were under different jurisdiction authority: Department of Education of Bangkok Metropolitan Administration; Office of the Basic Education Commission; and Commission of Higher Education.

2.1.2 Sample

In this study, the sample was fourth-grade students who were studying in the first semester of the academic year 2005 in Bangkok. Seven public schools and six private schools were selected by purposely-simple random sampling. One classroom from each school was selected randomly as the sample. The sample size of this study was 430. These thirteen schools under different jurisdiction authority were as follows:

1. School under jurisdiction authority of Commission of Higher Education is Srinakharinwirot University Prasanmitr Demonstration School (Elementary).

2. School under jurisdiction authority of Office of the Basic Education is Sainamtip Vidhaya School.

3. Schools under jurisdiction authority of Department of Education of Bangkok Metropolitan Administration are Darakam School, Wat Bangtoey, Wat Nimanoradee, Bangkhae (Nuang Sangwan Anusorn), and Sawasdee Vidhaya.

4. Schools under jurisdiction authority of Office of Private Education are Chinaworn Vidhaya, Amnuaywit School, ST.Dorminic School, Matirdei School, Chitralada School, and Somapa School.

The details of population and sample are described in table 5.

TABLE 5 DATA OF POPULATIN AND SAMPLE OF THAI FOURTH-GRADE STUDENTS IN SCIOENCE CLASSROOM CATAGORIZED BY, NUMBER OF CLASSROOM, AND GENDER.

Population				Sample			
Amount of classroom	Amount of Boys	Amount of Girls	Total	Number of sample	Amount of Boys	Amount of Girls	Total
4	95	129	224	1	24	32	56
3	48	45	93	1	15	16	31
2	36	64	64	1	19	13	32
5	80	85	165	1	16	22	33
10	152	108	360	1	15	21	36
3	60	50	110	1	19	17	36
5	92	75	167	1	18	15	33
6	85	98	193	1	17	15	32
6	110	97	207	1	18	16	34
7	256	-	256	1	37	-	37
5	-	162	162	1	-	32	32
5	100	105	205	1	19	22	41
6	118	97	205	1	18	18	36
Total 67	1232	1089	2321	13	218	239	457

2.1.3 Data collection procedure

1. Requesting permission from the subjects to collecting data.

2. Providing scientific reasoning skills test, questionnaires, and cognitive tests for sample groups. The data from 457 students were collected by the researcher in the first semester of academic year 2005 (June – September 2005).

3. Checking and selecting of answer sheet and questionnaires. There were 430 completed data (94.09%).

4. Coding and organizing the data.

2.2 Data analysis

2.2.1 Data analysis procedure

The data were analyzed by using SPSS for window version 11.5 and LISREL for window version 8.54. The steps of data analysis were as follows:

1. Basic statistics analysis: mean and standard deviation of causal factors; democratic child-rearing practice, authoritarian child-rearing practice, laissez-faire child-rearing practice, home educational support, quality of science teaching, primary mental abilities, scientific creativity, previous science grade, attitude towards science, including scientific reasoning skills.

2. Pearson product-moment correlation coefficient analysis

3. Structural equation modeling of causal factors influencing scientific reasoning skills. This step was used to test the hypothetical model consistent with the empirical data and to find out the effect decomposition; direct effect (DE), indirect effect (IE), and total effect (TE). The statistics for hypothesis testing in order to answer whether there were any causal factors related to scientific reasoning skills, path analysis were used. The LISREL program was used for this step. The fit statistics used to modify a model are as follows (Garson. 2005: Online, Diamantopoulos; & Siguaw. 2000: 110);

3.1 Chi-square (χ^2) and probability level (p), is the most common fit test. The chi-square value should not be significant if there is a good model fit, while a significant chi-square indicates lack of satisfactory model fit. The Chi-square (χ^2) / *df* should less than 2.00.

3.2 Goodness of fit index (GFI) and adjusted goodness of fit index

(AGFI) were used to determine if the model being tested should be accepted or rejected. GFI and AGFI should be greater than 0.90 for accepting the model.

3.3 Standardized root mean square residual, (SRMR): The smaller the SRMR, the better the model fits. SRMR is the average difference between the predicted and observed variances and covariances in the model, based on standardized residuals. SRMR should below 0.05 which indicated acceptable fit.

3.4 Root mean square error of approximation, RMSEA, is also called RMS or RMSE. By convention, there is a good model fit if RMSEA is less than or equal to .05. It is one of the fit indexes, which shows less affected by a sample size, though for smallest sample sizes it overestimates goodness of the fit. RMSEA is computed as [(chisq/((n-1)df))-(df/((n-1)df))]*.5, where chi sq is model chi-square, *df* is the degrees of freedom, and n is number of subjects.

3.5 The Q-Plots is a graphical display of residuals. Q-Plots order the standardized residuals by size and their percentage points in the sample distribution are calculated. Then the residuals are plotted against the normal deviates corresponding to these percentage points, called normal quantiles. The best possible fit would be indicated if all residuals are lying in a straight vertical line. An acceptable fit is indicated when residuals lie approximately along the diagonal, with steeper plots, greater than 45 degrees representing the better fits.

The fit statistics are used to modify a model as described above can be summarized in the following table.

TABLE 6 FIT INDICES

Fit Indices	Statistics Value
Chi-square (χ^2)	Not significance
Goodness of fit index (GFI)	> 0.90
Adjusted goodness of fit index (AGFI)	> 0.90
Standardized root mean square residual (SRMR)	< 0.05
Root mean square error of approximation (RMSEA)	< 0.05

4. Effect decomposition: direct effect (DE), indirect effect (IE), and total effect (TE) of causal factors influencing scientific reasoning skills of Thai fourth-grade student.

2.2.2 Statistics for analysis data

1. Basic statistics: mean ($\bar{X}$) and standard deviation (SD)

2. Statistics for measuring research instrument: Index of consistency (IOC), construct validity, item difficulty (p), item discrimination (r), and reliability (r_{tt}).

3. Statistics for testing hypothesis

3.1 Statistics for testing hypothesis 1: Pearson Product-Moment Correlation Coefficient

3.2 Statistics for testing hypothesis 2 and 3: Structural Equation Modeling with LISREL (SEM) such as

1) Chi square (χ^2)

2) Goodness of fit index (GFI) and adjusted goodness of fit index (AGFI)

3) Standardized root mean square residual, (SRMR) and Root mean square error of approximation, (RMSEA)

CHAPTER 4

RESULTS OF THE STUDY

In this study, the abbreviations are listed in this research as follows:

DEMOC	is	democratic child-rearing practice
AUTHO	is	authoritarian child-rearing practice
LAISS	is	laissez-faire child-rearing practice
HOME	is	home educational support
TEACH	is	science teaching quality
PMA	is	primary mental abilities
SCICR	is	scientific creativity
ATTI	is	attitude towards science
GRADE	is	previous science grade
SCIREA	is	scientific reasoning skills
$\overline{X}$	is	mean
S	is	standard deviation
r	is	Pearson product-moment correlation efficiency
R_m^2	is	general square multiple correlation of just-identified model
χ^2	is	chi-square
GFI	is	goodness of fit index
AGFI	is	adjusted goodness of fit index
SRMR	is	standardized root mean square residual
RMSEA	is	root mean square error of approximation
DE	is	direct effect
IE	is	indirect effect
TE	is	total effect
k	is	number of question of test or questionnaire
T	is	total score of each variable
df	is	degree of freedom
p	is	probability of reject hypotheses
β	is	beta coefficient or path coefficient

Presentation of data analysis is the following:

1. Basic analysis of variables

2. Pearson product-moment correlation analysis

3. Structural equation modeling of causal factors influencing scientific reasoning skills

3.1 Assessing fit of the model

3.2 Model modification

3.3 Effect decomposition: direct effect (DE), indirect effect (IE), and total effect (TE) of causal factors influencing scientific reasoning skills of Thai fourth-grade students.

1. Basics analysis of variables

In this section, scores of causal factors: democratic child-rearing practice, authoritarian child-rearing practice, laissez-faire child-rearing practice, home educational support, science teaching quality, primary mental abilities, scientific creativity, attitude towards science, prior students' science achievement, and scores of dependent variable, scientific reasoning skills, of 430 fourth-grade students were analyzed. Mean ($\overline{X}$), standard deviation (S), and others statistics for all variables in this study are listed in table 7.

TABLE 7 THE RESULTS OF BASIC ANALYSIS OF CAUSAL FACTORS AND DEPENDENT VARIABLE

variable			Basic Statistics				Interpretation
	k	T	max	min	$\overline{X}$	S	
DEMOC	10	50	50	25	36.43	5.620	High
AUTHO	10	50	33	24	28.30	6.199	Medium
LAISS	10	50	23	27	24.41	5.770	Medium
HOME	25	125	123	44	84.23	14.713	Medium
TEACH	25	125	94	36	60.17	7.106	Medium
PMA	167	167	148	38	106.01	22.802	Medium
SCICR	4	-	280	5	72.28	38.657	Medium
GRADE	-	4	4	0	3.38	0.968	Very good
ATTI	25	125	94	48	74.39	8.377	High
SCIREA	21	29	29	3	16.87	5.274	Medium

NOTE: Scientific creativity (SCICR) doest not have total score.

The results from the table 7 showed that democratic child-rearing practice based on students' perception is at a high level. Authoritarian child-rearing practice and laissez-faire child-rearing practice based on students' perception are at a medium level. Students have a medium level of home education support. Science teaching quality based on students' perception is at a medium level. Students have a high level of attitude towards science. In addition, students' previous science grades are very good. In addition, the results indicated that students' primary mental abilities, scientific creativity and scientific reasoning skills are at a medium level.

2. Pearson product-moment correlation coefficiency analysis

The correlation matrix of the variables considered in the study was analyzed by using Pearson product-moment correlation. The results are shown in table 8.

TABLE 8 THE RESULTS OF PEARSON PRODUCT-MOMENT CORRELATION COEFFICIENCY ANALYSIS AMONG VARIABLES.

Variable	DEMOC	AUTHO	LAISS	HOME	TEACH	PMA	SCICR	GRADE	ATTI	SCIREA
DEMOC	1.000	-.203**	-.176**	.230**	.193**	.548**	.398**	.347**.	.233**	.803**
AUTHO		1.000	.181**	-.053	.159**	-.188**	-.053	-.192**	-.269**	-.194**
LAISS			1.000	.026	-.183**	-.152**	-.190**	-.219**	-.292**	-.159**
HOME				1.000	.240**	.133**	.129**	.224**	.160**	.194**
TEACH					1.000	.192**	.086	.247**	.421**	.157**
PMA						1.000	.374**	.562**	.333**	.639**
SCICR							1.000	.259**	.162**	.418**
GRADE								1.000	.340**	.443**
ATTI									1.000	.271**
SCIREA										1.000

** Correlation is significant at the.01 level

According to table 8, the result indicated that a number of statistically significant correlation shared variance between many of the dependent variables. The maximum positive relation were a correlation between primary mental abilities and previous science grade (r = 0.562). The other positive relations were democratic child-rearing practice with primary mental abilities (r = 0.548), science teaching quality with attitude towards science (r

= 0.421). It is reasonable to conclude that students who had more primary mental abilities tended to be associated with better previous science grades. Students who received more democratic child-rearing practice tended to be associated with high primary mental abilities. Finally, having more positive attitude towards science teaching quality tended to be associated with a more positive attitude towards science.

The maximum negative relation was a correlation between laissez-faire child-rearing practice and attitude towards science (r = -0.292). The others with negative relations were authoritarian child-rearing practice with attitude towards science (r = -0.269), laissez-faire child-rearing practice and previous science grade (r = -0.219). It is possible to conclude that the students who received more laissez-faire child-rearing practice and authoritarian child-rearing practice tended to have attitude towards science at a low level. Students who received laissez-faire child-rearing practice tended to have previous science grade at a low level.

Furthermore, there were a number of significant correlations between dependent variables and scientific reasoning skills. Noteworthy, were the maximum positive significant correlation of scientific reasoning skills test with measure of democratic child-rearing practice (r= 0.803). The others were a correlation between scientific reasoning skills and primary mental abilities (r = 0.639), previous science grade (r = 0.443), scientific creativity (r = 0.418), attitude towards science (r = 0.271), home educational support (r = 0.194), and science teaching quality (r = 0.157), respectively. Whereas, there were negative significant correlations of scientific reasoning skills test between measure of authoritarian child-rearing practice (r = -0.194) and laissez-faire child-rearing practice (r = -0.159).

It is reasonable to conclude that students with more democratic child-rearing practice, primary mental abilities, previous science grade, scientific creativity, attitude towards science, home educational support, and science teaching quality would result in better scientific reasoning skills. In contrast, students with more authoritarian child-rearing practice and laissez-faire child-rearing practice would result in less scientific reasoning skills.

3. Structural equation modeling of causal factors influencing scientific reasoning skills

In this section, the researcher used LISREL 8.54 for analyzing structural equation modeling of causal factors influencing scientific reasoning skills. First, this program provided a model modification in order to test a hypothetical model with the empirical data.

Second, it provided an estimation of a direct, an indirect, and a total effect on both standardized and unstandardized forms.

3.1 Assessing fit of model

In this section, the researcher tested the hypothetical model. The fit indices were used whether it was consistent with the empirical data. The results are shown in the table 9 and the path model including standardize coefficiency is shown in figure 8.

TABLE 9 FIT INDICES (before revision)

Fit Indices	Statistics Value
Chi-square (χ^2), *df* = 12	87.6213
Probability level (p)	0.0000
Goodness of fit index (GFI)	0.9634
Adjusted goodness of fit index (AGFI)	0.8361
Standardized root mean square residual (SRMR)	0.0714
Root mean square error of approximation (RMSEA)	0.1218

According to table 9, the fit statistics pointed that the hypothetical model was not consistent with the empirical data. Chi-square (χ^2) was 87.6213 which were significant at the level .01. Chi-square (χ^2) / *df* was greater than 2, and probability level (p) was 0.0000. The goodness of fit index (GFI) was 0.9634 which reflected acceptable fits (>90), but the adjusted goodness of fit index was 0.8361 which reflected as not acceptable fits (<.90). The standardized root mean square residual (SRMR), and root mean square error of approximation (RMSEA) were 0.0714 and 0.1218 which reflected as not acceptable fits (>0.05). The largest standardized residual was 130.9 which was greater than 2.00. Finally, the standardized residuals normal probability or Q-Plot lay under the diagonal.

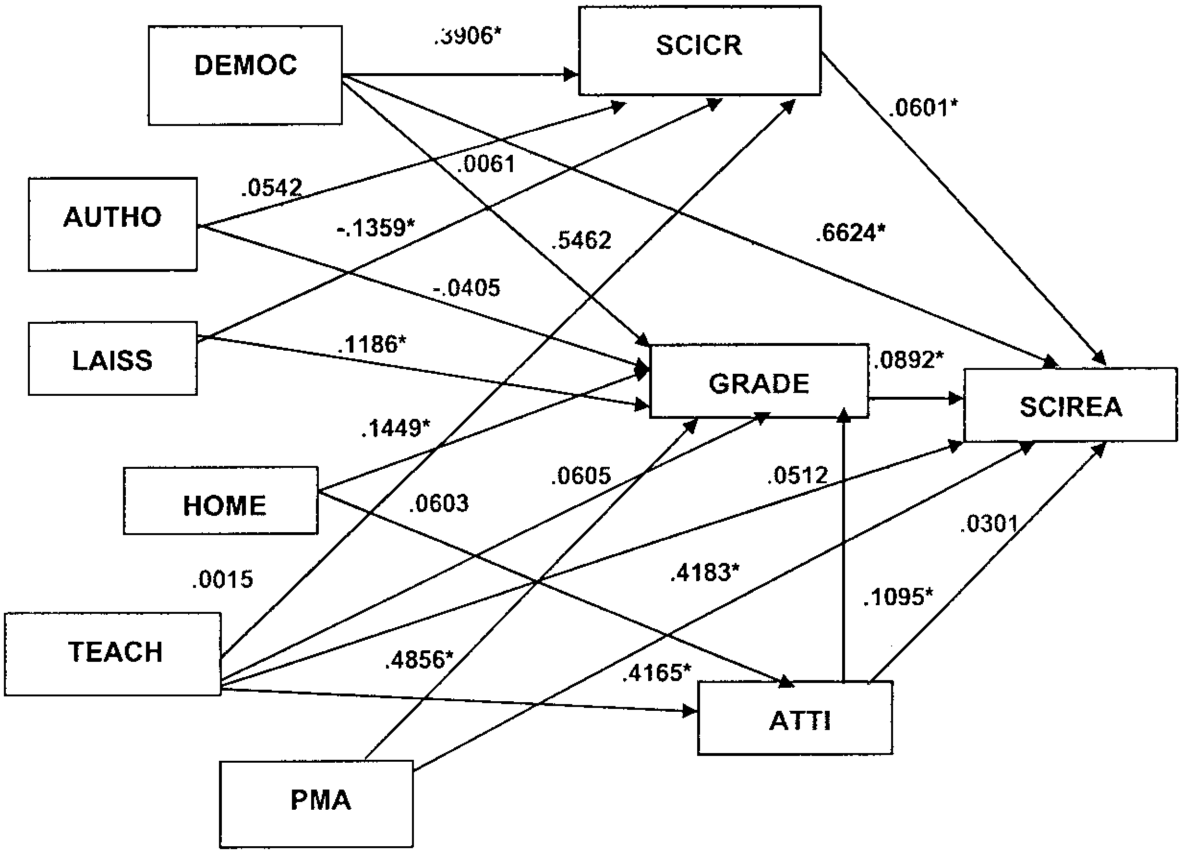

FIGURE 8 PATH MODEL WITH STANDARDIZED COEFFICIENCY (before revision)

Note: The decimal numbers are beta coefficient or path coefficient.

* means there is significant effect at the level of 0.05

According to figure 8, the results indicated that democratic child-rearing practice, primary mental abilities, previous science grade, and scientific creativity had significant direct effect on scientific reasoning skills at the level 0.01. Democratic child-rearing practice had significant direct effect on scientific creativity and previous science grade. Laissez-faire child-rearing practice had negative significant direct effect on scientific creativity and previous science grade. Home educational support had significant direct effect on previous science grade. Science teaching quality, primary mental abilities and attitude towards science had significant direct effect on attitude towards science.

The other insignificant paths were the paths from democratic child-rearing practice to previous science grade, authoritarian child-rearing practice to scientific creativity and previous science grade, home educational support to attitude towards science, science teaching quality to scientific creativity, previous science grade, attitude towards science and scientific reasoning skills, and attitude towards science to scientific reasoning skills.

3.2 Model modification

After testing the model fit, it was shown that the hypotheses model was not adequate. Inspection of structural coefficients, however, revealed that some hypothesized effects were neglegible, suggesting that a revised model might result in a better fitting and more parsimonious model. Thus, the researcher adjusted and retested the model by deleting non-significant parameters and by adding other parameters that will improve the fit based on theoretical justification and modification indices. The revised model and modification indices of the final model are shown in following section.

TABLE 10 FIT INDICES (after revision)

Fit Indices	Statistics Value
Chi-square (χ^2), *df* = 15	12.7581
Probability level (p)	0.6210
Goodness of fit index (GFI)	0.9941
Adjusted goodness of fit index (AGFI)	0.9783
Standardized root mean square residual (SRMR)	0.0164
Root mean square error of approximation (RMSEA)	0.001

According to table 10, the hypothetical model was consistent with the empirical data. The estimation of the structural model yielded a reasonably good-fitting model by the fit indices. First, the goodness of fit index (GFI), and adjusted goodness of fit index (AGFI) were 0.9941, and 0.9783 which reflected as acceptable fits (>.90). The chi-square (χ^2) was not significant (12.7581), (χ^2) / *df* was less than 2, and probability level (p) was 0.6210. Second, the standardized root mean square residual (SRMR), and root mean square error of approximation (RMSEA) were 0.0164 and 0.001 which reflected as acceptable fits (<0.05). Third, the largest standardized residual was 1.39 which was less than 2.00.

Finally, the standardized residuals normal probability or Q-Plot lies approximately along the diagonal, with sleeper plots.

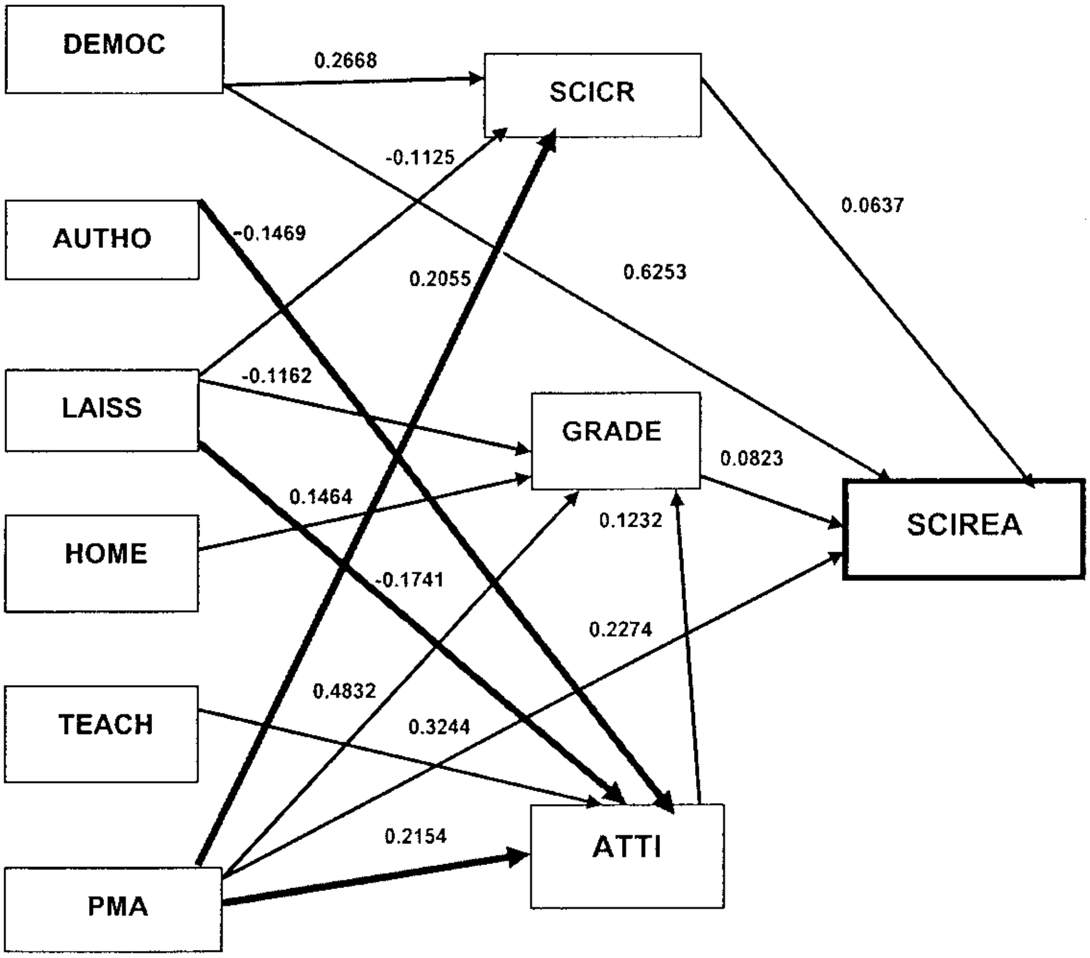

FIGURE 9 FINAL PATH MODEL WITH SIGNIFICANT STANDARDIZED COEFFICIENCY AT THE 0.05 SIGNIFICANT LEVEL (revised model).

Note: ⟶ (thick) means added path after revision.

⟶ (thin) means significant path before revision.

According to figure 9, seven insignificant paths were deleted from hypothesized structural model, including (a) authoritarian child-rearing practice on previous science grade and scientific creativity, (b) home educational support on attitude towards science, (c) science teaching quality on previous science grade, scientific creativity, and scientific reasoning skills, (d) attitude towards science on scientific reasoning skills. Three new path ways were added after revised, including (a) laissez-faire child-rearing practice on attitude towards science, (b) primary mental abilities on scientific creativity and attitude towards science.

The results indicated that democratic child-rearing practice had the strongest direct effect on scientific reasoning skills. (β = 0.6253). The others were primary mental abilities (β = 0.2274), previous science grade (β = 0.0823), and scientific creativity (β = 0.0637), respectively.

Primary mental ability was the greatest exogenous variable directly affecting on previous science grade (β = 0.4832). The others were science teaching quality affecting on attitude towards science (β = 0.3244), democratic child-rearing practice affecting on scientific creativity (β = 0.2668), and primary mental ability affecting on attitude towards science (β = 0.2154). In contrast, the exogenous variables negative affecting on attitude towards science were authoritarian (β = -0.1469) and laissez-faire child-rearing practice (β = -0.1741).

3.3 Effect decomposition

Standardized direct effect (DE), standardized indirect effect (IE), and total effect (TE) of final model were analyzed and shown in table 11

TABLE 11 STANDARDIZED DIRECT EFFECT (DE), STANDARDIZED INDIRECT EFFECT (IE), AND TOTAL EFFECT (TE) OF CAUSAL FACTORS INFLUENCING SCIENTIFIC REASONING SKILLS OF THAI FOURTH GRADE STUDENTS

Variable	SCICR			GRADE			ATTI			SCIREA		
	DE	IE	TE	DE	IE	TE	DE	IE	TE	DE	IE	TE
DEMOC	0.2668	-	0.2668	-	-	-	-	-	-	0.6253	0.0170	0.6423
AUTHO	-	-	-	-	- 0.0181	- 0.0181	- 0.1469	-	- 0.1469	-	-	-
LAISS	- 0.1125	-	- 0.1125	- 0.1162	- 0.0214	- 0.1376	- 0.1741	-	- 0.1741	-	- 0.0185	- 0.0185
HOME	-	-	-	0.1464	-	0.1464	-	-	-	-	0.0120	0.0120
TEACH	-	-	-	-	0.0400	0.0400	0.3244	-	0.3244	-	-	-
PMA	0.2055	-	0.2055	0.4832	0.0265	0.5097	0.2154	-	0.2154	0.2274	0.0550	0.2824
SCICR	-	-	-	-	-	-	-	-	-	0.0637	-	0.0637
GRADE	-	-	-	-	-	-	-	-	-	0.0823	-	0.0823
ATTI	-	-	-	0.1232	-	.1232	-	-	-	-	-	-

Structural Equation	SCICR	GRADE	ATTI	SCIREA
Square multiple correlation (R^2)	0.2031	0.3685	0.2981	0.7097

According to table 11 the results showed that;

1. The greatest standardized total effect on scientific reasoning skills was democratic child-rearing practice (β = 0.6423). The others were primary mental abilities (β = 0.2824), previous science grade (β = 0.0823), scientific creativity (β = 0.0637), home educational support (β = 0.0120), and laissez-fair child-rearing practice (β = -0.0185). These results indicate that scores on the factors: democratic child-rearing practice, primary mental abilities, previous science grade, scientific creativity, and home educational support would result in scientific reasoning skills. In contrast, more laissez-fair child-rearing practice would result in less scientific reasoning skills.

2. The greatest standardized direct effect on scientific reasoning skills was democratic child-rearing practice (β= 0.6253), the others were primary mental ability (β = 0.2824), previous science grade (β = 0.0823), and scientific creativity (β = 0.0637).

3. The greatest standardized indirect effect on scientific reasoning skills was primary mental abilities (β = 0.0550) which mediating through scientific creativity, previous science grade, and attitude towards science. The others were democratic child-rearing practice (β = 0.0170) which mediating through scientific creativity. Home educational support (β = 0.0120) mediated through previous science grade. These results indicated that primary mental abilities, democratic child-rearing practice, and home educational support tended to be indirectly associated with scientific reasoning skills. Laissez-faire child-rearing practice (β = -0.0185) mediated through scientific creativity, previous science grade and attitude towards science. As a result, it indicated that more laissez-faire child-rearing practice would result in less scientific reasoning skills.

4. The exogenous variables directly affecting on scientific creativity were democratic child-rearing practice (β = 0.2668), primary mental abilities (β = 0.2055), and laissez-faire child-rearing practice (β = -0.1125).

5. The exogenous variables directly affecting on previous science grade were primary mental abilities (β = 0.4832), home educational support (β =0.1464), attitude towards science (β = 0.1232), and laissez-faire child-rearing practice (β = -0.1162).

6. The exogenous variables directly affecting on attitude towards science were science teaching quality (β = 0.3244), primary mental abilities (β = 0.2154), authoritarian (β = -0.1469) and laissez-faire child-rearing practice (β= -0.1741).

7. The square multiple correlation (R^2) of scientific reasoning skills was 0.7097.

This result indicated that democratic child-rearing practice, primary mental ability, previous science grade, and scientific creativity were accounted for approximately 70.97 % of the variation in scientific reasoning skills attainment.

The square multiple correlation of previous science grade, attitude towards science, and scientific creativity were 0.3685, 0.2981, 0.2031, respectively. These indicated that laissez-faire child-rearing practice, home educational support, primary mental abilities, and attitude towards science were accounted for approximately 36.85% of the variation in previous science grade. Authoritarian child-rearing practice, laissez-faire child-rearing practice, science teaching quality and primary mental abilities were accounted for approximately 29.81% of the variation in attitude towards science. Democratic child-rearing practice, laissez-faire child-rearing practice and primary mental abilities were accounted for approximately 20.31% of the variation in scientific creativity.

CHAPTER 5

Conclusions, Discussions, and Recommendations

This research is the study of causal factors influencing scientific reasoning skills. The presentations are as follows:

1. Research objectives, hypothesis, and methodology
2. Conclusions
3. Discussions
4. Recommendations

Research objectives, hypothesis, and methodology

Research objectives

1. To study the relationship between the causal factors and scientific reasoning skills of Thai fourth-grade students.

2. To test whether the hypothetical model is consistent with the empirical data of Thai fourth-grade students.

3. To study the causal factors influencing scientific reasoning skills of Thai fourth-grade students.

Research hypothesis

In this study, the testing hypotheses were as follows:

1. There is a relationship between the causal factors and scientific reasoning skills. These causal factors involve democratic child-rearing practices, authoritarian child-rearing practices, laissez-faire child-rearing practices, home educational support, quality of science teaching, primary mental abilities, scientific creativity, previous science grade, and attitude towards science.

2. The hypothetical model is consistent with the empirical data.

3. There are some causal factors influencing scientific reasoning. The research hypotheses from the hypothetical model are as follows:

3.1 Democratic child-rearing practice has a positive direct effect on scientific reasoning skills, and a positive indirect effect on scientific reasoning skills by mediating through previous science grade, and scientific creativity.

3.2 Authoritarian child-rearing practice has a negative indirect effect on scientific reasoning skills by mediating through previous science grade, and scientific creativity.

3.3 Laissez-Faire child-rearing practice has a negative indirect effect on scientific reasoning skills by mediating through previous science grade, and scientific creativity.

3.4 Home educational support has an indirect effect on scientific reasoning skills by mediating through previous science grade, and attitude towards science.

3.5 Science teaching quality has a direct effect on scientific reasoning skills and an indirect effect on scientific reasoning skills by mediating through scientific creativity, previous science grade, and attitude towards science.

3.6 Primary mental abilities have a direct effect on scientific reasoning skills and an indirect effect on scientific reasoning skills by mediating through previous science grade.

3.7 Scientific creativity has a direct effect on scientific reasoning skills.

3.8 Previous science grade has a direct effect on scientific reasoning skills.

3.9 Attitude towards science has a direct effect on scientific reasoning skills and an indirect effect on scientific reasoning skills by mediating through previous science grade.

Research methodology

Samples

In this study, the samples were fourth-grade students who were studying in the first semester of the academic year 2005 in Bangkok. Seven public schools and six private schools were selected by purposely-simple random sampling. Seven public schools were difference jurisdiction (Department of Education of Bangkok Metropolitan Administration, Office of the Basic Education Commission, and Commission of Higher Education). One classroom from each school was selected randomly as a sample. The sample size of this study was 430.

Research Instruments

The research instruments composed of 3 types of tests and questionnaires. They were:

1. Scientific reasoning skills test

 1.1 Part 1 (multiple-choice items) 17 items. The reliability was 0.8646.

 1.2 Part 2 (essay items) 4 items. The reliability was 0.8216.

2. Questionnaires

 2.1 Child-rearing practices questionnaires. The reliability was 0.9236.

  2.1.1 Democratic child-rearing practice questionnaires (10 items)

  2.1.2 Authoritarian child-rearing practice questionnaires (10 items)

  2.1.3 Lassies-faire child-rearing practice questionnaires (10 items)

 2.2 Home educational support questionnaires (25 items) The reliability was 0.8989.

 2.3 Science teaching quality questionnaire (25 items) The reliability was 0.7214.

 2.4 Attitude towards science questionnaire (17 items) The reliability was 0.8007.

3. Cognitive test

 3.1 Primary mental abilities test (160 items) This test composed of 5 tests, the reliability were 0.8635, 0.8963, 0.8820, 0.8209, and 0.9726, respectively.

 3.2 Scientific creativity test (4 items) The reliability was 0.8635.

Data collection

The procedures of data collection in this study were the following:

1. The researcher collected the data from 457 fourth-grade students during June – September 2005.

2. There were 430 completed data (94.09%) that were analyzed.

Data analysis

The statistical analysis was composed of:

1. Basic statistic analysis: mean and standard deviation of causal factors including scientific reasoning skills.

2. Pearson product-moment correlation coefficient analysis.

3. Structural equation modeling of causal factors influencing scientific reasoning skills

 3.1 Assessing fit of the model

3.2 Model modification

3.3 Effect decomposition: direct effect (DE), indirect effect (IE), and total effect (TE) of causal factors influencing scientific reasoning skills of Thai fourth-grade students

Conclusions

1. There were relationships among causal factors and scientific reasoning skills. The greatest positive significant correlation of scientific reasoning skills test with the measure of exogenous variables was democratic child-rearing practice (r = 0.803). The other variables that had positive significant correlation with scientific reasoning skills were primary mental abilities (r = 0.639), previous science grade (r = 0.443), scientific creativity (r = 0.418), attitude towards science (r = 0.271), home educational support (r = 0.194), and science teaching quality (r = 0.157), respectively. Whereas, there was negative significant correlation of scientific reasoning skills test between measure of authoritarian (r = -0.194) and laissez-faire child-rearing practice (r = -0.159).

2. The hypothetical model was not consistent with the empirical data. The fit statistics for assessing model fit were, first, chi-square (χ^2), which was 87.62. Chi-square (χ^2) / *df* was greater than 2, and probability level (p) was 0.0000. Second, the goodness of fit index (GFI) was 0.9634 which reflected as acceptable fits (>0.90), but the adjusted goodness of fit index was 0.8361 which reflected as not acceptable fits (<0.90). Third, the standardized root mean square residual (SRMR), and root mean square error of approximation (RMSEA) were 0.0714 and 0.1218 which reflected as not acceptable fits (>0.05). The largest standardized residual was 130.9 which were greater than 2.00. Finally, the standardized residuals normal probability or Q-Plot lay under the diagonal.

In order to revise the model to be consistent with the empirical data, the researcher added and deleted some pathway based on literature and modification indices. The revised model was measured. Fit measure included chi-square (χ^2), probability of reject hypothesis (p), goodness of fit index (GFI), adjusted goodness of fit index (AGFI), standardized root mean square of approximation (SRMR), and root mean square error of approximation (RMSEA). These statistics are as follows; (χ^2) = 12.74 (*df* = 15), p = 0.6210, GFI = 0.9941, AGFI = 0.9783, SRMR = 0.0164, and RMSEA = 0.001. The square multiple correlation of scientific reasoning skills was 0.7097.

3. Some causal factors had a direct effect on scientific reasoning skills, and some

had an indirect effect. The detail of standardized direct effect, indirect effect, and total effect were as following;

3.1 Democratic child-rearing practice had a positive direct effect on scientific reasoning skills and a positive indirect effect on scientific reasoning skills by mediating through scientific creativity.

3.2 Authoritarian child-rearing practice had not any effect on scientific reasoning skills, but had a negative direct effect on attitude towards science.

3.3 Laissez-Faire child-rearing practice had negative indirect effect on scientific reasoning skills by mediating through previous science grade, scientific creativity, and attitude towards science.

3.4 Home educational support had an indirect effect on scientific reasoning skills by mediating through previous science grade.

3.5 Science teaching quality had not any effect on scientific reasoning skills, but had a direct effect on attitude towards science.

3.6 Primary mental abilities had a direct effect on scientific reasoning skills and an indirect effect on scientific reasoning skills by mediating through scientific creativity, previous science grade, and attitude towards science.

3.7 Scientific creativity had a direct effect on scientific reasoning skills.

3.8 Previous science grade has a direct effect on scientific reasoning skills.

3.9 Attitude towards science did not have any effect on scientific reasoning skills, but had a direct effect on previous science grade.

4. The final path model which was consistent with the empirical data was presented in following figure;

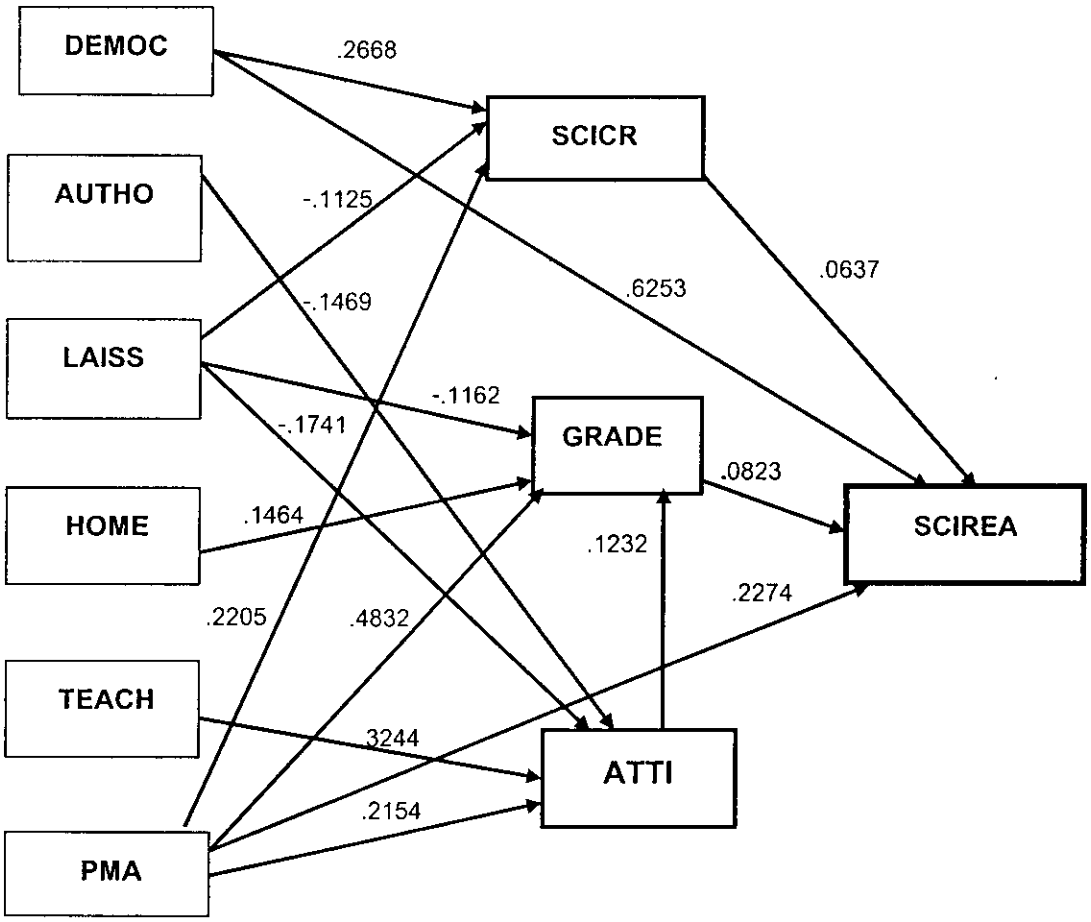

FIGURE 9 FINAL PATH MODEL WITH SIGNIFICANT STANDARDIZED COEFFICIENCY AT THE 0.05 SIGNIFICANT LEVEL

Discussions

The results of the study showed that, the hypothetical model was not consistent with the empirical data. After revising a model, there were some variables directly affecting on scientific reasoning skills, and some variables indirectly affecting on scientific reasoning skills. In order to understand more clearly about these variables, the discussion according with the research hypotheses will be described in the following section.

Hypothesis 1 "There is a relationship between the causal factors and scientific reasoning skills. These causal factors involve democratic child-rearing practices, authoritarian child-rearing practices, laissez-faire child-rearing practices, home educational support, quality of science teaching, primary mental abilities, scientific creativity, previous science grade, attitude towards science and scientific reasoning skills".

The finding was in line with the hypothesis and consistent with many research such as Yoelao (1992a: 97), Borger; & Walberg (1983a: Online), Mitatang (2004: abstract), Nethanomsak (1995: abstract) and Kumfoo (2000: abstract) who found that family valuables; child-rearing practices and home educational support had a correlation with thinking ability, school performance, creativity, and science learning. Reynolds; & Walberg (1994: 970) found that science achievement had correlation with attitude towards science, science teaching quality, and home environment. Ulanski (Staver; et al. 1989a: 256; citing Ulanski. 1987) found that attitude towards science was correlated with science achievement. LaRussa, Bodner, & Loughner (Staver; et al. 1989b: 256; citing LaRussa, & Bodner, & Loughner 1987.), and Unprasert (1999: abstract) found that primary mental abilities had a positive correlation with science learning.

Hypothesis 2 "The hypothetical model is consistent with the empirical data."

The finding did not support the hypothesis. The assessing fitting measure pointed that the hypothetical model was not consistent with the empirical data. These assessing fit measure including chi-square (χ^2), probability level (p), goodness of fit index (GFI), adjusted goodness of fit index (AGFI), standardized root mean square residual (SRMR), and root mean square error of approximation (RMSEA) were 87.62, 0.0000, 0.9634, 0.836, 0.0714 and 0.1218, respectively. The largest standardized residual was 130.9. In general, chi-square (χ^2), goodness of fit index (GFI), adjusted goodness of fit index (AGFI), standardized root mean square residual (SRMR), root mean square error of approximation (RMSEA), the largest standardized residual, and Q-Plot are statistics for assessing the model. If the model does not fit, the model will be revised by adding new pathways or deleting some path ways until the model has attainted an acceptable fit (Viratchai. 1999: 52; citing Joreskog; & Sorbon. 1989).

Hypothesis 3 "There is a statistic significance of various factors related to scientific reasoning skills."

Hypothesis 3.1 "Democratic child-rearing practice has a positively direct effect on scientific reasoning skills and an indirect effect on scientific reasoning skills by mediating through previous science grade, and scientific creativity."

The research finding was not consistent with the hypotheses. The results showed that democratic child-rearing practice had a positively direct effect on scientific reasoning skills and a positively indirect effect on scientific reasoning skills by mediating through only scientific creativity, not through science grade. In addition, democratic child-rearing practice had the greatest positive total effect on scientific reasoning skills. These findings were consistent with the previous research of Chaimongcol (1993a: 80), Prachoomvit (Chaimongcol. 1993a: 80; citing Prachoomvit. 1981), and Dornbusch; et al. (Leung, Lau, & Lam 1998a : Online; citing Dornbusch; et al. 1987) who found that democratic child-rearing practice had a positive correlation with creative thinking and it was the best predictor of creative thinking for fourth-grade students. This finding was also consistent with the finding of Punyasri (2002a: 158) who found that students with democratic child-rearing practice had higher problem solving ability than students with laissez-faire children rearing practice. This suggested that democratic parents provided their children with warmth, attention, and autonomy. They encouraged their children to be independent and individualistic. They also engaged in discussions and explanations over matters of discipline and family decision making. They also listened patiently to children's points of view as well as gave a sensitive guidance. These warmth and involvement created an emotional atmosphere in which the child was more receptive to parenting, which in turn had an effect on their thinking skill. The willingness to engage children in decision making provides them with negotiation skills that were useful in their social interaction outside family. These skills may facilitate children's outcome such as cognitive ability, academic performance and attitude (Beck. 1996: 76 ; Pike. 1996: Online; Darling, & Sternberg. 1993: 486). Sornthit (Punyasri. 2002c: 17; citing Sornthit. 1989) stated that democratic child-rearing practice was the best child-rearing practice for promoting student creative thinking. The empowerment of democratic parent was another reasoning of supporting the finding. The students performed better work in school, felt better about themselves as learners, set higher goals, and dream bigger dreamt when their parents were supportive, and encouraging. Therefore, the children of democratic parents had high performance, good academic achievement, high thinking ability, positive attitude, and leading to others positive outcomes.

Hypothesis 3.2 "Authoritarian child-rearing practice has an indirect effect on scientific reasoning skills by mediating through previous science grade, and scientific creativity."

The finding was not consistent with the research hypotheses. The result indicated that authoritarian child-rearing practice did not have any effect on scientific reasoning skills, but had a negatively direct effect on attitude towards science. This means that students who received authoritarian child-rearing practice from their parents would have a negative attitude towards science. This finding was in lined with the previous research of Chaimongcol (1993c: abstract) and Sukharom; et al. (1987: Online) who found that authoritarian child-rearing practice had a negative effect on children thinking ability development and other cognitive development. Dornbusch. et al. (Leung, Lau, & Lam. 1998b: Online; citing Dornbusch; et al. 1987) found that authoritarian child-rearing practice and permissive child-rearing practice were negatively associated with higher grade. Leung, Lau, & Lam (1998: abstract) found that academic achievement was negatively related to authoritarian child-rearing practice. Haladyra, Olson, & Shaughnessy (1982: 671) found little evidence that family background variables had significant influence on attitude towards science among fourth, seventh, and ninth grade students. Keeves (1975: 439) found a significant correlation of attitude towards science and structure of home. These can be explained that in authoritarian child-rearing practice, parents were strict, used punishment, and generally did not allow choice of freedom expressing their opinions. The child may be the cause of lacking curiosity, creativity and feeling of dependence. It was likely for them to become followers rather than leaders (Bord. 2005a: Online). The children were not capable of make a decision for themselves. They also had low self-esteem, and were aggressive and defiant. Moreover, the parents always forced their children in order to perform better in school. This cause stress, anxiety, and low emotional development which can affect children learning achievement and attitude towards learning.

Hypothesis 3.3 "Laissez-Faire child-rearing practice has an indirect effect on scientific reasoning skills by mediating through previous science grade, and scientific creativity."

The research findings were not in lined with the research hypotheses. The present results indicated that laissez-faire child-rearing practice had a negatively indirect effect on scientific reasoning skills by mediating through previous science grade, scientific creativity, and attitude towards science. This suggested that student who received laissez-faire child-rearing practice would have low previous science grade, low scientific creativity, and negative attitude towards science. As a result, these effects would cause students had low scientific reasoning skills. These result was consistent with Punyasri (1993c: abstract) who found that laissez-faire child-rearing practice had a negative correlation with creative thinking and problem solving ability. Komsakorn (1983: abstract) found that students who received laissez-faire child-rearing practice and democratic child-rearing practice showed different cognitive development. Laissez-faire child-rearing practice does not give the child much instruction as how to behave. There was no punishment or disciplines. No the child neither exhibited self-controlless or achievement motivation. He / she probably were not diligent or responsible. Children can not create or think well because parents did not give them any suggestion or help. In contrast, authoritarian child-rearing practice, parents are strict, used punishment, and generally don't allow choice of freedom of expression. The child may not develop curiosity, creative and feeling of dependence. They may become more followers than leaders (Bord. 2005b: Online). Moreover, the laissez-faire parents usually had not any expectation towards education. They did not give any guidance to their children. Parents' attitudes and expectation towards education were important for children's learning succeed. American Association of School Administrator (Peterson. 1998: Online citing American association of School Administrator. 1989) asserted that parents' expectation, an emphasis on achievement and role modeling, can encourage the child to succeed in their studying. Therefore, students who received laissez-faire child-rearing practice had low scientific creativity, low previous science grade, low scientific reasoning skills, and negative attitude towards science.

In conclusion, parents had an influence on the learning development of children. Children personality depends on not only genetic but also child rearing-practice. Child-rearing practice had an effect on children cognitive development, which involves a mental activity in all types, behavior, and attitude (Tragoonsalidh. 2000: 35; Alarcon. 2002: Online; Belsky. 1984: 84). In addition, a child's attitudes including creativity are largely shaped by its own experience with the world, but this was usually accomplished by an explicit teaching and an implicit modeling of parental attitudes or child-rearing practices (Oskamp. 1977: 127, Rungsinun. 1984: 167). It was important for parents to realize their child-rearing practice style and find a parenting style that works best for them and their children.

Hypothesis 3.4 "Home educational support has an indirect effect on scientific reasoning skills by mediating through previous science grade, and attitude towards science."

The research findings were not consistent with the research hypotheses. The results indicated that home educational support had an indirect effect on scientific reasoning skills which mediated through previous science grade and had a direct effect on previous science grade. These finding were consistent with prior research, in which Reynolds and Walberg (1991: 97, 1992: 371) found that home environment had the greatest indirect effect on science achievement of seventh and tenth grade public school students. It was consistent with Sheldon and Estein (2005: 1) who stated that family could improve students' mathematics skill and achievement in both elementary and secondary school students. The study of Koutsoulis; et al. (2001: 108) found that home support affected students' motivation in science and mathematics achievement in Cyprus. In Thai context, the results of this study were also consistent with Chinjunthuk (2004: abstract), Thathong (2003: abstract), and Punturat (2004: abstract) who found that psychological characteristic of family affected mathematics achievement of secondary school students. In addition, this research was consistent with Mitatang (2005: 111) who found that parental educational support had both direct and indirect effect on critical thinking abilities.

In science education, Gleason; & Shauable (1999: 343), Crowley (2001: 712), and Glaeson (2000: 5) suggested that parents-child interaction, such as providing informal scientific activities would develop not only engagement of students in the culture of learning science but also engaged them to practice scientific reasoning. Parents were children's first and most influential teacher. Parents' participation in education was very closely related to student achievement. Many activities such as reading books or discussing television shows or helping homework can be as important as an explicit teaching activity (Peterson. 1989: 1). Students performed better in school, had self-esteem, and higher goals, when their parents were knowledgeable, supportive, encouraging, and involved with their education. It is generally agreed that parents were their children's first teachers. From infancy through young adulthood, children depend on their parents to provide what they need physically, emotionally, and socially to learn and to grow. Throughout childhood, parents set a stage for learning everyday activities at home. When children begin their formal learning at school, parents continue to play an important role. Parents help structure the home learning environment, or provided the context which home learning activities take place. In science, many skills that help children succeed also help them in everyday life. Helping children acquire skills for understanding the world will enhance their success in science. These activities can promote and provide motivation for parents and children to discuss scientific events. While parents and children were doing these scientific support activities, parents shared, explained, and engaged students' in collaborative discussions and solving problem (Gleason; & Shauable. 1999: 343). Parents play an important role in their children's learning. Aside from being actively involved in their children's education, parents also provide a home environment that can affect learning. Parents serve as a model for learning, determine educational resources available in the home and hold particular attitudes and values towards education (Statistics Canada's Regional Reference Centers. 2005: Online).

Hypothesis 3.5 "Science teaching quality has a direct effect on scientific reasoning skills and an indirect effect on scientific reasoning skills by mediating through scientific creativity, previous science grade, and attitude towards science."

The research finding was not in lined with the research hypothesis. It indicated that quality of science teaching based on student perception did not have any effect on scientific reasoning skills, but had a direct effect on attitude towards science, and a direct effect on previous science grade by mediating through attitude toward science. This finding was consistent with previous results on teaching quality and attitude towards science in which teaching quality correlated to attitude towards science (Ebrahum. 2004: abstract; Stein. 1994: abstract; Walters. 2005: Online). The importance of how students felt about science subject has long viewed as a legitimate goal and was realized in science education for a long time ago. The development of positive attitude towards science is a critical component of science instruction because attitudes are learned either actively or vicariously, and can be taught. Teaching science by using interesting and meaningful activities for instance, inquiry teaching, hands-on, co-operative learning, and discussion influence students' positive attitudes (Kobella. 1989: Online; Gardner. 1991: 29). In this study, there was an indirect effect of quality teaching on previous science grade through attitude towards science but there was not any effect on scientific reasoning skills as expected, even though the students felt that they were taught by a child-centered technique. This could be explained by that child-centered science teaching in Thailand had just reformed in recent years. Science teachers may not use the inquiry teaching, because most of elementary teachers did not have enough science background and lack self-confidence (Soydhurum. 2001c: 38). They could let students to do hands on activities and appreciate them, but place a less emphasis on content and science thinking skills. Science content and science thinking skills are both important interrelated parts of science, with content knowledge acquisition secondary to the development of thinking skills. In addition, some hands on activities were not sufficient for being inquiry-based, and so it was possible for a lesson to be hands on without being aligned with standards (Blosser. 1987: Online; Cherilynn. 2000: Online).

Hypothesis 3.6 "Primary mental abilities have a direct effect on scientific reasoning skills and an indirect effect on scientific reasoning skills by mediating through previous science grade."

The result was not in line with the above hypothesis. It revealed that primary mental abilities had a strong effect on many variables in this study. Primary mental abilities had direct effect on scientific reasoning skills. In addition, primary mental abilities had indirect effect on scientific reasoning skills by mediating through scientific creativity, previous science grade, and attitude towards science. This result was consistent with the findings from a number of researchers who found intelligence and performance on formal reasoning tasks to be moderately correlated (Cloutier; & Goldshcmid. 1976: 25, Stuessy. 1988a: 47; citing Keating. 1975) and intelligence was a strong prediction of scientific reasoning skills (Stuessy. 1988b: 52). This study was, moreover, consistent with Martin (Kongdis. 2003: 56; citing Martin. 1974) who found that there was a correlation between primary mental abilities and math problem solving abilities in fourth-grade students. In Thai context, this finding was also consistent with Putprasert (1996: abstract) who found that students' cognitive ability and science process skill had a significant positive correlation at 0.01 level, and finding of Khotchomphu (2004: abstract) who found that mental abilities are one of the factors which related to problem-solving in science or science process skills. Primary mental abilities are human intelligence, which are ability to learn or succeed in problem solving, reason, and plan (Paik. 1998: Online; citing Epsench. 1982; Sternberg. 2000a: 89; citing Hogglerly). It is correlated with school performance and can predict students' ability in cognitive task. Students with high scores on test of intelligence tend to have high performance than their lower-scoring peers (Gottfredson. 2000: Online). It was also examined as a potential determinant of scientific reasoning skills, in addition both of them were correlated, and the former can strongly predict the latter (Cloutier; & Goldscmid. 1976:25; Stuessy. 1988a: 47; citing Keating. 1975; Stuessy. 1988b: 52).

Another reason for supporting this result was the characteristics of scientific reasoning test and primary mental abilities test. In this study, primary mental abilities test composed of 5 types of test including verbal meaning, number facility, reasoning, spatial relation, and perceptual speed. Some of them, such as reasoning, number facility, and spatial relations test were appropriate with the nature of science and scientific reasoning skills. The nature of science blends logic and imagination which are common features in mathematics and science and conforms to the principle of reasoning. (American Association for the Advancement of Science. 1994: 45). Hence, the students who performed highly in primary mental abilities could think, solve problems systematically, and well in scientific reasoning skills test.

In this study, primary mental abilities had an indirect effect on scientific reasoning skills by mediating through previous science grade, scientific creativity, and attitude towards science. This finding was consistent with Chinjunthuk (2004: abstract), Kinchampa (1995: abstract), Unprasert (1999: abstract), Tanpoonkiat (1991: abstract), and Sudeiad (1999: abstract) who found that intelligence had a positive correlation with science and mathematics achievement. This may be explained that intelligence is one of the important factors involving students' learning ability (Isarapreeda. 1995: 16). It can predict human performance and students' academic achievement. Students who had better mental ability can perform better than peers who had lower mental ability (Saiyoths. 1998: 32; Carroll. 1963: 723).

In addition, intelligence and scientific creativity were correlated. This result was similar to the findings of some Thai researchers, such as POO (1982: abstract), Unprasert (1990: abstract), Kanyook (2004: abstract), and Nethanomsak (1995: abstract) who found that students' intelligence had significant relationship with creative thinking. Intelligence and creativity were related (Sternberg. 2000b: 626; citing Torrance. 1975) Intelligence has a direct effect on creativity as Sternberg and Lubart (1995: 628) stated that there are six main elements that are formed creativity, intelligence, knowledge, thinking styles, personality, motivation, and the environment. Intelligence is considered as one of the sixth factors that, in confluence, generate creative thought and behavior. Therefore, students who have high intelligence can understand well, and have continuous systematical thinking which affect their creativity. Consequently, intelligence had a direct effect on creativity.

Another direct effect of primary mental abilities on endogenous variables in this study was attitude towards science. Attitude is a mental disposition of human individual to set for or against a definition object. This "disposition" is composed of feeling elements and some intellectual control (Draba. 1993: 444). Attitudes cannot be changed by simple education. They, however, can be changed through some personal characteristic, such as intelligence (Ferris. 2005: Online), and persuasion. People with superior intelligence may less easily be persuaded because they are likely to detect a weakness in another person's argument. Thus, there are many research found that there was a significance positive relationship between attitude towards science and intelligence, such as the study of Aiken and Aiken (1969: 295).

Hypothesis 3.7 "Scientific creativity has a direct effect on scientific reasoning skills. "

In the result of the study pointed that scientific creativity had a direct effect on scientific reasoning skills which was in lined with the research hypothesis and other research findings such as the research of Tripaken (2000: abstract), Chaiyapan (1995: abstract) who found that there was a significant relationship between scientific creativity and cognitive development at 0.05 level. This reason may be that scientific creativity and scientific reasoning skills are similar in their nature. With regards to the definition of scientific reasoning skills in this study, it is a kind of problem-solving or critical thinking which is used in science. Creativity also focuses on problem solving process. In fact, identifying a problem underlies all types of creativity (Clemons. 2005: Online; citing Slavkin. 2004; Moran. 1988: 1) Torrance (Craft. 2001: Online; citing Torrance. 1969) stated that creativity can be seen broadly as a process of sensing a problem, searching for possible solutions, drawing hypothesis, testing and evaluating, and communicating the results to others. When students engaged in active problem solving both critical thinking (reasoning) and creative thinking were important. First, students must analyze the problem, then they generate possible solutions; next they choose and implement the best solution; and finally, they evaluate the effectiveness of the solution. This process reveals an alternation between both critical and creative thinking. They are not really independent of each other (Harris. 1998: Online). Recently, Gobora (2002: 126) asserted that the creative process requires a thought shift from associative thinking to cause and effect thinking. It also relates to abductive reasoning (Gonzales. 2005: Online). Thus, giving students' opportunities to creative in science means allow them to find and solve problems in a scientific way.

Hypothesis 3.8 "Previous science grade has a direct effect on scientific reasoning skills."

The results indicated that previous science grade had a direct effect on scientific reasoning skills which was consistent with the research hypothesis. This finding was consistent with the research of Shauble (1991: abstract) who found that good learners were superior in many sub-skills; planning and controlling variables, generating hypothesis, and organizing data. According to Germann (1994: 768), students' academic achievement ability had a strong total effect on science process skills. According to science educational reform in Thailand, most schools had opportunities to design their school curricula. School science curriculum were revised in many aspects, such as content, learning process, and assessment. Students will develop their cognitive, affective, and psychomotor domains. These domains affect students' thinking abilities such as reasoning abilities. Moreover, each student's prior science learning and experience with the object or event under investigation will either facilitate or hinder his or her attempt at that skill. Unfamiliar contents will increase task complexity, whereas familiar one will reduce it. The appropriate knowledge could support the selection of thinking abilities, so good and poor learner used different strategies in solving problem. Developing an understanding of knowledge and the ability to retrieve useful knowledge is important for effective thinking. Students are generally not able to use thinking skills effectively without appropriate knowledge (Howe; & Warren. 1989: Online). This may be concluded that students reasoning ability depend on their prior science knowledge (Shauble. 1996: 97; Loharan. 2005: 3; Germann. 1994: 763).

Hypothesis 3.9 "Attitude towards science has a direct effect on scientific reasoning skills and an indirect effect on scientific reasoning skills by mediating through previous science grade.

The result of the study was not consistent with the research hypothesis. The results indicated that attitude towards science did not have any effect on scientific reasoning skills, but attitude towards science had only a direct effect on previous science grade. The finding was similar to those conducted by Simson; & Oliver (1990: abstract), Jovanic; & King (1998: abstract), Osborne & Collins (Pell; & Jarvis. 2003b: 1073; citing

Osborne; & Collins. 2000), Chinjunthuk (2004: 81), Pratoomta (2003: 88). Moreover, it was showed that attitude towards science had low indirect effect on scientific reasoning skills, although it was not significant. In science education, attitude towards science is defined as feelings, beliefs, and values about an object science, school science, the impact of science on society, or scientists themselves (Osborne. 2003: 1053). Attitude can influence children learning behavior. Children with more positive attitude towards science showed an increased attention to classroom instructions and participated more in science activities. In addition, attitude towards science influences children's attainment, consistency, and quality of class work. Therefore, many researches were conducted concerning an importance of attitudes towards science and the relationship between attitude towards science and science achievement. In young children, research finding clearly showed that early childhood experience serve as a major influence academic interest. Feeling of enjoyment and interest in science combined with success can lead to positive attitude towards science and through their achievement in science (Paul; & Jarvis. 2003a: 1072). This was supported by Millar; & Tesser (1989: 189) who stated that the affective and cognitive components of individuals are often independent to each other; both of them are complex interactions. Furthermore, this may be explained that positive emotions and relationship can enhance learning and memorizing, so that students who had a positive perception of their classroom contribute to develop a favorable attitude towards science and mediated through science achievement (Malowe; & Page. 1998: Online; citing Jensen. 1998).

In conclusion, this study investigated the relationship and causal factors influencing scientific reasoning skills that were increasingly recognized as an important educational objective in Thailand nowadays. An understanding of the impact of students' variables, family variables, school variables, and their interaction is significant on helping each child become a more effective learner. According to the results of the study, the hypothetical model was not consistent with the empirical data. This may be explained that, firstly, the sample of this study was young children, who were 9-10 years old, which differently I age, culture, and context from the literature. Secondly, the students may not be used to the characteristic of scientific reasoning test, which were essay test items in the second part. Students also had to choose not only the correct answer but also the correct explanation or reasoning. The finding revealed that science teaching quality did not have a significant direct and indirect effect on scientific reasoning skills as expected. This may be that science education in Thailand just had recently reformed. The misconception of teaching science by inquiry and child-centered may be occurred. Elementary science teachers may not have enough science concepts because most of them did not graduate in science. Lacking of science content and confidence may affect their science teaching. Elementary students may like science, and think science is an interesting and important subject, but this feeling or opinion on science could not have enough effect on scientific reasoning skills.

After the researcher revised the model, four major causal factors influencing scientific reasoning skills were found; democratic child-rearing practice, primary mental abilities, scientific creativity, and previous science grade. Democratic child-rearing practice and primary mental abilities also had an indirect effect on scientific reasoning skills. Democratic child-rearing practice had an indirect effect by mediating through science creativity. Primary mental abilities had an indirect effect by mediating through science creativity, previous science grade, and attitude towards science. The other factors indirectly affected on scientific reasoning skills were laissez-faire child-rearing practice which had a negative indirect effect by mediating through science creativity, previous science grade, and attitude towards science. Home educational support had indirect effect by mediating through previous science grade. Students' cognition is constructed both in and out school. As a view of constructivism, students come to classroom with their prior knowledge. In young children, family is a vital learning experience for preparing their knowledge that they will take with them through their lives. Interaction between parents and child in their daily activities could promote students' scientific reasoning skills (Gleason; & Schauble. 1999: 344; Crowley; et al. 2001: 714; Gleason 2000: 7). Discussing, working, playing together and other activities in a warm and supporting family in a democratic family will improve children's previous knowledge and prepare them for their school success. In contrast, in laissez-faire family children may not develop their cognitive as well as in democratic family because the parents do not give them any advice. The child tend to have less responsibilities, less achievement, and to be less assert, less cognitively competent and less self-regulated (Baumrind. 1991e: 57). These characteristics could have a negative effect on scientific reasoning skills.

Primary mental abilities were another direct effect influencing scientific reasoning skills. This can be interpreted that student who had high primary mental abilities will have high scientific reasoning skills. In addition, primary mental abilities had an indirect effect on scientific reasoning skills by mediating through science creativity, previous science grade, and attitude towards science. These results can be supported by a concept of intelligence from various researches that intelligence correlated to school performance, creativity, and years of education (Neisser; et al. 1996: 81). As a result, scientific creativity and previous science grade affected directly on scientific reasoning skills: this can be explained that students who gain more science knowledge in prior could gain better grade in their future studying. They would have better science concepts, better understanding in solving problem than peers who have less. Each student's previous knowledge and experience from their science learning or from their family can facilitate his or her attempt at developing scientific reasoning skills. These can mediate to attitude towards science, as well. Generally, students with positive scientific reasoning skills are interested in doing science activities which can promote their science learning and reasoning ability (Germann. 1994: 161). In summary, it is probable that experience and values of students from democratic family including schools science quality, and students' potential can provide them greater opportunity to excel in scientific reasoning skills.

Recommendations

According to the results of the study, the variables that had a direct effect on scientific reasoning skills of Thai fourth-grade students were democratic child-rearing practice, primary mental ability, previous science grade, and scientific creativity. Home educational support had indirect effect on scientific reasoning skills, whereas, laissez-faire child-rearing practice had negative indirect effect on scientific reasoning skills. In order to gain further insight, recommendations of additional studies about scientific reasoning skills are as follows:

1) Recommendations derived from the results of this study

1.1 Parents are the important factors for children development, especially for young child. According to the present study, family had many effects on scientific reasoning skills. Thus, parents should understand and concern about their roles for promoting student's thinking abilities and other cognitive development. Parents should:

1.1.1 Understand and use child rearing styles that work best for the family. Parent must combine warm, rational and reasonable control for more effective reinforcing agents and consider whether their parenting style is good for preparing their child for the twenty-first century. Democratic child-rearing practice should be emphasized in order to develop their children thinking skills. In addition, creating an atmosphere or environment at home and others activities in their communities will help to develop their child cognitive abilities. Well-balance experience can include various indoor and outdoor activities, field trips to museums, plays, books, games, open-mind discussion, and even selected television programs with meaningful discussion. With these activities, children can develop strategies, restraint of impassivity, planning skills, and ability to manipulate mental image and their thinking abilities through adolescence and adult age.

1.1.2 Prepares for parents quality: Parents should study and choose a suitable child-rearing practices for their culture and society. In addition, parents should participate in some discussion, workshop, seminar, or meeting in order that they can understand more clearly about child development and can apply for their family.

1.2 School is the second important factor which influencing child development. The activities which can promote students' thinking abilities are the following:

1.2.1 Teacher should concern and try to develop their student cognitive by using varieties of activities. Instruction should be restructured to reflect forms of learning which develop students' thinking ability. For instance, involving children in higher-level thinking skills, encourages the integration of subject areas through topics that are meaning and relevance to children's lives. In addition, it gives adequate time for the in-depth exploration of specific topics which may arise from spontaneous interest, and which can develop student's long-life thinking ability. Teachers should pay attention to encourage students in active learning, increase their learning experience, and construct safety learning environment. Safety environment, such as maintaining a relaxed, focus atmosphere that offers options for learning individually way can promote students' cognitive development.

1.2.2 Teachers should work co-operately with parents in order to increase valuable experience and to promote student's cognitive abilities. Organizing both formal and informal guidance or discussing with parents should be provided occasionally.

1.3 In order to develop students' intelligence and science achievement, firstly, policy makers and school administrators should concern and support the teacher in every educational level, particularly in young students. Secondly, school curricula should be expanded to include teaching of fundamental cognitive processing for students who lack of intellectual ability. Thirdly, school should work co-operately with others such as parent-teacher association in order to create some special projects or activities for developing children. Finally, the institute connected on science education, such as the IPST should support elementary science teacher to develop their inquiry teaching skills. Better science teaching skill including self confidence can promote students' science performance.

2) Recommendations for further research

The results of this study can explain only the fundamental information of the variables affecting on students' thinking ability. In order to fulfill more valuable results, the recommendations for further study are as follows:

2.1 The variables chosen in this study do account for approximately 70.97% of the variance, more research is needed to refine the knowledge of causal factors effects on scientific reasoning skills. The others 29% of variance were variables which did not include in this study. Studying other variables will explain more clearly on the variance of scientific reasoning skills. The other variables for future study should be concerned are as follows:

2.1.1 Parents. The parents can influence student's ability. In this study only child-rearing practices and home educational support were studied. According to many researches, there are others variables that influence child cognitive, as well. Future studies should include measurement of the value and support education in the house, for instance family relationship, parents' involvement, mother-child relationship, father-child relationship, and parent's education.

2.1.2 In situation when students' variable is a factor, the concept needs to be looked at more closely as to what it actually represents, such as self-esteem, locus of control, thinking styles, achievement motivation, age, and grade point average. These psychological characteristics can influence students' thinking abilities, as well.

2.1.3 In this study, the result indicated that science teaching quality only has effect on attitude towards science. Thus, there should be a follow- up and study of science teaching variables. In addition, the relative importance of other schools or teacher variables would be the better indicators for future. The other variables including science teacher qualifications, instructional environment, peer environment, and gender should provide more details.

2.2 The assessment of thinking skill is another interesting point. In the future study, using varieties of assessment thinking abilities in young child should be focused. The children will not perform well if they do not understand the language. An appropriate assessment for example, authentic assessment, interviewing, and observation should yield valuable data and indicators for future research.

2.3. The research design for further study can emphasize on other designs. For example, the latent of the growth curve model studies the longitudinal data. Another interesting design is testing hypothetical model consistent with the empirical data which collected as time series design. Using this design, the different model can be used to explain the learning process over the years. Studying the in-depth knowledge and elaboration of images and concepts such as the qualitative research can be focused in the future study. Therefore, the qualitative method such as case study, conversation analysis, focus group, and ethnography should yield more valuable data of family and teaching variables.

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Appendix

Appendix A

The Qualified Experts

The Qualified Experts

The science education experts

1. Dr. Precharn Dechsri	The Institute for the Promotion of Teaching Science and Technology (IPST)
2. Dr. Somsri Tangmonkolleart.	The Institute for the Promotion of Teaching Science and Technology (IPST)
3. Mr.Nathee Samart	The Institute for the Promotion of Teaching Science and Technology (IPST)
4. Mrs. Pakaidao Suthapornoitak	The Institute for the Promotion of Teaching Science and Technology (IPST)
5. Mr. Supod Vuthisopon	The Institute for the Promotion of Teaching Science and Technology (IPST)
6. Dr. Sunauta Manasmongkol	The Prasarnmit Secondary Demonstration School
7. Mr. Choavarit Ruayarchin	Educational Measurement, Srinakharinwirot University
8. Mrs. Saipin Kitja	Wat Thamonkol School
9. Mrs.Jintana Srilapo	Wat Bangbua School
10. Mr. Pongsak Pangkum-oan	Wat Samadum School

The psychological experts

1. Assoc. Prof. Dr. Kompech Chaisupakul	Educational Psychology, Srinakharinwirot University
2. Dr. Pasana Jularat	Educational Psychology, Srinakharinwirot University
3. Assoc. Prof. Vetahani Kreethong	Educational Psychology, Srinakharinwirot University
4. Assist. Prof. Nanta Sooraksa	Educational Psychology, Srinakharinwirot University
5. Assoc. Prof. Achara Sukharom	Behavioral Science Research Institute

Appendix B

Maximum and Minimum of Tests Score

TABLE 12 MAXIMUM AND MINIMUM SCORE OF TESTS CATAGORIZED BY SCHOOL

School	Primary Mental Ability rest		Scientific Creativity test		Scientific Reasoning Skill test	
	Max	Min	Max	Min	Max	Min
1	139	76	280	60	28	11
2	138	55	112	44	26	8
3	120	38	95	7	21	3
4	129	56	82	9	22	8
5	143	108	217	59	29	11
6	123	38	101	23	22	6
7	118	53	76	7	19	4
8	140	75	119	31	25	12
9	127	50	120	5	20	9
10	148	59	213	17	25	8
11	142	68	150	31	28	6
12	138	56	74	8	26	13
13	135	45	133	30	23	5

NOTE: Scientific creativity test does not have total score.

Appendix C

Examples of Research Instruments

แบบทดสอบวัดทักษะการคิดเชิงเหตุผลทางวิทยาศาสตร์
ชั้นประถมศึกษาปีที่ 4 (ตอนที่ 1)

คำชี้แจง

1. แบบทดสอบนี้ เป็นแบบทดสอบชนิดเลือกคำตอบ จำนวน 17 ข้อ ให้เลือกคำตอบที่ถูกที่สุด และตอบในกระดาษคำตอบที่กำหนดให้
2. ให้เวลาทำ 25 นาที
3. กรุณาอย่าขีดเขียนลงในกระดาษแบบทดสอบ

ขอขอบคุณนักเรียนทุกคนที่ให้ความร่วมมือในการทำแบบทดสอบครั้งนี้

<u>ตอนที่ 1</u> ให้นักเรียนอ่านข้อคำถามอย่างละเอียด แล้วเลือกคำตอบที่ถูกต้องที่สุด

****

<u>อ่านข้อความข้างล่างนี้แล้วตอบคำถามข้อ 1 - 2</u>

ตุ้ย บอกว่า "**ในอนาคต ผลไม้ที่ไม่มีเมล็ดบางชนิด เช่น ฝรั่ง องุ่น อาจจะสูญพันธุ์ได้ เพราะไม่มีเมล็ดสำหรับขยายพันธุ์** "

1. นักเรียนคิดว่าความคิดของ ด.ช. ตุ้ย **<u>ถูกหรือไม่</u>**

ก. ถูกต้อง
ข. ไม่ถูกต้อง

2. จากข้อ 1 นักเรียนตอบเช่นนั้น เพราะ

ก. พืชทุกชนิดต้องใช้เมล็ดในการขยายพันธุ์
ข. ฝรั่ง องุ่น ขยายพันธุ์ได้ดีโดยใช้เมล็ด
ค. พืชสามารถใช้ส่วนอื่นๆนอกจากเมล็ดในการขยายพันธุ์ได้
ง. พืชเป็นสิ่งมีชีวิตที่มีคุณสมบัติในการดำรงพันธุ์

แบบสอบถามเกี่ยวกับการอบรมเลี้ยงดู

****

คำชี้แจง

1. แบบสอบถามเกี่ยวกับสถานการณ์ระหว่างพ่อแม่กับนักเรียน ซึ่งแสดงถึงวิธีการปฏิบัติต่อนักเรียน
2. คำว่า "ผู้ปกครอง" ในแบบสอบถามนี้หมายถึง บุคคลที่ได้อบรมเลี้ยงดูนักเรียนมาเป็นเวลานานที่สุด อาจเป็น พ่อ แม่ ลุง ป้า น้า อา หรือ บุคคลอื่นๆก็ได้
3. ในการตอบแบบสอบถามให้นักเรียนระลึกถึงเหตุการณ์ตั้งแต่อดีตจนถึงปัจจุบันว่าผู้ปกครองได้ปฏิบัติต่อนักเรียนในลักษณะใด แล้วขีดเครื่องหมาย √ ลงในคำตอบท้ายข้อความที่ตรงกับความเป็นจริงที่สุด

ข้อ	ข้อความ	ระดับการปฏิบัติ				
		จริงมากที่สุด	จริงมาก	ไม่แน่ใจ	ไม่จริงมาก	ไม่จริงมากที่สุด
1.	ผู้ปกครองให้นักเรียนมีส่วนร่วมในการเสนอข้อคิดเห็นต่างๆ					
2.	ถ้านักเรียนทำผิด นักเรียนจะถูกทำโทษโดยไม่มีการถามถึงเหตุผลก่อน					
3.	ผู้ปกครองเปิดโอกาสให้นักเรียนอธิบายก่อนที่จะถูกลงโทษ					
4.	ผู้ปกครองไม่ค่อยให้ความสนใจกับสิ่งที่เกิดขึ้นกับนักเรียน					
5.	ผู้ปกครองมักเห็นนักเรียนดีกว่าคนอื่นเสมอ					
6.	ผู้ปกครองเปิดโอกาสให้นักเรียนพูดคุยปรึกษาได้ทุกเรื่อง					

แบบสอบถามการสนับสนุนของครอบครัวในการเรียนรู้วิทยาศาสตร์

****

คำชี้แจง

1. แบบสอบถามนี้เป็นแบบสอบถามเกี่ยวกับสิ่งต่างๆหรือ การทำกิจกรรมต่างๆที่พ่อแม่จัดให้เพื่อส่งเสริมการเรียนวิทยาศาสตร์ของนักเรียน คำว่า "พ่อแม่" ใบแบบสอบถามนี้ หมายความรวมถึงบุคคลอื่น ๆ ที่เลี้ยงดูนักเรียนมาเป็นเวลานานที่สุดด้วย

2. วิธีตอบแบบสอบถาม ให้นักเรียนระลึกถึงเหตุการณ์ตั้งแต่อดีตจนถึงปัจจุบันว่า พ่อแม่ได้ปฏิบัติกับนักเรียนในลักษณะใด แล้วขีดเครื่องหมาย √ ลงในคำตอบท้ายข้อความที่ตรงกับความเป็นจริงที่สุด

3. แบบสอบถามนี้จะไม่มีผลต่อคะแนนการเรียนของนักเรียน

ข้อ	ข้อความ	ทำเป็นประจำ	ทำบ่อย ๆ	ทำบ่อยปานกลาง	นาน ๆ ทำครั้ง	ไม่เคยทำเลย
1.	ผู้ปกครองซื้อหนังสือเกี่ยวกับวิทยาศาสตร์ให้นักเรียน					
2.	เมื่อประสบปัญหา ผู้ปกครองจะใช้วิธีการแก้ปัญหาเป็นขั้นตอน					
3.	ผู้ปกครองช่วยนักเรียนค้นคว้าความรู้วิทยาศาสตร์ทางจากแหล่งเรียนรู้ต่างๆ					
4.	นักเรียนไปชมพิพิธภัณฑ์กับผู้ปกครอง					
5.	ผู้ปกครองไม่ชอบ ถ้านักเรียนใช้เวลาว่างอ่านหนังสือการ์ตูน นิยาย เรื่องสั้นเกี่ยวกับวิทยาศาสตร์ที่ไม่ใช่หนังสือเรียน					

แบบสอบถามเกี่ยวกับเจตคติต่อวิทยาศาสตร์

****

คำชี้แจง

1. แบบสอบถามนี้เป็นแบบสอบถาม ความคิดเห็น ความรู้สึกของนักเรียนที่มีต่อวิทยาศาสตร์

2.ให้นักเรียนอ่านข้อความข้อความต่อไปนี้แล้วเขียนเครื่องหมาย √ ลงในช่องที่ตรงกับความเห็น ความรู้สึกของนักเรียน

3. แบบสอบถามนี้จะไม่มีผลต่อคะแนนการเรียนของนักเรียน

ข้อ	รายการ	ระดับความคิดเห็น				
		เห็นด้วยมากที่สุด	เห็นด้วย	เฉย ๆ	ไม่เห็นด้วย	ไม่เห็นด้วยมากที่สุด
คุณค่า และความสำคัญของวิทยาศาสตร์						
1.	การค้นพบทางวิทยาศาสตร์ช่วยให้มนุษย์เข้าใจธรรมชาติมากขึ้น					
2.	วิทยาศาสตร์เป็นอันตรายต่อชีวิตและสุขภาพ					
3.	มนุษย์สามารถหาคำอธิบายปรากฏการณ์ต่าง ๆได้โดยไม่ต้องอาศัยความรู้ทางวิทยาศาสตร์					
4.	วิทยาศาสตร์ทำให้คนเห็นแก่ตัว					
ความสนใจเกี่ยวกับวิทยาศาสตร์						
5.	ไสยศาสตร์น่าเชื่อถือมากกว่าวิทยาศาสตร์					

แบบสอบถามเกี่ยวกับคุณภาพการสอนวิทยาศาสตร์

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คำชี้แจง

1. แบบสอบถามนี้เป็นแบบสอบถามเกี่ยวกับสภาพ ลักษณะของกิจกรรมการเรียนการสอนของครู / อาจารย์ในวิชาวิทยาศาสตร์ที่ผ่านมา

2. ให้นักเรียนอ่านข้อความข้อความต่อไปนี้แล้วเขียนเครื่องหมาย / ลงในช่องที่ตรงกับสภาพความเป็นจริงที่เกิดขึ้นให้มากที่สุด

3. แบบสอบถามนี้จะไม่มีผลต่อคะแนนการเรียนของนักเรียน

ข้อ	รายการ	ระดับการปฏิบัติ		
		ปฏิบัติบ่อย	ปฏิบัติบางครั้ง	ไม่เคยปฏิบัติเลย
	การจัดกิจกรรม			
1.	ครูให้นักเรียนมีส่วนร่วมในการวางแผนการทำกิจกรรมการเรียน			
2.	ครูเตรียมกิจกรรมให้นักเรียนได้เลือกทำตามที่ตนสนใจ			
3.	ครูใช้วิธีการสอนที่ทำให้นักเรียนรู้สึกสนุกกับการเรียน			
4.	ครูให้โอกาสนักเรียนในการวางแผนการทดลองด้วยตนเอง			
5.	ครูให้นักเรียนได้ทำการทดลองด้วยตนเอง			

VITAE

VITAE

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CAUSAL FACTORS INFLUENCING SCIENTIFIC REASONING SKILLS OF THAI FOURTH-GRADE STUDENTS

AN ABSTRACT

BY

PORNTIP SIRIPATHARACHAI

Presented in partial fulfillment of the Requirements

for the Doctor of Education Degree in Science Education

at Srinakharinwirot University

March 2006

Porntip Siripatharachai. (2006). *Causal Factors Influencing Scientific Reasoning Skills of Thai fourth-Grade Students.* Dissertation, Ed. D. (Science Education). Bangkok: Graduate School. Srinakharinwirot University. Advisor Committee: Assoc. Prof. Dr.Sunee Heammaprasith , Assoc. Prof. Chusri Wongrattana, Dr. Parin Chaivisuthangkura.

The purposes of this study were 1) to study the relationships between the causal factors and scientific reasoning skills, 2) to test whether the hypothetical model is consistent with the empirical data of Thai fourth-grade students, 3) to study the causal factors that influence scientific reasoning skills of Thai fourth grade students.

The sample of 430 Thai fourth-grade students in the first semester of the academic year 2005 was purposely selected from seven public schools and six private schools located in Bangkok.

The research instruments composed of 3 tests: 1) a scientific reasoning skill test; 2) a primary mental abilities test; 3) a scientific creativity test; and 4 questionnaires on the following: 1) child-rearing practice; 2) attitude towards science; 3) home educational support; and 4)science teaching quality. The hypotheses were tested and the data were analyzed by Path Analysis through LISREL version 8.54. The results were the following:

1. The simple correlation coefficients between causes variables and scientific reasoning skills were statistically significant relationship at .01 level.

2. The revised model by measuring model fit using chi-square (χ^2), was 12.74 (*df* = 15, p= 0.6210), goodness of fit index (GFI= 0.9941), adjusted goodness of fit index (AGFI= 0.9783), standardized root mean square of approximation (SRMR= 0.0164), and root mean square error of approximation (RMSEA = 0.001).

3. The variables positively affecting on scientific reasoning skills directly were democratic child-rearing practice (β= 0.6423), primary mental abilities (β= 0.2274), previous science grade (β= 0.0823), scientific creativity (β = 0.0637).

4. The variables positively affecting on scientific reasoning skills indirectly were primary mental abilities through scientific creativity, previous science grade, and attitude towards science (β= 0.0550). Democratic child-rearing practice had an indirect effect on scientific reasoning skills by mediating through scientific creativity (β = 0.0170). Home educational support had an indirect effect on scientific reasoning skills by mediating through previous science grade (β = 0.0120). In contrast, laissez-fair

child-rearing practice had a negative indirect effect on scientific reasoning skills by mediating through scientific creativity, previous science grade, and attitude towards science (β = -0.0185).

5. The revised model explained 70.97 % of the variance in scientific reasoning skills.

ปัจจัยเชิงสาเหตุที่ส่งผลต่อทักษะการคิดเชิงเหตุผลทางวิทยาศาสตร์ของนักเรียนชั้นประถมศึกษาปีที่ 4

บทคัดย่อ

ของ

พรทิพย์ ศิริภัทราชัย

เสนอต่อบัณฑิตวิทยาลัย มหาวิทยาลัยศรีนครินทรวิโรฒ เพื่อเป็นส่วนหนึ่งของการศึกษา

ตามหลักสูตรปริญญาการศึกษาดุษฎีบัณฑิต สาขาวิทยาศาสตรศึกษา

มีนาคม 2549

พรทิพย์ ศิริภัทราชัย. (2549). *ปัจจัยเชิงสาเหตุที่ส่งผลต่อทักษะการคิดเชิงเหตุผลทางวิทยาศาสตร์ของนักเรียนชั้นประถมศึกษาปีที่ 4.* ปริญญานิพนธ์ กศ.ด. (วิทยาศาสตรศึกษา). กรุงเทพฯ: บัณฑิตวิทยาลัย มหาวิทยาลัยศรีนครินทรวิโรฒ. คณะกรรมการควบคุม: รองศาสตราจารย์ ดร.สุนีย์ เหมะประสิทธิ์, รองศาสตราจารย์ ชูศรี วงศ์รัตนะ, อาจารย์ ดร.ปรินทร์ ชัยวิสุทธางกูร.

การวิจัยครั้งนี้มีจุดประสงค์เพื่อ 1) ศึกษาความสัมพันธ์ระหว่างตัวแปรสาเหตุกับทักษะการคิดเชิงเหตุผลทางวิทยาศาสตร์ 2) ตรวจสอบความสอดคล้องระหว่างโมเดลปัจจัยเชิงสาเหตุที่สร้างขึ้นกับข้อมูลเชิงประจักษ์ 3) ศึกษาปัจจัยเชิงสาเหตุที่มีอิทธิพลทั้งทางตรงและอิทธิพลทางอ้อมต่อทักษะการคิดเชิงเหตุผลทางวิทยาศาสตร์ของนักเรียนชั้นประถมศึกษาปีที่ 4

ประชากรที่ใช้ในการศึกษาครั้งนี้เป็นนักเรียนที่กำลังศึกษาอยู่ในชั้นประถมศึกษาปีที่ 4 ภาคเรียนที่ 1 ปีการศึกษา 2548 ซึ่งเป็นโรงเรียนรัฐบาลและโรงเรียนเอกชนที่มีสังกัดแตกต่างกันและอยู่ในเขตกรุงเทพมหานคร กลุ่มตัวอย่างที่ใช้ในการศึกษาได้มาจากการสุ่มแบบเฉพาะเจาะจงโดยเป็นโรงเรียนรัฐบาล 7 โรง และโรงเรียนเอกชน 6 โรง ทำการสุ่มอย่างง่ายเพื่อให้ได้กลุ่มตัวอย่างโรงเรียนละ 1 ห้องเรียน รวมเป็นจำนวนกลุ่มตัวอย่างทั้งสิ้น 430 คน

เครื่องมือในการวิจัยประกอบด้วยแบบทดสอบ 3 ฉบับ ได้แก่ 1) แบบทดสอบทักษะการคิดเชิงเหตุผลทางวิทยาศาสตร์ 2) แบบทดสอบสมรรถภาพพื้นฐานทางสมอง 3) แบบทดสอบความคิดสร้างสรรค์ทางวิทยาศาสตร์ และแบบสอบถาม 4 ฉบับได้แก่ 1) แบบสอบถามรูปแบบการอบรมเลี้ยงดู 2) แบบสอบถามการสนับสนุนของครอบครัวในการเรียนวิทยาศาสตร์ 3) แบบสอบถามคุณภาพการสอนวิทยาศาสตร์ 4) แบบสอบถามเจตคติต่อวิทยาศาสตร์ สถิติที่ใช้ในการวิเคราะห์ข้อมูลคือ การวิเคราะห์แบบเส้นทาง (Path Analysis) โดยใช้โปรแกรม LISREL version 8.54

ผลการวิจัยสรุปได้ดังนี้

1. ค่าสัมประสิทธิ์สหสัมพันธ์ระหว่างตัวแปรสาเหตุ (รูปแบบการอบรมเลี้ยงดูแบบประชาธิปไตย แบบปล่อยปละละเลย แบบเข้มงวดกวดขัน การสนับสนุนของครอบครัว คุณภาพการสอนวิทยาศาสตร์ สมรรถภาพพื้นฐานทางสมอง ความคิดสร้างสรรค์ทางวิทยาศาสตร์ ผลการเรียนรู้เดิมวิชาวิทยาศาสตร์ เจตคติต่อวิทยาศาสตร์) กับทักษะการคิดเชิงเหตุผลทางวิทยาศาสตร์ พบว่า มีนัยสำคัญทางสถิติทุกค่าที่ระดับ .01

2. โมเดลสมมติฐานไม่สอดคล้องกับข้อมูลเชิงประจักษ์ โดยพบว่ามีค่าไค-สแควร์ (χ^2) เป็น 87.62 GFI = 0.9634 AGFI = 0.8361 SRMR = 0.0714 RMSEA = 0.12

หลังจากปรับแก้โมเดลแล้วทำให้ได้โมเดลที่มีความสอดคล้องกับข้อมูลเชิงประจักษ์ โดยมีค่าไคแสควร์ (χ^2) เป็น 12.74 (*df* = 15, p= 0.6210) GFI= 0.9941 AGFI= 0.9783 SRMR= 0.0164 และ ค่า RMSEA = 0.001

3. ตัวแปรที่มีอิทธิพลทางตรงแบบบวกต่อทักษะการคิดเชิงเหตุผลทางวิทยาศาสตร์ ได้แก่ รูปแบบการเลี้ยงดูแบบประชาธิปไตย (β= 0.6423) สมรรถภาพพื้นฐานทางสมอง (β= 0.2274) ผลการเรียนรู้เดิมวิชาวิทยาศาสตร์ (β= 0.0823) และความคิดสร้างสรรค์ทางวิทยาศาสตร์ (β = 0.0637).

4. ตัวแปรที่มีอิทธิพลทางอ้อมแบบบวกต่อทักษะการคิดเชิงเหตุผลทางวิทยาศาสตร์ ได้แก่ สมรรถ ภาพพื้นฐานทางสมอง โดยส่งผ่านทางความคิดร้างสรรค์ทางวิทยาศาสตร์ ผลการเรียนรู้เดิมวิชาวิทยาศาสตร์ และเจตคติต่อวิทยาศาสตร์ (β= 0.0550) รูปแบบการเลี้ยงดูแบบประชาธิปไตย มีอิทธิพลทางอ้อมโดยส่งผ่านทาง ความคิดสร้างสรรค์ทางวิทยาศาสตร์ (β= 0.0170) การสนับสนุนของครอบครัวมีอิทธิพลทางอ้อม โดยส่งผ่านทางผลการเรียนรู้เดิมวิชาวิทยาศาสตร์ (β= 0.0120) ในทางตรงข้าม รูปแบบการเลี้ยงดูแบบปล่อยปละละเลยมีอิทธิพลทางอ้อมแบบลบต่อทักษะการคิดเชิงเหตุผลทางวิทยาศาสตร์โดยส่งผ่านทางความคิดสร้าสรรค์ทางวิทยาศาสตร์ ผลการเรียนรู้เดิมวิชาวิทยาศาสตร์ และเจตคติต่อวิทยาศาสตร์ (β= -0.0185)

5. ตัวแปรสาเหตุทั้ง 9 ตัวแปรสามารถอธิบายความแปรปรวนของทักษะการคิดเชิงเหตุผลทางวิทยาศาสตร์ได้ร้อยละ 70.97