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THESIS

ENHANCING LOWER SECONDARY SCHOOL THAI STUDENTS' UNDERSTANDING OF LIGHT: SOCIAL CONSTRUCTIVIST APPROACH

THEERAPONG SANGPRADIT

A Thesis Submitted in Partial Fulfillment of
the Requirements for the Degree of
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In terms of teaching and learning science, the concept of light is a very important concept. Light is a basic concept that is related to everyday life and is necessary for students' understanding of natural phenomena. Understanding the concept of light will help students to understand more advanced concepts. Numerous studies point to promising ways of understanding students' thinking about light. Moreover, students have many misconceptions about light. In this study, the Light Learning Units (LLU), using a social constructivist approach, were developed to enhance students' understanding of light.

The study was divided into three phases: Exploration, Development, and Implementation and Evaluation. In the first phase, thirty seven eighth grade science teachers in schools under the Bangkok Metropolitan Administration (BMA) were surveyed about the current state of teaching and learning the concept of light. Three of them were selected to be interviewed in-depth. Moreover, the students of the three selected teachers were asked to assess the Light Diagnostic Test (LDT). The findings from phase I were used to guide the development of the LLU in the second phase. In the third phase, three teachers from phase I were asked to implement the LLU. The effects of the implementation of the LLU on teachers' teaching and students' learning were investigated. Multiple data gathering methods were used to ensure the trustworthiness of the findings. The multiple data gathering methods included classroom observations with videotape recording, field notes, semi-structured interviews, and the students' reflections.

The findings indicated that the three teachers implemented the LLU differently because the teachers were different in terms of teaching style and their content knowledge. Two teachers implemented the LLU by focusing on students' prior knowledge, using a meaningful context to help students' development of the concepts in the real world, encouraging students by asking them thoughtful and open-ended questions, giving the students an opportunity to construct their own learning through interaction with their peers, and focusing on the students' cooperative work. These strategies developed teachers' content knowledge and teaching strategies. All of the teachers were happy with their teaching and felt that the LLU had helped their students to enjoy doing the activities in the LLU. In addition, the students paid more attention during the lessons, and the unit enhanced the students' understanding of the concept of light. However, some students still had misconceptions about some concepts of light.

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Student's signature Thesis Advisor's signature

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CHAPTER I

INTRODUCTION

This chapter begins by describing the background and to the research study and the significance of the study which includes the topic of students' understanding of light concept, teaching light concept and social constructivism. It also presents research purposes and questions, anticipated outcomes, context of the study, definition of terms, and summary and preview.

Background of the Study

During the past ten years, Thailand has undergone rapid changes in all aspects, including its economy. Because of heightened competitiveness in the market world (Office of Education Council [OEC], 2004), Thailand has faced economic crises that have led to increased unemployment together with its consequent problems, like poverty, drug abuse, and crime.

Thailand is trying to find a way to deal with its many problems. The country is trying to improve its human resources by developing educated and skillful people that can support the transformation of the economy (Office of National Education Commission [ONEC], 2002). It realizes that humans are the most important key to the development of society and the economy. Any country that has citizens who are well educated and skillful in science will perform better than countries that do not have those skills (ONEC, 2002).

Thailand seeks to educate its citizens to have higher-level knowledge and skills including competencies in new technologies. Citizens are increasingly expected to be life-long, autonomous and self-regulated learners and to have the ability to adapt readily to changing circumstances. While Thailand understands the necessity of strengthening the knowledge base for the entire country, the quality of education of the Thai people has on average lowered and the absolute educational standards are low in comparison with those of other countries at the same developmental level. This cannot continue if Thailand is to become a leader in the world.

Science is the one area of knowledge that supports the development of society and the economy, because it is important for developing many new strategies, products, technologies. In Thailand science is vital because it helps people have a better life. Those people who have scientific knowledge help to improve their own life, as well as that of the society and the nation (ONEC, 2002).

However the performance of Thai students in the Third International Mathematics and Science Study (TIMSS) was lower than that of other countries, like Hong Kong, Singapore and New Zealand (Forgione, 2001). The average science score of Thai students in grade 8 in 1999 ranked 24th among the 38 countries. Moreover, Thai students lacked knowledge especially in application and problem solving skills (ONEC, 2001). Thus, the educational system in Thailand needs improvement to meet the demands of a knowledge-based economy (ONEC, 2001, 2003; OEC, 2004).

Furthermore, before the Thai science education reformation ten years ago, teaching and learning in classrooms was not very student centered. The teachers were the authorities in the classroom and most believed that teachers were the only ones with knowledge. Students just received information from teachers. This created learners unable to think analytically, share opinions, or seek knowledge themselves. The teaching and learning process caused students to feel discouraged, stressful and unhappy while they learned (ONEC, 2002). Thus, Thailand urgently needs to improve its education system.

Education reform has resulted in policies and plans to bring about necessary changes within the Thai system. Initial research was carried out into the successful experiences and educational provisions included within the constitutions of other countries, and these were subsequently considered for application in the Thai system. ONEC also prepared legal provisions on education for consideration of the Constitution Drafting Council with the result that the 1997 Thai Constitution contains extensive provision on education, including equal rights for 12-years of basic education that is free of charge, promotion of local wisdom, national arts and culture, and development of the teaching profession (ONEC, 1999).

The result of these policy changes is the National Education Act B.E. 2542, effective in August 1999. The principal objectives of the Act are to ensure that education promotes the full development of the people in all aspects including physical and mental health, intellect, knowledge, morality, integrity, and the pursuit of a desirable lifestyle in accordance with society and in harmony with other people (ONEC, 1999). According to the Act, the provision of education shall be based upon the principles of a lifelong education for all, the participation of all segments of society in educational provision, and continuous development of the bodies of knowledge and learning processes (ONEC, 1999). Major aspects of this reform are:

Learning reform - ONEC has conducted extensive research into development of learner-oriented education which allows students to develop at their own pace and within their individual potential.

Administrative reform - adjustment of the administrative structure includes upgrading the teaching profession by reorganizing systems for teachers, faculty staff and educational personnel; and increasing efficiency in the utilization of resources and investment for educational purposes. (ONEC, 1999)

For the science curriculum, Thailand has a core science curriculum that called the National Science Content Standards (IPST, 2002). This science curriculum guides for all schools of Thailand. It emphasizes that all students are expected to be scientifically literate persons who have the knowledge, skills and attitude of scientists and knowledge about managing natural resources in a sustainable way.

Both the National Education Act (ONEC, 1999) and the National Science Content Standard (IPST, 2002) emphasize that "an important goal for science education is to encourage students to develop their own scientific conceptions for understanding and explaining natural phenomena." Teaching science should be a meaning to students to apply to their everyday life (ONEC, 1999; IPST, 2002; ONEC, 2002). The specific goals of science education for Thailand are to have all science educators, teachers, parents, schools and communities provide science education for Thai students so they can reach the desired knowledge, skills and attitude.

Significance of the Study

Students' Understanding of Light Concept

The physical science concept of light will be the focus of this study because light is a basic concept that is related to everyday life and is necessary for students' understanding of natural phenomena such as mirages and rainbows (Shapiro, 1994). For example, everyone is familiar with a plane mirror and its uses in daily life. Light is also used for transmitting information and reading compact disks in CD players and filters are used for protecting the eyes. The concept of light has long been a focus for learning in school science programs and in national and international documentation on science education (American Association for the Advancement of Science [AAAS], 1993; NRC, 1995 and IPST, 2002). In addition, light is an important content area in science education to help students understand and explain more advanced scientific concepts like optical fibers and lasers. Because of its many practical applications and importance within the physical sciences, improvement of students' scientific understanding of light is a significant challenge to science educators.

The students' understanding of phenomena associated with light has attracted interest from a number of researchers in difference countries. Work has been done in England, New Zealand, Sweden, Switzerland, India and USA (Osborne *et al*., 1990). Numerous studies point to promising ways of understanding student thinking about light. Some of the earliest research findings reported in this area are by Piaget (1974) who noted that young children make no connection between eye and object whilst at a later stage they commonly think of vision as a passage from the eye to the object. This research is consistent with the works of Ramadas and Driver (1989) who indicated that Swedish pupils aged 12-15 have misconceptions about how light travels an object to the eyes. Most students believed in a visual ray model in which they see objects because there are rays from their eyes that hit the objects. Moreover, this result also was found in the studies of Anderson and Karrqvist (1983) and Watts (1985).

Other students' misconceptions about light were found in a study by Guesne focused on students' understanding about light. He used interview techniques to get 13-14-year-olds to talk about reflection using mirrors. The study showed that students have many misconceptions about reflection (Guesne, 1978). As same as the work of Jung (1981) that provided 12-years-old boys and girls with a mirror and reported that in 90% of the cases students spoke of seeing their images on the surface of the mirror rather than from behind the mirror. Many students suggested that because light is reflected from the surface of the mirror, that it is the place where the image is formed. In addition, the work of Watts (1985) and a study by Goldberg and McDermott (1986, 1987) showed that students who were enrolled in the third quarter of an algebra-based or calculus-based introductory physics course at the University of Washington held the same misconceptions.

Moreover, Shapiro (1994) found that a large percentage of students believes that when light coming from a flashlight strikes a rock it stops on the surface rather than reflecting from the rock. Many students stated that light reflects from mirrors and shiny or metallic objects, but not from other types of objects, such as rocks or clothing. Several studies have shown that the students have difficulty understanding image formation on the plane mirror (Jung, 1981; Aderson and Smith, 1983; Guesne, 1985; Watts, 1985; Goldberg and McDermott, 1986; Ramandas and Driver, 1989; Feher and Meyer, 1992; Fetherstonhaugh and Treagust, 1992).

Most students believe that the image exists on the mirror surface or is just behind it. Because of these and other difficulties students have with light (Shapiro, 1994), this study proposes to investigate the ways to improve the teaching and learning of concepts involved with the topic of light.

Teaching Light Concept

Science achievement of the students in lower secondary school in Thailand is very low (OEC, 2004). Forty-three percent of teachers encountered problems with the study of teaching and learning science in schools in a study at lower secondary levels of the Bangkok Metropolis Administration. Problems cited were many. First was teacher lack of content in science as most didn't graduate with major in science. Second, the teachers primarily used chalk and talk strategies, not strategies that actively involved students. Third, the assessment in students' learning outcomes mostly came from the teacher made tests. Fourth, teachers reported that there was an insufficiency of material such as experimental tools and media in classrooms. Finally, most of the teachers stated that they must teach other subjects in addition to science (Meinoratha, 1997).

Similarly, the researcher observed 3 eighth grade teachers teaching science in the second semester, academic year 2005 and found that they mostly used lectures and gave exercises to their students while they were teaching the topic of light in their school in Thailand. There was no discussion about content during teaching and most of the students could not do the exercises that the teachers gave them. In an experiment about refraction of light, many groups of students failed the experiment because they could not measure the angle of reflection and refraction and there was not enough material for all the students. One of teachers in schools said that light is difficult for students to understand and the school lacks materials for teaching about light. Undoubtedly, this teacher still has a problem about teaching and learning.

In Thailand, there has been much research on the teaching of light. For example, Worrapan (2003) studied teaching for changing student misconceptions about the refraction of light among eleventh grade students. The study used the teaching strategy created by Hesse which has three steps. The first one was determining the prior concepts of the students. The second was provoking conflict between students' prior concepts and new concepts to be learned. The last one is the teacher helps students gain more confidence in their new concepts. Comparing with a pretest and posttest, Worrapan (2003) found that students better understood the scientific concepts after using the teaching strategy of Hesse. Similarly, Tinsandee (2004) studied how to change misconceptions about the velocity and the reflection of light with eleventh grade students also using the teaching strategies of Hesse. Comparing pretest to posttest scores showed that the students better understood the scientific concepts after using these teaching strategies.

Pulputsa's study (2004) compared teaching strategies proposed by Wittrock and IPST concerning the velocity of light, the reflection of light, the refraction of light, and seeing. There are four stages in Wittrock's teaching strategy which is similar to the strategy of Hesse. First, find the prior concepts of the students. Second, encourage the students to learn and share the prior concepts in the classroom while the teacher explains the scientific concepts to the students. Third, has the students do an experiment that is designed to provoke a conflict between students' prior concepts and their new concepts. Finally, generate new knowledge to use in other situations. IPST's teaching strategy is a strategy that is used in the IPST teaching manual and it is based on the processes of inquiry, problem solving and hands-on /minds-on activities. The study compared test scores after using the two strategies and found that Witrock's teaching strategy helped the students understand more than the IPST's strategy. In addition, Wittrock's teaching strategy created fewer misunderstandings than the IPST strategy.

Social Constructivism

Social constructivism is a philosophy of learning which describes how people learn and construct their knowledge through participation with more capable peers and as a teacher. Social constructivism is a particular view of knowledge, a view of how we come to know. In this view, learning is constructed through interactions with others and focuses on learning as sense-making rather than on the acquisition of rote knowledge that exists somewhere outside the learner (Pea, 1993; Atwater, 1996; Shepardson, 1996; Oldfather *et al*., 1999; Valanides, 2002).

Social constructivism builds on the works of Vygotsky that Learning is a social activity in which learners are constructing meaning though discussion and negotiation with peers and teachers. Vygotsky's ideas for addressing this included the development of social conditions to help student learns in inclusive classrooms in ways consistent with the student-centered approaches recommended in the National Education Act (B.E. 2542) of Thailand.

Many researchers suggested that the teaching and learning of science should consider students' prior knowledge and that students should construct their own new knowledge after considering what they already know. There are several instructions based on the social constructivist approach. For example, Wood, Cobb, and Yackel (1995) suggest that teaching strategies using social constructivism as a referent include teaching in contexts that might be personally meaningful to students, negotiating taken-as-shared meanings with students, class discussion, small-group collaboration, and valuing meaningful activity over correct answers. Hand, Treagust, and Vance (1997) examined on student perceptions of social constructivism in grade 7-10. Results by questionnaires and interviews showed that most students liked teaching and learning approaches that consisted with social constructivism more than those to which they had been previously exposed and students were appreciative of the opportunity to use their own ideas and knowledge. Also, in Thailand, Worrapan's study (2003) and Pulputsa's study (2004) used the strategies of Wittrock and Hesse to help students understand more about the topic of Light. Both strategies used an active teaching and learning. The results of these studies showed that the students still held some misconceptions in some concepts of light. Consequently, the development of a teaching approach that was based on social constructivist of learning was claimed to be a way to promote better learning when students would have an opportunity to be actively involved in the learning process.

Research Purposes

This study aimed to investigate the effectiveness of implementing the Light learning unit which based on social constructivism to enhance an instruction and learning the concept of Light. The specific purposes of the study are:

1. To investigate how Thai teachers typically teach concepts about Light in grade 8.

2. To investigate how Thai students understand the concepts of Light.

3. To investigate science teachers' teaching of and students' learning the concepts of light by using the Light Learning Unit (LLU).

4. To promote eighth grade science students' understanding of concepts about Light by using the Light Learning Unit (LLU).

Research Questions

The research answered the following questions in the study:

1. How do Thai teachers typically teach concepts about Light in grade 8?

2. How do Thai students understand the concept of Light?

3. How and to what degree are Thai science teachers able to implement the Light Learning Unit (LLU)?

4. How does the implementation the Light Learning Unit (LLU) enhance students' scientific understanding of concept about light?

Anticipated Outcomes

1. Thai science teachers would have a teaching unit that is based on the goals of the National Education Act B.E. 2544 (ONEC, 2002) and the National Science Curriculum (IPST, 2002). Then, they could adapt the teaching unit to teach about Light in their classrooms.

2. Thai science teachers and science educators would receive information of a new teaching unit for learning. This would enable them to adapt the process to create their own teaching unit.

Context of the Study

This study has three phases which include a) exploratory of the current state of teaching and learning and the students' understanding about light, b) design and development of Light Leaning Unit (LLU), and c) implementation and evaluation of the unit. In the first phase, the current state of teaching and learning was examined from 37 eighth grade teachers in schools under the Bangkok Metropolis Administration. The thirty seven teachers completed the questionnaire about 1) background information; 2) the current state of teaching and learning which included the use of curriculum and textbooks, teaching preparation, teaching methods, and measurement and evaluation, and 3) problems encountered upon instructing about light and needs of the teachers related to the teaching and learning. Then, three of thirty seven teachers were purposefully selected to be in-depth interviewed about the current state of teaching and learning about light. The first phase also explores the students' understanding about light. The 114 students of three selected teachers were asked to complete the Light Diagnostic Test (LDT). In the LDT, there were 6 main concepts about light. The concepts of light include Nature of Light, Image Formation, Refraction of Light, Optical Instrument, Color, and Seeing. In the second phase, the two surveys in the exploratory phase revealed the state of teaching and learning the concepts of light, along with the student understanding of the concept about light and the review of the literature were used in designing the Light Learning Unit (LLU).

The third phase was the implementation and evaluation of the unit. In this phase, the implementation and evaluation of the unit was examined from 3 eighth grade teachers in schools under the Bangkok Metropolis Administration. In all cases, pseudonyms were used to represent the schools' and teachers' names. Sompong was the teacher in Sara school, Pranee was the teacher in Pattana School, and Chaichana was the teacher in Charoen School. Sara School and Pattana Schools were in the same district. The distance between two schools was around 3 kilometers. Charoen School is far from Sara School about 15 kilometers and Charoen School is far from Pattana School about 17 kilometers. Three teachers will assess the effectiveness of the unit by classroom observation, written reflection. Table 1.1 shown each teacher's background and experience.

Table 1.1 Teachers' background and experience

Name	**Mr.Sompong**	**Ms.Panee**	**Mr.Chaichana**
Sex	Male	Female	Male
Age	35	40	45
Highest degree	B.Ed (Biology)	B.Ed (General science)	M.Sc (Botany)
Teaching Grade level	Grade 8	Grade 8	Grade 8 and 11
Years experience in teaching the concept of light	4	2	6

This phase also explores the students' understanding about light after implementing the unit. The students of three selected teachers in each school were asked to complete the Light Concept Test (LCT). Then, there were three focused students from each classroom. The three focused students were selected to focus in the study by using their worksheets to compare their understandings before and after the implementation. In the LCT, there were 6 main concepts about light. The concepts of light include Nature of Light, Image Formation, Refraction of Light, Optical Instrument, Color, and Seeing.

Definition of Terms

The Light Learning Unit (LLU) is comprised of the lesson plans, student manual and instructional materials and media that are ready to be used by the teachers. Each lesson plan contains the information about the main concept, learning outcomes, instructional procedure, instructional materials, worksheets and suggestions on formative assessment. The content of LLU follows the National Science Curriculum Standards (IPST, 2002) and is divided into eight lessons on the topic of light; the nature of light, the reflection of light, the curve mirrors, the refraction of Light, the image formations from lenses, the optical instruments, color, and seeing and light intensity. The activities of all lessons used social interaction between teacher and students and students and students. Group work, group and whole class discussion, and designing the experiment in group are the main strategies of the unit.

The schools under the Bangkok Metropolitan Administration (BMA) are the school under the authority of Bangkok. These schools had the kindergarten, primary and lower secondary levels. The students of BMA school usually come from only those who lived in Bangkok and the BMA spent the money for all educational stuffs.

The students' understanding of light is the students' ideas on the concept of light that can be measured by testing and from their worksheet. The students' answers were categorized into four groups. These four groups were scientific concept, partial scientific concept, alternative conception, and no response.

Summary and Preview

This study aims to investigate ways to improve the teaching and learning about concepts of light by using a social constructivist approach. Teaching about light using traditional teaching strategies does not promote students' scientific understandings of the concept of light. Accordingly, the development of a teaching approach that is based on a social constructivist philosophy of learning can promote better learning because students will have an opportunity to be actively involved in the learning process by doing the group activities (Davis, 1993). They can interact with each others. That will help them to build the knowledge by themselves. Therefore, this study aims to develop a new teaching intervention based on social constructivist principles that can enhance the students' understanding.

Chapter 2, the literature review, will discuss the learning theories, the theoretical framework of the current study which is social constructivism, the tenets of social constructivism, the state of teaching and learning about the concepts of light and students' conception about the concept of light. Moreover, the social constructivist teaching strategies to enhance the understanding of light, the concept of light in Thai science curriculum, and some misconception about the topic of light will also discuss.

Chapter 3, research methodology, will start by reviewing the methodology of the study, interpretivism, and its philosophical basis, characteristics, a case study design, and the research framework. It also presents the data analysis in each phase of the study. Finally, the researcher discusses the ethical concerns and how to confirm the trustworthiness of the research results of this study.

Chapter 4 discusses first two research questions. The first research question explores the current state of teaching and learning which included the use of curriculum and textbooks, teaching preparation, teaching methods, and measurement and evaluation, and also problems encountered upon instructing about light and needs of the teachers related to the teaching and learning. The second research question explores the students' understanding about light.

Chapter 5 discusses the design and development of Light Leaning Unit (LLU) which was used to promote scientific understanding of the concept about light. The process of the unit design and development and the organization of content and activities of Light Learning Unit (LLU) are discussed too. Moreover, the comparison of contents and activities between Light Leaning Unit (LLU) and IPST curriculum will be presented.

Chapter 6 discusses the implementation and evaluation of the Unit. The chapter starts with the workshop before the introduction to introduce and train the teachers to use the Light Learning Unit (LLU) and take their comments on the LLU for improvement and adopt or adapt for each of them implementing appropriately. Moreover, there are teacher support meetings which are held during the implementation to give continuous support and to give them to reflect on their teaching. The chapter introduces three case studies of the implementation. In each case, teacher background, school and classroom setting, and the students' background are described. The last two research questions are posed and investigated in each case. The findings on how teachers implemented the unit in their own setting and how this affected the students understanding of light are discussed. Then, all results illustrates the cross case analysis which researcher will look across all the cases in term of the similarities and differences.

Chapter 7 focuses on the conclusions and discussions of research findings and implications of the study. The research framework is reviewed. Then, the discussions and conclusions of the study are described in each phase. In first phase, the findings from the situation of teaching and learning about light and students' understandings about light are discussed. In second phase, the design and development of LLU is discussed. In the last phase, the three teachers' implementation of the Light Learning Unit (LLU), and students' understandings of light after the implementation of the LLU are also discussed. At the end of the chapter, implications and some recommendations are provided.

CHAPTER II

REVIEW OF LITERATURE

Introduction

Chapter 1 highlighted the significance of the current study and the problems that students face in understanding the concepts of light from the previous research. Moreover, it indicated that using social constructivist ideas in the classroom can make the students learn effectively. This chapter begins with constructivism, and the types of constructivism including social constructivism, social constructivism applied to teaching and learning, social constructivist teaching strategies, social constructivist assessment, relevant research on social constructivist teaching, Thailand's educational background and educational reform in Thailand, the concept of light in the Thai Science curriculum, students' alternative conceptions of the concept of light, teaching and learning of the concept of light, implications of social constructivism on teaching the concept of light, and a summary of this chapter.

Constructivism

Constructivism is defined by many different theorists. The best starting point to thinking about constructivism is a definition provided by Von Glasersfeld (1997). He claims that constructivist learning experiences are founded in the belief that all knowledge is constructed, built up by each student through interaction and active participation in the learning process. Students also use personal experiences to construct their understanding, which implies that everyone already has knowledge and understanding and that new knowledge is built upon previous understandings. Fosnot (1995) states that Constructivism is a theory about knowledge and learning and describes both what knowing is and how one comes to know. In this view of constructivism, learning is a constructive process in which the learners are building knowledge by themselves.

Scott (1987) defines a constructivist in science as one who perceives students as active learners who come to science lessons already holding ideas about natural phenomena, which they use to make sense of everyday experiences. Such a process is one in which learners actively make sense of the world by constructing meaning.

Shapiro (1994) and Eggen and Kauchak (1997) claims that science knowledge is not waiting to be discovered but it is we who create meanings. In this view, knowledge is a mental construction. This means that learners create their own meaning and that learning is both personal and social situation.

Cobb (1994), Bruning, Schraw, and Ronning (1995), and Brooks (1998) define constructivism in the terms of psychological and philosophical perspective that refer to the idea that learners construct knowledge for themselves. Each learner individually (and socially) constructs meaning as he or she learns.

Wheatley (1991) suggests two principles of learning through the constructivist theory. The first one states that knowledge is not passively received, but is actively built up by the cognizing subject. Ideas and thoughts cannot be communicated in the sense that meaning is packaged into words and sent to another who unpacks the meaning from the sentences. That is, as much as we would like to, we cannot put ideas in student's heads, they will and must construct their own meanings. The second one states that the function of cognition is adaptative and serves the organization of the experiential world, not the ontological reality. This means that the learner does not find truth but construct explanations of their experiences.

Tobin and Tippins (1993) claimed that constructivism has been used as a theoretical framework or referent to teachers in their teaching. They stated that constructivism is conceptualized as a set of beliefs about knowing that has the potential to facilitate different ways of thinking about education, of framing problems, and of formulating answers that extend into areas not considered when objectivism was used as a referent. They also would add to the definition of the construction of knowledge in science education. They state that the constructed knowledge of science is viewed as a set of socially negotiated understandings of the events and phenomena that comprise the experienced universe. They further explain that in order to create new knowledge, it must be accepted by the scientific community as viable because of its coherence with other understandings and its fit with experience.

Although there were a variety of definitions of constructivism, basically, constructivism means that as learners experience something new they internalize it through their past experiences or knowledge constructs they have previously established. In other word, learners make sense of the world by interpreting new information in terms of what they already known. Fundamentally, constructivism asserts that we learn through a continual process of constructing, interpreting, and modifying our own representations of reality based on our experiences of reality (Jonassen, 1994). For example, every student has had an experience about seeing a rainbow. If they know that rainbow occurs during rain, then they can relate their prior knowledge from rainbow and refraction of light. It means that they can bridge the knowledge that raindrops act like tiny prisms, refracting and reflecting the light and separating the color.

Types of Constructivism

There are many ways to classify types of constructivism. In this thesis, the constructivism will focus only on personal, in particular radical constructivism and social views of constructivism.

Radical Constructivism or Personal Constructivism

Radical Constructivism as proposed by Von Glasersfeld, states that knowing is a state of adaptation of an individual to the individual's environment. New knowledge is constructed by learners from the interaction of experiences and current knowledge beliefs (Von Glasersfeld, 1989).

Radical Constructivism as proposed by Piaget, states that intelligence consists of two interrelated processes, organization and adaptation. People organize their thoughts so that they make sense, separating the more important thoughts from the less important ones as well as connecting one idea to another. At the same time, people adapt their thinking to include new ideas, as new experiences provide additional information. This adaptation occurs in two ways, through assimilation and accommodation. In the former process, new information is simply added to the cognitive organization already there. In the latter, the intellectual organization has to change somewhat to adjust to the new idea (Berger, 1978).

Von Glasersfeld (1995) views radical constructivism as two basic principles. These views of radical constructivism are the follows:

1. Knowledge is not passively received either through the senses or by way of communication, but it is actively built up by the cognizing subject.

2. The function of cognition is adaptive and serves the subject's organization of the experiential world, not the discovery of an objective ontological reality.

Even though radical constructivism or the cognitive science theory of Piaget is a theory that can explain how people learn, it lacks a consideration of the social dimension of learning. If knowledge construction is seen solely as an individual process, then this is similar to what has traditionally been identified as discovery learning. But the process of knowledge construction must go beyond personal process.

Moreover, Tobin and Tippins believed constructivism should in cooperate the social component of knowledge. Tobin and Tippins (1993) implied that knowledge has both individual and social components that cannot be meaningfully separated and enables us to construct learning environments where multiple ways of knowing are sought and valued.

Social Constructivism

Social Constructivism builds on the work of Vygotsky. He was the soviet development psychologist. His view of learning is a social activity in which learners are involved in constructing meaning through discussion and negotiations with peers and teachers (Atwater, 1996; Osborne, 1996; McMahon, 1997; Derry, 1999).

Vygotsky (1987) emphasized socially constructed concepts and relates scientific and everyday ways of knowing. He also emphasized the role of language and culture in cognitive development, arguing that language and culture play essential roles both in human intellectual development and in how they perceive the world. People’s linguistic abilities enable them to overcome the natural limitations of their perceptual field by imposing culturally defined sense and meaning on the world. Language and culture are the frameworks through which humans experience, communicate, and understand reality. In social constructivism, education is not an affair of telling or being told, but an active and constructive process (Dewey, 1916). Hence, social constructivism posits that knowledge is constructed by learners and learning is social.

Learning science under a social constructivist framework involves students making meaning of the world through both individual and social processes. Vygotsky proposed the term of Zone of Proximal Development (ZPD). Zone of proximal development of learners is defined as the learner’s range of ability with and without assistance. Thus one end of the range is the student’s ability level without assistance and the other end of the range is the learner’s ability level with assistance. For example, the students talk about what makes a rainbow. One student expresses the idea that the rainbow occurs because of the rain. Another student expresses the idea that the rainbow occurs because of the sunlight. From this example, the students interact through dialogue, and they help to extend each other's understanding of what makes a rainbow. When students learn individually they cannot go further but when they learn collaboratively they can extend the learning of all.

The Tenets of Social Constructivism

Social constructivist perspectives hold that knowledge cannot be transmitted but must be constructed by learners and knowledge construction involves both individual and a social processes (John-Steiner and Mahn, 1996; Driver *et al*., 1994) In this study, the researcher view the tenets of social constructivism as

- Learner's previous knowledge constructions, beliefs, and attitudes are considered in the knowledge construction's process.

- Learning and development is a social collaborative activity.

- Learning should occur in a meaningful context and not separated from learning and knowledge children develop in the real world.

- Scaffolding is facilitated to help students perform just beyond the limits of their ability.

- Problem-solving, higher-order thinking skills and deep understanding are emphasized

- Assessment is authentic and interwoven with teaching.

These six tenets of social constructivism will be emphasized in this study in terms of interpreting data.

Social Constructivism towards Teaching and Learning

Learning science under a social constructivist framework involves students making meaning of the world through both individual and social process (Driver, 1994). In teaching and learning, students should have opportunity to test their new knowledge claims with peers and link new ideas with personal experience and existing knowledge (McRobbie and Tobin, 1997).

McRobbie and Tobin claimed that the teachers should know that the students come to classroom with their ideas and these ideas may come from personal experience and existing knowledge. The teaching and learning should be set in terms of letting the students learn through social interaction. The teachers should make activities that all students have a chance to participate in group. On the other hands, the teaching should emphasize collaborative learning and social context.

Brooks and Brooks (1993) identified the characteristics of constructivist teachers as following.

- Encourage and accept student autonomy and initiative.

- Use a wide variety of material, including raw data, primary sources, and interactive materials and encourage students to use them.

- Inquire about students' understandings of concepts before sharing their own understanding of those concepts.

- Encourage students to engage in dialogue with the teacher and with one another.

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

- Engage students in experiences that show contradictions to initial understandings and the encourage discussion.

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

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

The role of the teacher is to recognize these strongly held conceptions that children bring to the classroom and provide experiences that will help them build on their prior knowledge (Duit and Confrey, 1996). The teachers should act as a tour guide mediating between children's everyday world and the world of science (Driver *et al*., 1994).

Maddux, Johnson, and Willis (1997) describe the four principles applied in any Vygotskian classroom as follows:

- Learning and development is a social, collaborative activity.
- The ZPD can serve as a guide for curricular and lesson planning.
- School learning should occur in a meaningful context.
- Relate out-of-school experience to the child's school experience.

Social Constructivist Teaching Strategies

There are many strategies consistent with social constructivist teaching. All of these strategies focus on the social interaction between both teacher and student and student and student.

Collaborative Learning

Collaborative learning is one of the most important social constructivist teaching strategies. Collaborative learning is one of the educational approaches involving joint intellectual effort by students, or students and teachers. Usually, students are working in groups of two or more, searching for understanding, solutions, or meanings, or creating a product. Collaborative learning activities vary widely, but most center on students' exploration, not simply the teacher's presentation or explication of it (Smith and MacGregor, 1990).

Cooperative Learning

Cooperative learning allows for learning and development to become social collaborative activities (Rice and Wilson, 1999). This type of activity requires that students work primarily in groups (Brooks and Brooks, 1993). The groups can be any size. Cooperative learning activities should not be simply activities that are called group work and that require the students to just search for answers to fill out a worksheet. In contrast, cooperative learning should require students to collaborate and critically analyze issues, which causes them to develop higher-level thinking skills. Some sample cooperative learning activities are group problem solving, group inquiry, simulations, and debates. The activities encourage creativity, and foster higher-level thinking (Brown, 1999). Teachers can foster cooperative skills – listening, respecting others, encouraging, explaining, summarizing, checking for understanding, and disagreeing in a civil manner by showing students that in their groups they must talk about the work, drill each other on the material, share answers, share materials, and encourage one another to learn

The cooperative groups by Johnson and Johnson (1987) described five elements of cooperative learning as follows:

- Positive interdependence which means the individual success depends on the success of the group.

- Face-to-face interaction which means the interaction of the group is very important.

- Individual and group accountability which mean the goal of instruction is for every student and group.

- Interpersonal and small-group skills which mean the teachers should teach the students about the skills to function effectively.

- Group processing which mean the feedback of the teachers is very important to encourage the students' improvement.

One cooperative approach that find effective and readily adaptable to middle school classroom is called think-pair-share. Following an activity, demonstration, or discussion, students are asked to:

- Think about what they just observed or talked about and (individually) write down two or three of the key ideas in their own words;

- Turn to their lab partners and listen to each other's ideas;

- Move as a team to another group and repeat the sharing (or participate in a whole-group sharing). This strategy is both efficient and engaging.

The benefits of cooperative learning are well studied and documented. Many researches on cooperative learning confirmed that cooperative learning has positive on students' achievement, problem solving and motivation to learn (Nastasi and Clements, 1991; Qin, Johnson, and Joshnson, 1995). Cooperative learning encourages better attitudes towards peers and improved self-esteem (Slavin, 1990).

Discussion

According to Larson (1999), Wileen and White (1991) stated that it (discussion) is characterized as a structured conversation among participants who present, examine, compare and understand similar and diverse ideas about an issue. Discussion is an excellent way to engage students in thinking and analyzing or in defending one side of an issue, rather than listening to lecture. Students must also respond to one another, rather than interacting intellectually only with the instructor.

Gall (1985) reported that discussion is an effective way to promote higher-level thinking, develop student attitudes, and advance student capability for moral questioning. Hipkins *et al.* (2002) argue that discussion can provide opportunities for students to clarify and share their own understandings, test out their understandings, ask questions and challenge the views of other students and the teacher, and use the new ideas with confidence. Moreover, Larson (1999) states that discussion may require teachers to relinquish to students more of their authority over the instructional process than recitation or questioning does.

Questioning

Questioning is the most common strategy that teachers use for involving students in the learning process (Bliss, 1995; Glenn, 2001; Amos, 2002). Indeed, Amos (2002) reports that up to one-fifth of what a teacher says in a classroom is likely to be in the form of questions. If teachers ask open-ended questions, they allow students to think freely and flexibly, to express their own ideas and thoughts without thinking that they have to give one ‘right’ answer and they promote successful discussions that stimulate student participation (Harlen, 1999). Amos (2002) supports the use of open-ended questions, arguing that closed and subject-oriented questions that rely on linear processes and logical reasoning discourage students from thinking differently from the teacher and may deter students from answering the questions asked. The quality of teacher questions is also important.

In checking students’ understanding, teachers should ask open-ended questions that allow students to express their own understanding and conceptions, and put less emphasis on recalling facts that reduce opportunities for students to be creative and critical in their thinking (Harlen, 1999; Amos, 2002; She and Fisher, 2002). Amos (2002) argues that such questions require students to apply, analyze, synthesize, and evaluate information. She and Fisher (2002) suggest that questions should help students interpret their observations, link new learning to what students already know, and stimulate their thinking.

In summary, many research studies indicate that teaching strategies based on a constructivist perspective could encourage students learning. From social constructivist perspective, the development of understanding by discussion of ideas with peers is an essential part of learning and involves articulation, clarification, elaboration and negotiation. Accordingly, students should be encouraged to be involved in putting language to ideas, testing their understandings with peers and listening and making sense of the ideas of the other students (McRobbie and Tobin, 1997). Therefore, this research study focuses on using effective teaching strategies based on constructivism, and social interaction will be taken into this account, and added to the research.

Social Constructivist Assessment

One important component of the teaching and learning process is assessment and a constructivist teaching approach to teaching requires constructivist assessment. Brown and Knight (1994) state that assessment is at the heart of the student experience.

Jones states that the goal of constructivist teaching is to assist students in building their own understanding and then assessments should be aligned with this view of learning. He proposed that alternative assessments such as concept maps and portfolios can be used as constructivist assessments. In addition, Ernest, Brooks and Brooks (1999) identified that authentic assessment is best achieved through teaching by interactions between both teacher and student and student and student and observing students during meaningful tasks (Jones, 1997).

Rust (2005) states that students should be actively engaged with every stage of the assessment process in order that they truly understand the requirements of the process, and the criteria and standards being applied. They should subsequently produce better work.

Jonassen (1992) recommends evaluation strategies that are consistent with the two main aspects in constructivism, namely, learning is a process of construction, and context is important in the learning process. He suggests that effective assessment should be part of the instructional process. Students' demonstrations of knowledge acquisition, their products and their actions while performing science activities are evaluated.

Relevant Research on Social Constructivist Teaching

There are many research studies about teaching approaches based on constructivism and social constructivism in the foreign countries.

Linn and Songer (1991) found that when they used constructivist curriculum, the understanding about thermodynamics of middle school student significantly increased. Windschitl and Andre (1998) compared the effects of constructivist versus objectivist teaching techniques in a college physiology class and found that the constructivist learning environment produced significantly greater conceptual change.

Shepardson and Britsch (2001) studied the role of children's journals in elementary school science activities because they wanted to expand their understanding of children's science learning. They examined children's activity across a variety of dimensions, including observing the ways children approach science experiences, how children interact with peers, and the products they create–the drawings, writings, and constructions children make to represent their understandings. Their sample was 6 kindergarten and 6 fourth-grade students. Kindergarten students engaged in science activities about dissolving and they wrote a science journal. Fourth-grade students engaged in science activities about sound and also wrote in their science journals. In addition, they collected data through audiotape and videotape recordings, journals in science activities, and field notes. The result was that children reconceptualized their understandings of the science investigation and phenomena by using three types of mental contexts imagination, experience and investigation. The children's representations of their imaginary, experienced and/or investigative worlds were shaped by other texts and structures such as school science texts. The conclusion was that the role of journals in the science curriculum can be enhanced and elaborated if journals allow children to use various child selected combinations of writing and drawing to construct and represent their understandings.

Valanides (2002) studied about aspects of constructivism. He thought that classroom-based discourse would support students' conceptual growth because the knowledge construction process is shaped and validated by students' interactions with students, the teacher, and the physical environment. An experimental setting was used in a class of 23 sixth-grade students to prompt discussions about shadows. Students were asked to predict the position and other characteristics of shadows. Data were collected on audiotapes and videotapes of their discourse. The result was that students made strong progress toward achieving more scientifically correct understanding of shadow phenomena by discussion because dialogue induced students to think and reconsider their initial conceptions about shadows.

Bell *et al*. (1985) used conservation tasks. They determined that children working with peers showed more cognitive growth than children working alone. However, there were particular conditions that were in place for children who derived the most from this opportunity. For example, the child had to be actively engaged in the problem-solving activity and not merely observing the more advanced peer. In addition, if the partner's cognitive level was too much in advance of the child's, the outcome mirrored that expected of interactions with adults.

Radziszewska and Rogoff (1988) compared children's interactions with adults and peers, using one group of peer partners who had been taught to use an optimal strategy for completing an errand-planning task and another who had received no special preparation. When the children were later asked to plan without assistance, those children who had collaborated with adults were more successful than those who had worked with prepared or unprepared peers.

In Thailand, there are a few research reports that were influenced by the constructivist approach in science.

Leengjaroonrat (2000) studied about Effects of Constructivism Learning Process and Portfolilo on teaching Energy and Life, and Home Electrical Appliances in Mathayomsuksa 3 Kasetsart University Laboratory School. The purpose of this research was to compare IPST's (the Institute for the Promotion of Teaching Science and Technology) learning process, the constructivist learning process, and a constructivist learning process with portfolio. The population consisted of 108 students, with 36 students taught by IPST's learning process, 36 students taught by the constructivist learning process, and 36 students taught by constructivism learning process with portfolio. He collected the data by journal, concept test, application test and attitude toward science test. He found that the students who learned by the use of constructivism learning process with portfolios had increased understanding of concepts about Energy and Life, and Home Electrical Appliances.

Nopakoon (2002) studied about the Development of a Model of Learning and Teaching Science Process Using Constructivism Approach in the Fifth Grade of Kasetsart University Laboratory School. The subjects were persons in Kasetsart University Laboratory School in the academic year of 1999 and 2000. They were 3 science teachers in the fifth grade who voluntarily participated in the research, 17 students in each year, 5 administrators and 117 parents of the students in the academic year of 2000. The instruments that were used in this research were field notes and interviews. When she implemented the constructivist teaching approach, the teachers' instructional behaviors were consistent with the principles of constructivist approach. The students expressed learning behaviors including thinking, analyzing, and decision making.

Thailand Educational Background and Education Reform

There have been many changes in education in Thailand. Between 1238 and 1868, there was no formal education. Education was provided by the royal institution of instruction (Rajabunditt) only to princes and sons of nobles. Common children learned in the temple provided and taught by the Buddhist monks (Ministry of Education, 1998).

During the early Bangkok period, a number of treaties were concluded with foreign powers, mostly in the form of a Treaty of Friendship and Commerce. King

Rama IV realized that the kind of education provided by the monastery and the court was not adequate for future government officials. For this reason, he commanded that measures be taken to renovate the education of the country. It was decided that a good knowledge of English would form a part of the new educational requirements, as it had become a necessary key to further knowledge. The policy of educational modernization was further pursued by King Rama V (1868-1910). Recognizing the need for better-trained personnel in royal and governmental services, he opened a school in the palace to educate young princes and the sons of nobles in 1871.

In 1921, the Compulsory Primary Education Act was proclaimed, requiring every child between the ages of 7 and 14 to receive free primary education. Then, in 1932, educational policies and plans were again revised, extending compulsory education to five and six year olds.

Nowadays, Thailand has undergone even more education reform. This has resulted in policies and plans to bring about necessary changes within the Thai system. Thailand's educational system is divided into four levels, namely pre-school, primary, secondary and tertiary levels. The provision of pre-school, primary and secondary education, including vocational and technical education is under the responsibility of the Ministry of Education, while the provision of tertiary education is under the supervision of both the Ministry of Education and the Ministry of University Affairs.

Thai education has undergone much reform in recent years. There are many aspects to education reform in Thailand. These include:

- Expanding provision of free basic education both formal and non-formal from nine to twelve years, and extending compulsory education from six to nine years.

- Providing education to meet the learners' basic learning needs, upgrading their skills, and encouraging their self-development so that they may continuously improve their quality of life and livelihood.

- Implanting internal and external quality assurance system in schools and education institutions.

- Reforming administration and management of education to encourage full participation of local educational authorities and local community.

- Encouraging private sector participation in educational provision by liberalizing rigid rules and regulations.

- Reforming pedagogy by emphasizing learner centered activities and establishing life-long learning centers.

- Reforming the curriculum, allowing for contribution/ participation of stakeholders, to meet new challenges and demands of different groups of learners with an emphasis on mathematics, science, and technology in parallel with the promotion of pride in national identity and cultural heritage.

- Reforming resource allocation at the national level on the basis of equity and encourage local educational authorities and communities to mobilize their resources for education.

According to the education reform, The Institute for the Promotion of Science and Technology Teaching, [IPST, (2002)] has responded to the government policy by developing the National Science Curriculum Standards to be the standard criteria for teaching and learning science. According to these standard Thai students would be able to:

- Understand the principles and theories of basic science.

- Understand the boundaries, nature and limitations of science.

- Use skills to inquire about and explanation of science and technology.

- Develop thinking processes and imagination, their ability to solve problems, management, communicative skills and decision making.

- Realize influentially and affectively the relationships among science, technology, human beings and environment.

- Use knowledge of science and technology to advance society and everyday life.

- Be a human who has scientific attitudes, moral, ethics, values for utilizing science and technology creatively (IPST, 2002).

From these goals, primary and secondary school science should include the following key aspects for organizing teaching and learning science (Pravalpruk, 1999):

- The understanding and application of science concepts: in the areas of science facts, concepts, principles and theories from life systems, physical systems and earth and space systems.

- Investigative science: the study of science as inquiry, providing a set of interrelated processes by which scientists pose questions which investigate phenomena and cultivate deeper understanding of natural phenomena.

- Connective science: the study of the connections between and within the natural sciences, between science and mathematics, and between science and technology.

- Science, technology and society: the study of how science and technology are influenced by, and influence environment and society.

The teaching and learning should promote the linking of local wisdom, modern technology and experiences in everyday life for the students (ONEC, 2002). IPST developed the National Science Content Standard (IPST, 2002). This Standard has eight strands. The eight strands consist of: Living things and living processes; Life and the environment; Substance and their properties; Force and motion; Energy; Earth changing processes; Astronomy and space; Nature of science and technology.

The Concept of Light in the Thai Science Curriculum

The Institute for Promotion of Teaching Science and Technology (IPST) has the mandate from the Ministry of Education to implement the subject matters of science, mathematics and technology. It sets the standards for learning at the basic level, the standards for learning at different levels and provides core subject matters for basic education.

This research study will focus on the topic of light. Light is contained in strand 5: Energy of Thai science curriculum. The topic of light is typically presented early in the elementary school curriculum. Light and shadow is a topic commonly studied when children are in grades 2 to 3. Such topics as the fact that light moves in straight lines, the nature of light reflection, and refraction, light traveling through various media, the light spectrum, and color mixing are typically studied in limited detail by children in grades 4-6. Light is studied in greater depth in secondary school.

Table 2.1 Basic science content standard about Light topic in each level

Level standards (grade 1-grade 3)	**Level standards (grade 4-grade 6)**	**Level standards (grade 7-grade 9)**	**Level standards (grade 10-grade 12)**
	1. Experiment and explain how light travels from its source and moves though different mediums and how light energy is transformed into	1. Experiment, analyze and explain reflection and also calculate relevant quantities and draw images 2. Discuss and explain how light	1. Experiment, analyze and explain refraction of light when light is propagated in the different medium and use Snell's law 2. Investigate and

Table 2.1 (Continued)

Level standards (grade 1 – grade 3)	Level standards (grade 4 – grade 6)	Level standards (grade 7 – grade 9)	Level standards (grade 10 – grade 12)
	electrical energy, and give examples of uses of solar cells 2. Experiment and explain the distribution of white light though prisms and apply the knowledge to discuss natural phenomena	intensity affects the human eye and that of other organisms	analyze the properties of light such as diffraction and interference 3. Experiment and discuss polarization of light 4. Experiment and discuss intensity of light

All of the concepts in the three levels are connected and the higher concepts require that the basic concepts from lower levels be mastered. This thesis will focus on the concept of light in grade 8. According to National Science Curriculum Standards (IPST, 2002) in grade 8, the content of light is divided into 3 themes, light and seeing, the refraction of light and its application and seeing and intensity of light which includes six main sub topics as follows:

1. Reflection
2. Refraction
3. Image formation from mirror and lens
4. The application of refraction
5. Seeing
6. Light intensity

Figure 2.1 shows the conceptual framework of the topic of light in IPST textbook. .

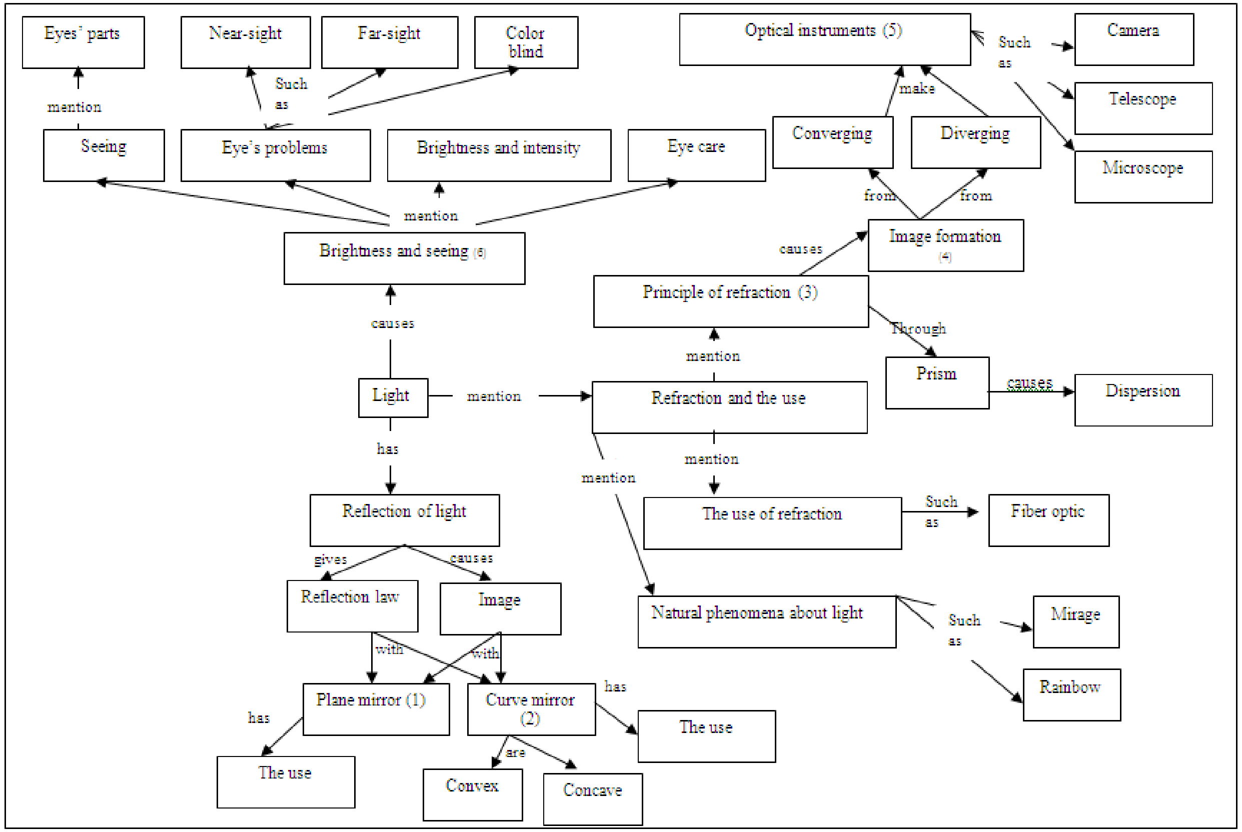


Figure 2.1 Conceptual framework of the topic of light in IPST textbook

IPST Textbook

Concept 1: The Reflection of Light by the Plane Mirror (3 periods)

Content: The law of reflection of light, the characteristics of image formed by the plane mirror, and the ray diagram of the image formed by plane mirror.

Activities: Teacher probe the students explain about the reflection by plane mirror and students do experiment about the concept of reflection by plane mirror and image formation by plane mirror. After finishing the experiment, there is a whole group discussion about the questions from the textbook.

Concept 2: The Reflection of Light by the Curved Mirrors (3 periods)

Content: the characteristics of curved mirrors (concave and convex mirrors), the characteristics of image formed by the curved mirror, the ray diagram of the image formed by curved mirrors and the useful of the reflection by curved mirrors.

Activities: Teacher probes the students to explain about the reflection by curved mirrors and students do experiment about the concept of reflection by curved mirrors and image formation by curved mirrors. After finishing the experiment, there is a whole group discussion about the questions from the textbook.

Concept 3: The Refraction of Light (3 periods)

Content: the refraction of light, the light dispersion, the refraction of light in daily life, and the application of refraction of light.

Activities: Teacher demonstrate the students about the refraction of light and pose questions for the students to think about and then students do experiment about the concept of refraction of light and the formation of rainbow. After finishing the experiment, there is a whole group discussion about the questions from the textbook.

Concept 4: Lens (3 periods)

Content: the characteristics of lenses (converging and diverging lenses), the light ray when the light passes through the lenses, the image formation by the lenses, and the total reflection of light.

Activities: Teacher let students do experiment about the concept of lens. After finishing the experiment, there is a whole group discussion about the questions from the textbook.

Concept 5: Optical Instruments (2 periods)

Content: the concept of optical instruments (microscope, telescope, and camera)

Activities: Teacher let students find the information about optical instruments and do the report and then do the presentation.

Concept 6: Brightness and Seeing (2 periods)

Content: seeing, the eye's problems, the light intensity, the eye care.

Activities: Teacher let students find the information about optical instruments and do the report and then do the presentation.

Students' Alternative Conception of the Concept about Light

There are many alternative conceptions regarding the topic of light because light is an abstract concept that is hard for the children to understand. For example, image formation using mirrors and lenses are common topics and students hold many alternative conceptions regarding these topics (Anderson and Smith, 1983; Feher and Meyer, 1992; Fetherstonhaugh and Treagust, 1990; Goldberg and McDermott, 1986;

Guesne, 1985; Jung, 1981; Ramandas and Driver, 1989; and Watts, 1985). Jung (1981) studied the use of mirrors with 12-year-old boys and girls. This study showed that 90% of the students think that images exist on the surface of mirror, rather than from behind the mirror. Many students suggested that because light is reflected from the surface of the mirror, that it is the place where the image is formed. Watts (1985) examined student conceptions of light as a case study. Data were collected by interviewers that indicated the students held misconceptions about image formation by a plan mirror. The students thought that the images were on the mirror.

Fethestonhaugh and Treagust (1992) examined the students' understanding of light and its properties. Data were collected through a diagnostic test from grade 8 and 10 students (age 13-15 years) that indicated that the students held misconceptions about seeing. Students seemed to use a visual ray model that reflects light onto the eyes from an object or something leaves the eye to strike the object. Salley (1996) examined children's ideas on light and vision. She found misconceptions when she studied 28 children involved from one class from Years 4 (age 9) though to Year 6 (age 11). The data were derived from children's drawings and written responses, and from small group interviews. The data indicated that most students use a visual ray model that reflects light onto the eyes then onto an object or something leaving the eye to strike the object or light shining all over the place and when it gets to the object, it comes back down to your eyes, then bounces off your eye and goes back to the object, so that you can see it.

Anderson and Smith (1983) studied students understanding of color. They found that most of students thought that color was a property of the object viewed and that what we see is the actual color of the object rather than the color of the light reflected from the object.

In Thailand, students also hold misunderstandings about light. Sangsupata (1995) found that Thai students have misconceptions in basic science concepts like light and optics. Such understanding is essential to the learning more advanced science concepts including laser and optical fiber. Punputsa, (2004), Worrapan, (2003), and Tinsandee, (2004) showed that Thai students held a misconception about light in many topics such as the velocity of light, the reflection of light, the refraction of light, and sight. Worrapan (2003) studied teaching for changing student misconceptions about the refraction of light among eleventh grade students. The study used the teaching strategy created by Hesse which has three. One first determines the prior concepts of the students. Then, one provokes conflict between students' prior concepts and new concepts to be learned. In the last part the teacher helps students gain more confidence in their new concepts. Comparing the pretest and posttest, Worrapan (2003) found that students better understood the scientific concepts after using the teaching strategy of Hesse. Similarly, Tinsandee (2004) studied how to change misconceptions about the velocity and the reflection of light with eleventh grade students also using the teaching strategies of Hesse. Comparing pretest to posttest scores showed that the students better understood the scientific concepts after using these teaching strategies.

Teaching and Learning of the Concepts about Light

In Thailand, there has been much research on the teaching of light. For example, Worrapan (2003) studied teaching for changing student misconceptions about the refraction of light among eleventh grade students. The study used the teaching strategy created by Hesse which has three parts. One first determines the prior concepts of the students. Then, one provokes conflict between students' prior concepts and new concepts to be learned. In the last part the teacher helps students gain more confidence in their new concepts. Comparing the pretest and posttest, Worrapan (2003) found that students better understood the scientific concepts after using the teaching strategy of Hesse. Similarly, Tinsandee (2004) studied how to change misconceptions about the velocity and the reflection of light with eleventh grade students also using the teaching strategies of Hesse. Comparing pretest to posttest scores showed that the students better understood the scientific concepts after using these teaching strategies.

Pulputsa’s study (2004) compared teaching strategies proposed by Wittrock and IPST concerning the velocity of light, the reflection of light, the refraction of light, and seeing. There are four stages in Wittrock’s teaching strategy which is similar to the strategy of Hesse. First, find the prior concepts of the students. Second, encourage the students to learn and share the prior concepts in the classroom while the teacher explains the scientific concepts to the students. Third, the teacher has the students do an experiment that is designed to provoke a conflict between students’ prior concepts and their new concepts. Finally, generate new knowledge to use in other situations. IPST’s teaching strategy is a strategy that is used in the IPST teacher guide book and it is based on the processes of inquiry, problem solving and hands-on /minds-on activities. The study compared test scores after using the two strategies and found that Witrock’s teaching strategy helped the students understand more than the IPST’s strategy. In addition, Wittrock’s teaching strategy created fewer misunderstandings than the IPST strategy.

Implication of Social Constructivism on Teaching Light

To enhance students’ scientific understanding of light, the teaching approaches as presented earlier, ask students to actively involved in the process of socially shared their thought. Teaching approaches for the concept of light, for instance, ask the students to work in groups or in pairs to share and examine their idea related with the concept of light. The students in collaboration with others have to determine their thought and solving problems.

Theoretical Framework of this Thesis

The literature on students understanding of the concept about light indicates that the concept of light is an abstract and hard to understand especially the concept of image formation by mirror and lens, color. Previous studies show that students had their prior knowledge in the concept about light. These may be scientific or alternative conception from the students’ experiences or others that may effect to their understanding. To get the successful teaching of the concept about light, the students should learn and work though their prior knowledge, building a consistent new understanding based on accurate scientific idea. The students should have opportunity to share their idea and discuss their own experiences to their friends and the teachers because the approaches of learning through interacting by comparing with others and the students are usually more motivating and it also promotes higher order thinking. By these reasons, this study is informed by the social constructivism with the emphasis on students' prior knowledge, language mediates learning, students-students or students-teachers interactions.

Summary

There are many research studies in science education on student's understanding, students' problems, and teaching and learning of the concept of light. In Thailand, there has been not much on doing research on the concept of light or there has been only find out the concept of the students. To know the situation of teaching and learning the concept of light in Thailand, finding out that situation is very important. This comes to answer the first two research questions; how do Thai teachers teach the topic of Light and what do Thai students understand about the concept of Light.

In addition, the review literature shown there are many teaching approaches based on social constructivist teaching that promote students understanding of the concept of light and which are related to Thai National Education Act (1992). The main strategy focused on learning science under a social constructivist framework involves students making meaning of the world through both individual and social processes. Vygotsky proposed the term of Zone of Proximal Development (ZPD). Zone of proximal development of learners is defined as the learner's range of ability with and without assistance. Thus one end of the range is the student's ability level without assistance and the other end of the range is the learner's ability level with assistance. There are collaborative and cooperative learning, discussion, and questioning. Some of teaching approach was developed and used as learning activities in the light learning unit which aim to promote students' understanding the concept of light. Not only the information of the review literature used to develop the unit, but also used the information from the pilot study about the situation of teaching and learning the concept of light and the students’ understanding about light.

In next chapter, Chapter 3 methodology will start by reviewing the methodology of the study, interpretivism, and its philosophical basis, characteristics, research design, and the research framework. It also presents the data and analysis in each phase of the study. Finally, the researcher discusses the ethical concerns and how to confirm the trustworthiness of the research results of this study.

CHAPTER III

RESEARCH METHODOLOGY

Introduction

This chapter describes the research methodology used in the study. The chapter first starts by reviewing the methodology of the study, interpretivism, and its philosophical basis, characteristics, and research design. All these ideas are applied to the current research design. Then, the research explains the research framework, three phases of the study, the exploratory phase, the unit design and development, and the unit implementation and evaluation. It also presents the data and analysis in each phase of the study. The data sources include the primary and secondary data sources, surveys, individual and focus group interviews, reflection, students' pre and post tests, classroom observations, and researcher field notes. Then, this chapter describes the data analysis. Finally, the researcher discusses the ethical concerns and how to confirm the trustworthiness of the research results of this study.

Research Methodology

Interpretivism

A paradigm is a way of looking at the world or a way of breaking down the complexity of the real world and expressing what is important, what is legitimate, what is reasonable (Kuhn, 1970).

There are two ways to view the world; positivism and naturalistic paradigm. The positivism paradigm believes that one truth exists out there, and one must be objective to find it. The aim is to try and standardize the field of study to make sense of it and to get the answer to one specific question. On the contrary, the naturalistic paradigm believes that there are many truths as we socially construct the truth. There are multiple realities and different people have different perceptions and experiences.

The naturalistic paradigm is used to inductively and holistically understand human experience in context-specific settings (Patton, 1990). This paradigm allows for and appreciates the study of phenomena within its natural setting, insisting that the research interaction should take place with the entity-in-context for fullest understanding (Lincoln and Guba, 1985). It recognizes the researcher as the instrument, taking into account the experiences and perspectives of the researcher as valuable and meaningful to the study (Lincoln and Guba, 1985). It relies on qualitative methods, which capture a more complete picture of individual-lived experience instead of a narrow perspective of generalizations (Lincoln and Guba, 1985). It employs inductive data analysis to provide more understanding of the interaction of mutually shaping influences and to explicate the interacting realities and experiences of researcher and participant (Lincoln and Guba, 1985). It allows for emergent design because it is inconceivable that enough could be known ahead of time about the many multiple realities to devise the design adequately and because the diverse perspectives and value systems of researcher and participant interact in unpredictable ways to influence the outcome of the study (Lincoln and Guba, 1985).

In summary, the naturalistic paradigm states that realities are multiple, constructed, and holistic (Lincoln and Guba, 1985). The aim of such a paradigm is to seek information about the reality of the individual or group being studied. This is in contrast to the positivist view that reality is single and fragmented. This study focuses on information from the participants about their own perceptions and roles. A naturalistic approach used to obtain this type of information and the naturalistic paradigm is more consistent with the interpretive research for studying and understanding the experiences and perspectives of the participants in this study.

Characteristics of Interpretive Research

Interpretive research is based on a naturalistic paradigm. Interpretive research allows the researcher to examine:

- The science classroom as socially and culturally constructed environments.

- The nature of teaching as one feature of that learning environment.

- The way in which teachers and students make sense of, and give meaning to their interactions as the central element of educational process (Erickson, 1986).

The procedure of interpretive research tends to enter into long relationships with the teachers for the purpose of learning about the manner in which teachers do their work, how they think about it, and what forces influence their thought and actions. The interpretive researcher enters into long term relationships with teachers that permit discourse with them about their work. The discourse begins with observation of teachers at work in their classrooms, in laboratories, and in interactions with students. Ultimately, over time, as rapport among teachers, students, and the researcher develops, it leads naturally to discussion of the meaning-perspectives.
To analyze data, interpretive research uses inductive data analysis. Inductive analysis helps the researcher to understand the interpreted data and produces explicit, recognizable, and accountable interaction between the researcher and participants (Lincoln and Guba, 1985). The important considerations in planning and conducting interpretive research are multiple perspectives, multiple data generation methods, ethics, and ways of ensuring trustworthy data generation and analysis.

Due to interpretive research, it was important to include multiple perspectives and multiple data generation methods when investigating the views of Thai teachers and students. To validate inquiry outcome, the researcher always negotiates the meanings and interpretations of participants from which data have been drawn (Guba and Lincoln, 1985; Bryman, 2001).

Multiple data generation methods use various types of data that help the researcher to build thick descriptions of the participants' frameworks (Southerland, Smith and Cummins, 2000). The use of multiple sources of data can help the researcher gain different insights into the participants. The researcher used interpretive research as a methodology in this study because it is concerned with the understanding of human behavior from participants' own frames of reference and attempts to interpret and understand the meaning and perspective of participants, i.e., teachers and students in the classroom, in the search for patterns of meanings-in-action (Hoepfl 1997).

Research Design: Case Study

A case study is an ideal methodology when a holistic, in-depth investigation is needed (Feagin, Orum, and Sjoberg, 1991). Case studies, on the other hand, are designed to bring out the details from the viewpoint of the participants by using multiple sources of data. Case studies have been used in varied investigations, particularly in sociological studies and in instruction. Yin (1994) saw the case study as an empirical enquiry that investigates a contemporary phenomenon within its real-life context when the boundaries between phenomenon and context are not clearly evident. The qualitative approach to a case study is described wherein the value of a case study relates to the in depth analysis of a single or small number of units such as a person, an organization, or an institution and it is the common research strategy in different disciplines, for example, education (Ball 1983, Burgess 1985, Hammersley 1986, Stake 1995, Hancock, 1998). Moreover, Yin (1994) writes that the case study inquiry copes with technically distinctive situations in which there will be many more variables of interest than data points, as one result, relies on multiple sources of evidence, with data needing to converge in a triangulating fashion, as another result, and benefits from the prior development of theoretical propositions to guide data collection and analysis. Yin (1994) presented at least four applications for a case study model:

- To explain complex causal links in real-life interventions.

- To describe the real-life context in which the intervention has occurred.

- To describe the intervention itself.

- To explore those situations in which the intervention being evaluated has no clear set of outcomes.

In this research, the case study method helped the researcher to understand the teachers' implementation and impact of the unit on the teachers and students in their real-life context. It helped the researcher to investigate how and to what degree Thai science teachers are able to implement the Light Learning Unit (LLU) and how teacher implementation of the Light Learning Unit (LLU) influenced students' scientific understanding of light.

Research Quality: Trustworthiness

The criteria for judging quality in a naturalistic paradigm are creditability, transferability, dependability, and confirmability. These criteria are intentionally designed to parallel the rigorous criteria that have been used within the positivist paradigm: creditability parallel to internal validity, transferability parallel to external validity, dependability parallel to reliability, and confirmability parallel to objectivity (Guba and Lincoln, 1989).

Credibility: In the positivist paradigm, the researcher employs experimental methods and quantitative measures to test hypothetical generalizations (Hoepfl, 1997). They also emphasize the measurement and analysis of causal relationships between variables (Denzin and Lincoln, 1998). Internal validity is defined conventionally as the extent to which variations in an outcome or dependent variable can be attributed to control variation in an independent variable (Guba and Lincoln, 1989). Joppe (2000) provides the following explanation of what validity is in quantitative research: validity determines whether the research truly measures that which it was intended to measure or how truthful the research results are. Researchers generally determine validity by asking a series of questions, and will often look for the answers in the research of others. The internal validity is established by controlling and/or randomizing processes to diminish a number of threats including history, maturation, testing, instrumentation, statistical regression, differential selection, experimental mortality, and selection. Conversely, a naturalistic paradigm seeks to understand phenomena in context-specific settings, such as real world settings [where] the researcher does not attempt to manipulate the phenomenon of interest (Patton, 1990). Internal validity is replaced by creditability criterion. There are many techniques used to increase creditability including the adequacy of data from the field, which should involve drawing on different data types gathered in different ways from different participants (Lincoln and Guba, 1985).

Transferability: In the positivist paradigm or traditional criteria for judging quantitative research, external validity is defined as the generalizability of the findings of a particular inquiry to other contexts or with other subjects (Guba and Lincoln, 1989; Cohen, Manion, and Morrison, 2000). However, alternative criteria for judging qualitative research can use external validity as transferability. Transferability refers to the degree to which the results of qualitative research can be generalized or transferred to other contexts or settings. From a qualitative perspective, transferability is primarily the responsibility of the one doing the generalizing. In qualitative research, there are many ways that can enhance transferability, including doing a thick description. The person who wishes to transfer the results to a different context is then responsible for making the judgment of how sensible the transfer is.

Dependability: In the positivist view, reliability means the consistency of an inquiry and is a precondition for validity (Guba and Lincoln, 1989; Maykut and Morehouse, 1994; and Cohen *et al*., 2000). On the other hand, it emphasizes the need for the researcher to account for the ever-changing context within which research occurs. The researcher is responsible for describing the changes that occur in the setting and how these changes affect the way the researcher approaches the study.

Confirmability: This refers to the extent to which the characteristics of the data, as posited by the researcher, can be confirmed by others who read or review the research results (Bradley, 1993). confirmability is determined by checking the internal coherence of the research product, namely: the data, the findings, the interpretations, and the recommendations. There are many strategies to enhance confirmability. The researcher can document the procedures for checking and rechecking the data throughout the study. The researcher can actively search for and describe negative instances that contradict prior observations. And, after the research study, one can conduct a data audit that examines the data collection and analysis procedures and makes judgments about the potential for bias or distortion.

Ethical Concern

Because educational and social research is a part of human research, ethical dilemma is an issue in educational and social research (Cohen *et al*., 2000). Therefore, each stage in the research sequence may be a potential source of ethical problems (Cohen, *et.al*, 2000). The costs/benefit ratio is a fundamental concept expressing the primary ethical dilemma in social research. So, in planning research, researchers have to consider the social benefits, and possible benefits accruing from the research may take the form of crucial findings leading to significant advances in theoretical and applied knowledge. The benefits to participants could take the form of satisfaction in having made a contribution to science and a greater personal understanding of the research area under scrutiny (Frankfort-Nachmias and Nachmias, 1992). Access to the organization or school where the research is to be conducted and acceptance by those whose permission one needs before embarking on the task is important (Cohen, *et.al*, 2000). The access to personal records, both as a primary or secondary source of data, must be approached both ethically and legally (Anderson and Arsenault, 1998).

Informed consent, confidentiality, and the safety and welfare of the participants are employed by a significant number of studies for ethical reasons (Cohen *et al*., 2000). The participants were informed about the purposes and procedures of the investigation and they also were informed that they had a right to participate or withdraw from any step of the study. In addition, in the final report, all participants are expected to use pseudonyms. Another person who can identify them from the information given must be provided.

Design for Current Research

Introduction

This section explains the research framework of the study which includes three phases of the study; exploratory phase, design and development of the unit, and implementation and evaluation of the unit. The research design section of the first phase includes the development of probing data collection, the current state of teaching and learning the concept of light in the academic year 2005, and light diagnostic tests in the academic year 2006. In the second phase, the guiding principles for constructing the unit, the structure of the unit, and the unit itself were described. The unit called the Light Learning Unit (LLU), which includes its content, activities, and the duration of each lesson, are previewed. The full details of the design and development of the LLU will be presented in Chapter V, The design and development of the Light Learning Unit (LLU). The last phase, implementation and evaluation of the unit, includes a section which first describes the workshop that was set up to introduce the LLU to the teachers. It then describes the data collection process and analysis in each phase of the study. Finally, the researcher discusses the ethical concerns and techniques used to enhance the trustworthiness of the research results of this study.

Research Framework

The research study is divided into three phases: the exploratory phase, the design and development of the unit, and implementation and evaluation of the unit.

The exploration phase focuses on the exploration of the current state of teaching and the learning of the concept of light in the academic year 2005, and Thai students' understanding of the concept of light in the academic year 2006. The procedure of this phase, the current state of teaching and learning the concept of light, is first explored by a questionnaire called the "Current State of Teaching and Learning the Concept of light (CSTLL). The teachers filled out the CSTLL and 3 of them were randomly selected to participate in in-depth interviews on the current state of teaching and learning the concept of light. Second, the exploration of the students' understanding of the concept of light was measured by testing. Three classes from three schools took the Light Diagnostic Test (LDT) in November 2006. The students were selected from one class of each selected teacher.

The designing and development of the unit phase focuses on the design and development of a unit called the Light Learning Unit to promote scientific understanding of the concept of light. The unit was designed from March-November, 2007 under the supervision of a research committee which consisted of three university lecturers, one from the faculty of science, and the other two from the faculty of education who had expertise in curriculum planning and design, pedagogy, and assessment and evaluation. Based on the test and survey results from the exploratory phase, the guidelines for school science curriculum were developed from the National Science Curriculum Standards (IPST 2002), student backgrounds, Thai classroom contexts, and school policies.

The unit implementation and evaluation phase examines how and to what degree Thai science teachers are able to implement the Light Learning Unit.
In November 2007, a workshop was set up for the Grade 8 Science teachers who would be participating in the first phase of the study. The workshop aimed to introduce the use of the LLU and asked teachers to comment and make suggestions. In December 2007, in the second semester of the academic year 2007, the LLU was implemented by three teachers. The researcher conducted a multi-site case study to examine how the implementation of the LLU in the classroom setting could enhance student scientific understanding of the concepts of light. In conducting a case study, participants' observations were the key data gathering method used. Using participants' observations, multiple measures and data sources such as testing, interviewing, classroom observation, were combined to make meaning of what had happened in the classroom setting to answer the research questions. This data was used to evaluate the effectiveness of the unit in terms of the promotion of scientific

understanding and student and teacher satisfaction. The phases of study, research questions, data collection, and timeline are summarized in Table 3.1.

Table 3.1 Data sources and timeline of the implementation of the unit

Phases of the Study and Research Questions	Participants	Data Sources	Timeline
Exploratory Phase			
RQ1: How do Thai teachers typically teach the concept of Light in grade 8?	37 science teachers for the questionnaire 3 of them to be interviewed 3 grade 8 science teachers	Questionnaire, and Interview questions	November 2005
RQ2: How do Thai students understand the concept of Light?	114 students from three schools in Bangkok	Light Diagnostic Test (LDT)	November 2006
Unit Design and Development Phase		Designing the LLU unit	March-November, 2007
Unit Implementation and Evaluation Phase			
RQ3: How and to what degree are Thai science teachers able to implement the Light Learning Unit (LLU)?	3 science teachers	21 Classroom observations, 21 field notes, 24 teacher reflections, 3 teacher focus group meetings, 9 students' reflection, and interviews	December 2007 - February 2008
RQ4: How does teacher implementation of the Light Learning Unit (LLU) influence students' scientific understanding of light?	9 eighth grade students from 3 schools (3 in each school)	9 concept tests and classroom observations, 9 samples of student's work sheets	December 2007 - February 2008

Data Gathering Methods

This section presents all data sources, data collection, and data analysis used in three phases of the study. The data sources used in this study include:

1. Light Diagnostic Test (LDT)
2. The Current State of Teaching and Leaning the Concept of Light Questionnaire (CSTLL)
3. Interview questions to explore Current state of Teaching and Leaning the Concept of Light
4. Light Learning Unit (LLU)
5. Workshop and Teaching Support Meeting
6. Classroom observation
7. Light Concept Test (LCT)
8. Writing Reflection sheet from students
9. Students' work sheets

Light Diagnostic Test (LDT)

The Light Diagnostic Test (LDT) is a test which was completed by 114 eighth grade students to determine their understanding of the concept of light. The Light Diagnostic Test (LDT) was designed to determine the students' understanding of Light in schools under the Bangkok Metropolitan Administration in the 2006 academic year. There were 27 items in LDT. This test probed students' understanding of eight concepts: the nature of light, the reflection of light, the Curve Mirrors, the refraction of light, image formations from lenses, optical instruments, color, and light intensity and seeing. Some items on the test were adapted from previous research (Anderson and Karrqvist, 1983). LDT is two-tier. To complete the test, the students first chose the right answer and then chose or wrote down the correct reason that corresponded to multiple choice answers. The students' responses and explanations related to light concepts were analyzed into four categories. These were: scientific conception (SC), partial scientific conception (PSC), alternative conception (AC), and no response (NR).

The Current State of Teaching and Leaning the Concept of Light Questionnaire (CSTLL)

The Current State of Teaching and Learning Light Questionnaire (CSTLL Questionnaire) was designed to explore the current state of teaching and learning the concept of light in schools under the Bangkok Metropolitan Administration in the 2005 academic year. The questionnaire consists of three parts: personal data, teaching and learning light, problems, and teachers' needs. The questionnaire was used to gather 1) background information; 2) data on the current state of teaching and learning which included the use of curriculum and textbooks, teaching preparation, teaching methods, and measurement and evaluation, and 3) problems encountered while teaching the concepts of light, and the needs of teachers related to the teaching and learning of the concepts of light.

The format used on the first part was a checklist. The teachers were asked to complete questions about their sex, age, highest degree, area of science they had graduated from, experiences teaching the topic of Light, hours per week teaching science, and workshops they had participated in. The format used on the second part consisted of both a checklist and open-ended questions. On the checklist, teachers were asked to complete the questions concerning the curriculum, the books they used, preparation time prior to teaching, the role they acted while they taught, and how they assessed their students. In the open-ended question section, they were asked to complete the questions concerning the way they prepare their lesson plans, the strategies they used when they started their lessons, and how they set up activities for their students. The format for the teachers' problems and needs section consisted of open-ended questions. To analyze data gathered by descriptive statistics and percentage.

Interview Questions to Explore Current State of Teaching and Leaning the Concept of Light

Three teachers were interviewed in-depth about 1) background information; 2) the state of instruction including the use of curriculum and textbooks, teaching preparation, teaching methods, and measurement and evaluation, and 3) problems encountered when teaching the concept of light, and the needs of the teachers related to teaching and learning. The process used to construct the teacher interview protocol was:

1. Formulate the purpose of the interview, which was to explore the current state of teaching and learning and the concept of light.

2. Study criteria and theories of constructing the types of questions and responses that fit with teachers' definitions of the exploration of the current state of teaching and learning the concept of light.

3. Construct items regarding the exploration of the current state of teaching and learning the concept of light.

4. Consult the committee and science teachers and examine content validity, language, and suitability of items.

5. Revise interview protocol based on the committee's and science teachers' feedback and suggestions.

6. Try out interview protocol to examine the clarity of language and suitability of items and revise again.

7. Implement interview questions with individual science teachers.

To analyze the data, transcripts were categorized. The responses of all teachers to each of the questions were then compared to determine similarities and differences among teachers' answers.

The Light Learning Unit (LLU)

For teachers, the unit is ready to use and includes lesson plans, a student manual, instructional materials, and resources. Each lesson plan contains information about the content, learning outcomes, teaching guidelines, instructional materials, worksheets and suggestions on formative assessment. The content of the unit follows the National Science Curriculum Standards (IPST, 2002). The eight concepts regarding the topic of light include the nature of light, the reflection of light, curve mirrors, the refraction of light, image formations from lenses, optical instruments, color, and light intensity and seeing. The activities included in all lessons use social interaction between the teacher and students and students and students. Group work and whole class discussion were the main strategies of the unit. The organization of the content and the activities of the light learning unit is shown in Table 3.2

Table 3.2 The organization of content and activities of Light Learning Unit (LLU)

Lessons	Activities	Hours
Lesson One: The Nature of Light	Design a concept map about light by working in groups, present the concept map to the whole class, and discuss the concept map.	2
Lesson Two: The Reflection of Light	Discuss the students' experiences with reflection from a mirror. Do the reflection experiment and draw a ray diagram. All activities are done working in groups.	3
Lesson Three: Curve Mirrors	Pair discussion about curve mirrors. Do a reflection experiment and draw a ray diagram. All activities are done working in groups.	2

Table 3.2 (Continued)

Lessons	Activities	Hours
Lesson Four: The Refraction of Light	Answer a question about refraction to determine prior knowledge. Do the refraction and formation of rainbow experiments and draw a ray diagram. All activities are done in groups.	3
Lesson Five: Image Formation From Lenses	Answer the questions about image formation from lenses to determine prior knowledge. Do the image formation from lenses experiment and draw a ray diagram. The students will use a computer program about image formation from lenses and watch a movie clip about image formation from lenses. All activities are done in groups.	3
Lesson Six: The Optical Instruments	Answer the questions about the optical instruments to determine prior knowledge. Then, design and construct simple optical instruments and present the results to the whole class.	2
Lesson Seven: Color	Answer the questions about color to determine prior knowledge. Do the color experiment. The students will use a computer program and watch a movie clip about color. All activities are done in groups.	2
Lesson Eight: Light Intensity and Seeing	Answer the questions about light intensity and seeing to determine prior knowledge. Then, design an activity about light intensity and seeing and present it to the whole class.	3

Workshop and Teacher Support Meeting

Three eighth grade science teachers who participated in the exploratory phase were asked to implement the unit. Before implementing the unit, the researcher set up a one day workshop during the first week of November 2007 to demonstrate the lessons for the teachers. Then, the researcher set up two meetings (the last week of January 2007 and the first week of March 2007) with the teachers to hear the results of the unit implementation from the teachers and also to understand the problems each teacher faced during their implementation. The teachers were given an opportunity to ask questions about the unit regarding either the demonstration or the materials.

Classroom Observation

Classroom observation was an important method used to gather data to answer the third research question. It started in three schools in December 2007, during the second semester of the 2006 academic year. It was used to investigate how and to what degree Thai science teachers are able to implement the Light Learning Unit (LLU). The researcher observed eight lessons of all grade 8 classes in all schools by himself. Before implementation, the researcher had visited the classrooms to build the rapport with the students and tried to become part of the class. The following process was used to obtain the observation data:

1. Construct classroom observation field notes to see how participating teachers implement the Light Learning Unit (LLU) and how students learn using the units.
2. Identify the purpose of each observation that is to be examined.
3. Study the criteria and theories of constructing the classroom observations and analyze the characteristics of what will be observed.
4. Revise field notes.
5. Observe 3 eighth grade classrooms.

To analyze the data, the researcher coded and categorized the data and then developed a set of categories from the data. Then, the categories were refined, finding the relationships and patterns across the categories to understand the teachers' implementations being studied.

Interview questions to explore implementation and learning while using the Light Learning Unit (LLU)

Teachers were asked about the teacher's role, student's role, teaching approaches, teaching activities, materials and media, questioning and assessment strategies used by teachers, and responses and participation of students in the classroom. Moreover, teachers were asked what their satisfaction level was regarding the lesson when they use the unit and any problems or suggestions they had. The process of constructing the teacher interview protocol was:

1. Formulate the purpose of the interview which is to explore the implementation and learning while using the Light Learning Unit (LLU).

2. Study criteria and theories of constructing different types of questions and responses that fit with teachers' definitions of implementation and learning.

3. Construct items about implementation and learning units.

4. Consult the committee and science teachers and examine content validity, language, and suitability of items.

5. Revise interview protocol based on the committee's and science teachers' feedback and suggestions.

6. Try out the interview protocol to examine the clarity of language and suitability of items and revise again.

7. Implement the interview protocol with individual science teachers.

To analyze the data, the transcripts were categorized. The responses to each question from all of the teachers were then compared to determine the similarities and differences between the teachers' answers.

Light Concept Test (LCT)

LCT is a concept test that was used 2 times, before and after the implantation of the unit, like a pre-test and post test. There were 27 items like those in the LDT. This test probes student understanding of eight concepts: the nature of light, the reflection of light, the curve mirrors, the refraction of light, image formations from lenses, optical instruments, color, and light intensity and seeing. Some items on the test were adapted from previous research (Anderson and Karrqvist, 1983). The LCT is a four choice multiple test. The students' responses and explanations related to light concepts were analyzed into four categories. These were: scientific conception (SC), partial scientific conception (PSC), misconception (MC), and no response (NR).

The steps used to construct the Light Concept test (LCT) were:

1. Define the content framework of light with a concept map.

2. List proportional knowledge statements and agree that concept maps and the proportional knowledge statements are accurate (Treagust, 1988, 1995).

3. Review related documents and text books concerning the concepts of light.

4. Construct tables of specification.

5. Construct the test.

6. Consult the committee to examine content validity, correctness, and the suitability of the questions on the test.

7. Revise the test.

8. Preparation.

Writing Reflection Sheet from Students

Students wrote down their reflections focusing on teaching and learning in the classroom, and their feelings about the teaching of their teachers, and their level of satisfaction while in the classroom. The teachers allowed their students to write their reflections after finishing all of the lessons. To analyze the data, the researcher coded and categorized the data and then developed a set of categories from the data. He then refined the categories to find relationships and patterns.

Students' Work Sheets

Three focused students of each school' worksheets were used to reflect their understanding of the concepts about light. The students wrote their thought in the worksheets in the students' book. The students' worksheets used to support as an evidence for the Light Concept Test (LCT).

Ethical Concerns

In this study, ethical concerns are an important topic. Informed consent, confidentiality, and the safety and welfare of the participants were used in the study. Before the collection of data, the researcher and all participants including both teachers and students were informed about the purposes and procedures of the investigation. Moreover, the students were guaranteed that their answers would not have any effect on their scores or grades. All teachers and students were addressed using pseudonyms. The researcher avoided any harassment of the participants. For example, the researcher did not threaten students, teachers, or people who were involved in any steps of the research procedure. All participants were informed that they had a right to participate or withdraw from any step of the study. At the end of the study, the researcher reported his findings to the participants and asked the participants to give permission to publish those findings.

Techniques Used to Enhance the Trustworthiness of the Research Results of this Study

In addressing credibility, the researcher attempted to demonstrate that a true picture of the phenomenon under scrutiny is being presented by using data triangulation. Data triangulation is a method to enhance credibility by crosschecking the findings between time, space, and persons. An example of data triangulation in this study was the use of multiple methods of data collection. These methods included teacher interviews, a student diagnostic test, student writing reflection, classroom observations, and students' work.

To allow transferability, the researcher provided sufficient details of the context of three schools and backgrounds of the teachers' and students' achievements to decide whether the prevailing environment was similar to another situation and whether the findings could justifiably be applied to another setting.

To allow the dependability, researchers should at least strive to enable a future investigator to repeat the study. To do so, the researcher reported any and all changes during the study to allow the reader to understand what factors were changed, in what context the changes were made, and how those changes were interpreted.

Finally, to achieve confirmability, researchers must take steps to demonstrate that findings emerge from the data and not their own predispositions. This means that all the facts in the study presented can be tracked to their source and the logic used to interpret the facts can be confirmed by the advisory committee.

Summary

An interpretive methodology was used in this study because it suits the research questions which involved the study and understanding of the experiences and perspectives of the participants including student conceptions and teachers' teaching in natural settings and interpreting these phenomena from multiple perspectives. This study used multiple data methods. To interpret the data, qualitative data analysis methods including triangulation were used. The criteria developed by Lincoln and Guba (1985) were used to ensure the trustworthiness of the findings. Ethical concerns were also addressed in the chapter. The next chapter (Chapter 4) presents the results from Phase I of this study concerning the students' understandings about Light and the situation regarding teaching and learning about Light.

CHAPTER IV

EXPLORATORY PHASE

Introduction

This chapter presents the results and discussion of two studies. The first was on teachers' opinions on the current state of teaching and learning the concept of light in Thailand in the academic year 2005. The participants were 37 science teachers in schools under the Bangkok Metropolis Administration (BMA). Science teachers completed the questionnaire in November, 2005 and 3 of 37 teachers were selected to be interviewed about 1) background information 2) the current state of teaching and learning which included the use of curriculum and textbooks, teaching preparation, teaching methods, and measurement and evaluation, and 3) problems encountered when teaching the concepts light and the needs of the teachers related to teaching and learning the concepts of light. The three teachers were selected because they were willing to be interviewed in-depth and willing to implement the Light Learning Unit (LLU). The second study was on students' understanding of the concepts of light. 114 students of three selected teachers were asked to complete the Light Diagnostic Test (LDT) in November 2006 in schools under the Bangkok Metropolitan Administration (BMA) in the academic year 2005. The three classes were from public lower secondary schools consisting of mixed ability and gender Grade 8 students (13-14 years old). There were 26-42 students per class who had studied the concepts of light. The students were taught about the concept of light for five weeks following the National Science Content Standards and School-based Curriculum. At the end of this chapter, the implications of the findings for teaching and learning are discussed.

The State of Teaching and Learning the Concept of Light

This phase of the study focused on the current state of teaching and learning the concept of light by 37 eighth grade science teachers in schools under the Bangkok Metropolitan Administration (BMA) in the 2005 academic year. The researcher sent a questionnaire to 58 teachers from 58 schools from October-December 2005. Thirty-seven completed questionnaires from 37 teachers were returned to the researcher, 63% of the completed questionnaires. Then, the researcher selected 3 teachers to be interviewed in-depth regarding the current state of teaching and learning the concept of light. The three selected teachers were a purposive sampling and they were willing to be interviewed in-depth. They wanted to develop their social constructivist teaching skills and wanted to participate in the implementation of the light learning unit (LLU). The three selected teachers were interviewed about 1) background information, 2) the current state of teaching and learning the concept of light which included the use of curriculum and textbooks, teaching preparation, teaching methods, and measurement and evaluation, and 3) problems encountered and the needs of the teachers when teaching the concepts of light in the academic year 2005.

Results

This section presented the results of the questionnaire and teacher interviews regarding the current state of teaching and learning the concept of light. The results of the questionnaire are shown in terms of 1) background information, 2) the current state of teaching and learning which included the use of curriculum and textbooks, teaching preparation, teaching methods, and measurement and evaluation, and 3) problems encountered when teaching the concepts of light and the needs of the teachers related to teaching and learning in the academic year 2005. Following are details of the results.

Background Information

The results from the questionnaire showed that seventy-six percent of the teachers were female and twenty-four percent were male. The majority of teachers were from 26 to 30 and 31 to 35 years old, had less than 6 years of experience teaching the concept of light, had bachelor's degrees in science as their highest degree, and taught science 16-20 hours per week. They also taught other disciplines including mathematics, health science, physical science, and vocational education.

Only 19 percent of the teachers had participated in the concept of light workshop and 24 percent had participated in the teaching preparation workshop which included ways to develop lesson plans, and how to use the activities in the classroom. Three teachers out of 37 were interviewed. These 3 teachers, Sompong, Pranee, and Chaichana, wanted to develop their social constructivist teaching skills and wanted to participate in the implementation of the Light Learning Unit (LLU). Following are details of the background information of the three teachers from the interview.

Sompong was a male lower secondary school teacher. He usually taught the seventh and eighth grade. He had 10 years of experience teaching science and 4 years of experience teaching the concept of light. He had a teaching workload of 18 hours per week. He was a classroom teacher and was involved in preventing and solving students' problems. He was 35 years old and had a bachelor's degree in education with a major in biology. He had participated in a concept of astronomy workshop, but had never participated in any concept of light teaching workshops. For that reason, he skipped some topics when he taught the concept of light including the curved mirror, and the calculation of image formation including the focus and distance of an image and the drawing of a ray diagram from both mirrors and lenses.

Pranee was a female lower secondary school teacher. She usually taught eighth grade. She had 15 years of experience teaching science and 2 years of experience teaching the concept of light. She taught grade 8 science and health science. She had a teaching workload of 16 hours per week. She also was a classroom teacher and school activity teacher. She was 40 years old. She had a bachelor's degree in education and her major was biology. She had never participated in any workshop involving the concept of light or teaching the concept of light at all. She admitted that she had no confidence teaching the concept of light. Sometimes, when teaching, she skipped some concept of light topics including the curve mirror, calculations about image formation including focus and the distance of an image, and the drawing of a ray diagram from both mirrors and lenses. Sometimes, she invited other teachers who were familiar with advanced concepts to teach to her students.

Chaichana was a male lower secondary and high school teacher. He usually taught the seventh, eighth and eleventh grade students. He had 16 years of experience teaching science and 6 years of experience teaching the concept of light. He had a teaching workload of 20 hours per week. He also was a classroom teacher, a teacher assigned to prevent and solve student problems, and he had responsibility for Army Reserve Force students. He was 45 years old. He had a bachelor’s degree in education, his major was biology, and he had a master’s degree in botany. He had never participated in any workshop regarding the concept of light or taught the concept of light.

The Current State of Teaching and Learning the Concept of Light

The current state of teaching and learning the concept of light is presented in terms of the use of curriculum and textbooks, teaching preparation, teaching methods, and measurement and evaluation. Following are the details of the current state of teaching and learning.

The Use of Curriculum and Textbooks

All 37 science teachers used the school curriculum that is based on the IPST Science Curriculum. Regarding textbooks, most of the teachers (59%) used science textbooks from private publishers. Ten percent of the teachers used both IPST science textbooks and textbooks from private publishers. One percent of the teachers used only the IPST science textbook.

All three of the interviewed teachers used the school curriculum, based on IPST standards, as a core curriculum. Chaichana and Sompong used the textbook from ISPT, but Ms. Pranee used textbooks from various publishers. Pranee thought that the IPST textbook was not intensive enough in its content. For example, the students should know about the concept of color, but concepts of color are not covered in the IPST textbook

Teaching Preparation

Most of the teachers (81%) usually spent 2-10 hours each week to prepare their lessons. The process of the preparation had two steps. First the teachers looked at the whole content from the science textbook and then matched the content with the IPST Science Curriculum Standard. After that, they wrote their lesson plans which included the learning objectives, main ideas, instructional processes, materials, equipment and learning resources, assessment, and the teachers' journals, which were completed after their teaching was finished.

All of the three interviewed teachers spent 2-10 hours each week to prepare their lessons. Pranee looked at the whole content from the science textbook. Then she wrote down her conclusions. After that, she wrote her lesson plan which included the learning objectives, main ideas, instructional processes, materials, equipment and learning resources, assessment, and her teaching journal. Sompong and Chaichana looked at the whole content from the science textbook and then matched the content with the IPST Science Curriculum Standards. After that, they wrote their lesson plans which included the learning objectives, main ideas, instructional processes, materials, equipment and learning resources, assessment, and their teaching journals. Sometimes, they performed the planned experiments themselves prior to teaching their lessons.

Teaching Methods

To start the lesson, most of the teachers (59%) discussed the concepts that the students had studied in the previous period and sometimes administered pre-tests to encourage the students to think and to be prepared to study the intended concepts. The teachers used about 13-18 hours total to teach the concepts of light. They taught 6 concepts including the reflection of light, image formation by lenses and mirrors, refraction of light, optical instruments, seeing and light intensity. There are only 2 teachers who did not teach the concept of light intensity. When they taught the concept of the reflection of light, refraction of light, and image formation by mirror and lens, most teachers (67%) used experiments as their teaching strategy. When they taught the concepts of the application of the refraction of light, seeing, and light intensity, most teachers (45%) used lectures as their teaching strategy.

On the questionnaire, the researcher asked the teachers to indicate their teaching methods when teaching the concept of light. All teachers used lecturing, demonstrating, and experimenting. Among the three teachers who were interviewed and willing to participate this study, Pranee used both lecturing and experimentation. She explained, "I let my students write a report before they studied the concept. Then, I let them determine if the report they had completed and the results from the experiment were the same or different. Finally, we had question and discussion period about the concept." (Pranee's interview, November, 2006)

Regarding his teaching strategy, Chaichana said, "When I teach the concept of light, I usually gave my students some knowledge before teaching. Then I let my students do the experiment and a presentation. I am concerned that my students have to do all of the activities cooperatively." (Chaichana's interview, November, 2006)

Sompong said, "First, I gave the students some idea about the topic of light by explaining the content because my students had low attention spans, then I let them do the experiment to support the content that I had given them." (Sompong's interview, November, 2006)

Measurement and Evaluation

All of the teachers assessed their students' learning by observing, testing, and reviewing students' homework or notebooks. The teachers also used lab reports and presentations as student tasks. They used observation records to check student participation while doing activities, both individually and in groups, and they also used peer assessment.

Pranee used pretests and posttests, students' homework or notebooks, student presentations, lab reports, and students' presentations, as teaching strategies. Pranee also used the performance assessment. She compiled the observation records by herself to assess her students' learning. Sompong and Chaichana used pretests and posttests.

Problems Encountered upon Instructing the Concept of Light and the Needs of the Teachers

Followings are details of the problems encountered upon instruction of the concepts of light and the needs of the teachers.

Problems Encountered upon Instructing about Light

Most teachers (81%) faced the problem of a lack of content knowledge. Fifty-seven percent of the teachers had problems writing lesson plans. Eighty-one percent of the teachers lacked new teaching strategies and equipment, materials, and learning resources. When the researcher asked the teachers which was the most difficult concept of light to teach, 68 percent of them thought that image formation from mirror and lens was the most difficult. Details are shown in table 4.1

Table 4.1 Percentages of the teachers choosing the topics of light which they found difficult to teach to their students

Concept of Light	Percentages
Image formation from mirrors and lenses	68.9
The refraction of light	44.8
The reflection of light	41.3
Seeing	34.4
Light intensity	31.0
The application of refraction of light	27.5

The three interviewed teachers, Pranee, Sompong and Chaichana, also had a lot of problems when they taught the concept of light. Pranee thought that she had problems with the content. She said, “After two years teaching the concept of light, I feel that this concept is hard to understand and to teach. The students don’t want to study it because it is difficult. For me, I don’t want to teach the calculations needed to find the quantity of lenses. For example the focal length, and the image distance. I feel that I do not have expertise regarding this concept”. (Pranee’s interview, November, 2006)

Chaichana and Sompong also agreed with Pranee about the problems they encountered when they taught the concept of light. Chaichana said, “The concept of light is difficult for both teachers and students. To understand this concept, the students have to understand the basic concept first and the students should have necessary mathematical skills.” (Chaichana’s interview, November, 2006)

When the researcher asked the teachers which were the most difficult concepts of light to teach, three of them had the same answer. They thought that image formation from mirrors and lenses was the most difficult concept.

Needs of the teachers

Most of teachers (89.1%) needed to know more about content knowledge. When the researcher asked the teachers which concepts of light they needed to know the most about, most of the teachers (70.27%) said that they needed to understand image formation from mirrors and lenses, followed by the application of refraction of light (54.1%), and the refraction of light (51.3%).

Fifty-seven percent of the teachers needed to know more about writing lesson plans. Eighty-one percent of the teachers needed to know more about new teaching strategies, equipment, materials, and learning resources.

Among the three teachers who were interviewed, Pranee needed to know more about content knowledge, and Sompong and Chaichana needed to know more about new teaching strategies, equipment, materials, and learning resources.

Discussion

This research study is the study of the current state of teaching and learning which included the use of curriculum and textbooks, teaching preparation, teaching methods, and measurement and evaluation, and also problems encountered upon instructing about light and needs of the teachers related to the teaching and learning.

The result of this research is consistent with the study of Boonchoob (2000) and Meinoratha (1997) which found that most of science teachers were female. This research is also consistent with Rodlong (1986) which found that the majority of science teachers graduated with a bachelor's degree majoring general science and this is appropriate to teach lower secondary school science class because teaching science in lower secondary school requires knowledge of all science disciplines together with science content from primary education through high school. Moreover, science teachers have to teach other subjects, such as mathematic, health science, physical science and vocational education. This is consistent with research of Meinoratha (1997) and Rodlong (1986).

For use of curriculum and textbooks, the result of this research is consistent with the research of Meinoratha (1997) which found that science teachers used the curriculum of the Institute for the Promotion of Teaching Science and Technology (IPST.).

For the use of science textbook, this study found that most teachers used the IPST science and private publisher textbooks. For the teaching preparation, the result of this research is consistent with research of Meinoratha (1997) which found that science teachers spent approximately 2-10 hours a week for teaching preparation by studying the content in textbook and Teacher Guide book. Teaching Preparation is important because it gives teachers more confidence to teach. But research is not consistent with the study of Rodlong (1986) which found that the majority of teachers (57.1%) didn't spend time for teaching preparation because teachers have many responsibilities and tasks. To start the lessons, the result found that teachers reviewed the concept from the previous period. The teachers didn't connect the student prior knowledge to the new concept.

The use of teaching methods was consistent with the research of Meinoratha (1997) and Rodlong (1986). The teacher used lecture, demonstration and experiment. Considering of prior knowledge, hand on and mind on activities can help the students have a better understanding by doing experiment. This result is the same as the study of Tinsandee (2004), Pulputsa (2004) and Taraban *et al*. (2006). For the measurement and evaluation, the results of this research is consistent with research of Meinoratha (1997) and Chotisoot (2003) which found that science teachers used various kinds of assessment including pretest and posttest, students' homework or notebooks, lab report, the student's presentation and the assignment as the report, student task.

The use of various kind of assessment is consistent with IPST (2002) which stated that science should assess both knowledge and process skills as well as the attitude towards science. Moreover, this study was consistent with Jonassen (1992) which said that measurement and evaluation should be part of the process of teaching. So, the use of a variety of assessments is to help students develop a better learning (Black and Wiliam, 1998; White and Frederiksen, 1998). For problems and needs of teachers, teachers needed equipment, material, and learning resources. The result of this research was consistent with the research of Meinoratha (1997) and Rodlong (1986) which found that science teachers needed equipment, material, and learning resources.

Not only the current state of teaching and learning the concept of light but also the students' prior knowledge is influential to their understanding the concepts of light. The following section presents students' prior knowledge is influential to their understanding the concepts of light and also discussed how it affected on their learning.

Students' Understanding of the Concepts of Light

This phase of study focused on students' understanding of the concepts of light. The students in three classes in three lower secondary schools taught by three selected teachers were asked to complete the Light Diagnostic Test (LDT) in November 2006 in schools under the Bangkok Metropolitan Administration (BMA) in the academic year 2005. The three classes were in public lower secondary schools consisting of mixed ability and mixed gender grade 8 students (13-14 years old). There were 26-42 students per class. They had studied the concepts of light. The students were taught by teachers during a 5-week unit on the concepts of light following the National Science Content Standards and School-based Curriculum. The following sections report on the results of the students' understanding of the concepts of light.

Results

This section shows the percentage of students who selected scientific, partial scientific concepts, alternative conceptions, and no response to the concepts of light from the Light Diagnostic Test (LDT). The concepts of light include Nature of Light, Image Formation, Refraction of Light, Optical Instrument, Color, and Seeing. Following are the details of students' understanding of the concepts of light.

The Nature of Light

There are three sub concepts which make up the concepts of the Nature of Light: the travel of light, light source, and media of light. Table 4.2 shows the students' understanding of each sub-concept of the nature of light.

Table 4.2 Percentages of students' understanding in each sub concept of nature of light

Nature of Light Concepts	Percentages of the Students' Understanding			
	Scientific Concept	**Partial Scientific Concept**	**Alternative Conception**	**No Response**
Travel of light	45	0	53	2
Light source	3	0	94	3
Media of light	8	43	44	5

To determine students' understanding of the travel of light concept, the researcher let the students choose the sentence which explained how far light goes and why. Forty-five percent of the students chose the concept that states that light can go further and further until it is blocked by something. Fifty-three percent of the students held the alternative conception that light only travels as far as it is visible, that light travels as far as possible, and that light travels until it is out of energy. Two percent of the students did not respond to the question.

Regarding the light source concept, three percent of the students believed the scientific concept that light emanates, leaving each point of the light source, and propagates, diverging in all spatial directions. On the other hand, 94% of the students held the alternative conception that light is an entity which is located in space (a region around the light source), light from a luminous object travels only as far as it can illuminate the area surrounding the luminous object, light fades away with distance from the source, light goes out only in a radial direction, or each point on a luminous object emits light in one direction. Three percent of the students did not respond to the question.

Regarding the media of light concept, the researcher presented a situation to the students concerning the three media and showed the amount of light that could pass through them. The students were asked to classify which of the media was transparent, translucent, or opaque. Eight percent of the students demonstrated an understanding of the scientific concept because they chose the correct answer calling an object that can block light an opaque object, calling an object that allows light to totally pass through it a transparent object, and calling an object which allows light to partially pass through it a translucent object. Forty-four percent of the students held alternative conceptions because they did not choose the correct answer. Some of them thought that light can partially pass through an opaque object. Forty-three percent of the students had a partial understanding of the concept because they thought that light can pass through both transparent and translucent objects, but they incorrectly believed that there is no difference between transparent and translucent objects. Five percent of the students didn't respond to the question.

The common alternative conceptions of the nature of light are summarized as follows:

- Light travels as far as it is visible or light travels as far as it is possible.

- Light travels as far as possible until it is out of energy.

- Each point on a luminous object emits light in one direction.

- Light from a luminous object travels only as far as it can illuminate the area surrounding the luminous object.

- Light fades away with distance from the source.

- Light can pass through an opaque media.

- There is no difference between transparent and translucent objects.

Image Formation

There are three sub concepts that make up the concept of image formation including image formation by a plane mirror, a curved mirror, and a lens. Table 4.3

shows the students' understanding of each sub concept of image formation by a plane mirror, a curved mirror, and a lens.

Table 4.3 Percentages of students' understanding of each sub concept of image formation

Mirror and Lens Concepts	Percentages of the Students' Understanding			
	Scientific Concept	Partial Scientific Concept	Alternative Conception	No Response
Image formation by plane mirror				
1. Image formation by a plane mirror lies behind the mirror	4	0	89	7
2. Image is a left-right reversal	25	0	73	2
Image formation by a curved mirror				
1. Concave mirror	26	0	61	13
2. Convex mirror	23	0	61	16
Image formation by a lens				
1. Image formation by lens 1	26	0	46	28
2. Image formation by lens 2	16	0	60	24

Regarding the concept of image formation by a plane mirror, 24.5 percent of the students believed that the image lies behind the mirror. Eighty-nine percent of the students held this alternative conception because they thought that an object has its image behind the surface of the mirror in a position in front of the observer. Seven percent of the students did not respond to the question.

Regarding the concept of image formation by plane mirror, the image is a left-right reversal. Twenty-five percent of the students held this scientific concept. Seventy-three percent of the students held the alternative conception because they thought that the image of the object was exactly the same as the actual object. Two percent of the students did not respond to the question.

Concerning the concept of image formation by a curved mirror, the researcher let the students explain where the image existed and the size of the image. He asked them to calculate the focal length of the concave mirror when the researcher put the object between the focal point (f) and 2f by the concave mirror. Twenty-six percent of the students believed the correct concept because they knew that the image existed between 2f to infinity and the image would be bigger than the actual object. Sixty-one percent of the students held a alternative conception because they thought that the image existed between the focal point (f) and 2f, and that the image would be the same size as the actual object. Thirteen percent of the students did not respond to the question.

There was one more question about image formation by a curved mirror. The researcher gave a situation where the object was placed 0.05 meters in front of the curved mirror. Therefore, the virtual image would exist 0.1 meters behind the mirror. The researcher asked the students if the curved mirror was concave or convex and asked them to calculate the focal length of the curved mirror. Twenty-three percent of the students could calculate the focal length, which was 0.1 meters, and they could explain that the curved mirror was concave. Sixty-one percent of the students believed the alternative conception because they chose the wrong answer. Thirteen percent of the students did not respond to the question.

On the topic of image formation by a lens, the researcher presented a situation where an object was placed 0.18 meters in front of the lens. Therefore, the image existed 0.06 meters in front of the lens. The researcher asked the students if the lens was a converging or diverging lens and asked them to calculate the focal length and the magnification of the lens. Twenty-six percent of the students correctly calculated the focal length of 0.09 meters, and they could explain that the lens was a converging lens. They could also explain that the magnification of the lens was 1/3. Forty-six percent of the students held a alternative conception because they chose the wrong answer. Twenty-eight percent of the students did not respond to the question.

There was one more question about image formation by a lens. The researcher gave a situation where an object was placed 0.1 meters in front of a converging lens with a focal length of 0.05 meters. The researcher asked the students to find the types of image, the image distance, and the magnification of the lens. Sixteen percent of the students correctly calculated the image distance of 0.1 meters, could explain that the image was a real image, and that the magnification of the lens was 1. Sixty percent of the students held a alternative conception because they chose the wrong answer. Twenty-four percent of the students did not respond to the question.

The common alternative conceptions about image formation by a plane mirror, a curved mirror, and a lens are summarized as follows:

- The image of an object is on the mirror surface.

- An object has its image behind the surface of the mirror in a position in front of the observer.

- The image of an object is exactly the same as the actual object.

- When the object is between the focal point (f) and 2f of the concave mirror, the image exists between the focal point (f) and 2f and it would be the same size as the actual object.

The Refraction of Light

There are three sub concepts used to measure the concepts of the refraction of light: refraction, the refraction of a prism, and refraction when the incident light rays are perpendicular to two medium. Table 4.4 shows the students' understanding of each sub concept of the refraction of light.

Table 4.4 Percentages of students' understanding of each sub concept of the refraction of light

Refraction of Light Concepts	Percentages of the Students' Understanding			
	Scientific Concept	**Partial Scientific Concept**	**Alternative Conception**	**No Response**
The refraction of light				
1. the refraction of light 1	17	0	82	1
2. the refraction of light 2	16	0	84	0
The refraction of a prism	8	4	87	1
The refraction that occurs when the incident light rays travel perpendicularly to two medium	11	7	77	5

Regarding the concept of the refraction of light, the researcher let the students chose the possible refracted ray that expressed the refraction of light when light traveled from oil into water. Seventeen percent of the students chose the correct refracted ray that expressed the refraction of light when light traveled from oil into water. Eighty-two percent of the students held alternative conceptions because they did not choose the correct refracted ray. Only 1 percent of the students had no response.

On another question, the students were asked to point to the location of an image of a fish when the observer stood on the bank. Sixteen percent of the students chose the correct answer and reasoned that when they observed the fish, it would have appeared to have been shallower than it actually was because of the refraction of light. Eighty-four percent of the students had the alternative conception that when they saw the fish, they would have seen the image of fish appearing deeper than it actually was because the speed of light through the water is faster than the speed of light through the air.

Regarding the concept of refraction of a prism, the researcher let the students choose a picture and give reasons for the refraction of light when light travel into a prism. Eight percent of the students chose the correct picture and gave the correct reason for the refraction of light when light travels into prism. They thought that when white light travels through a prism, the angle of refraction is different for different colors of light. Purple is refracted the most and the red is refracted the least. Eighty-seven percent of the students held alternative conceptions because they did not choose the correct picture and the correct reasons to explain why purple light is the least refracted and red light is the most refracted. Four percent of the students had partially correct scientific conceptions because they chose the picture which expressed the refraction of light, but they thought that the spectrum of a rainbow made by a prism is continuous and each color has its own exact boundary. Only one percent of the students had no answer.

Concerning the concept stating that refraction occurs when incident light rays travel perpendicular to two medium, the researcher let the students choose the answer and reasons which explained what happens when light passing from one medium into another hits the second medium at right angles to its surface. Eleven percent of the students believed that light will not change direction when passing from one transparent material into another if it hits the second material at right angles to its surface. Because the front waves of the incident light travel to the medium at the same time, refraction of light does not occur. Seventy-seven percent of the students held the alternative conception that refraction still occurs because light travels from one medium to another medium or there is just the transmission of light from one medium to another. Four percent of the students had partial scientific conceptions because they thought that the refraction of light does not occur, but that light will reflect to the opposite side. Five percent of the students did not respond to the question.

The common alternative conceptions regarding the refraction of light are summarized as follows:

- When students see the fish and they see the image of a fish is deeper than it actually is because the speed of light through water is faster than the speed of light through the air.

- When white light travels through a prism, the angle of refraction is different for different colors of light. Purple rays are the least refracted and red rays are the most refracted.

- When light travels from one medium into another it hits the second medium at right angles to its surface. Refraction still occurs because light travels from one medium to another medium, or there is just the transmission of the light from one medium to another.

Color

There are four sub concepts used to measure the concepts of color which include color in white light, a colored object in colored light, color by filter, and seeing color. Table 4.5 illustrates the students' understanding in each sub concept of color.

Table 4.5 Percentages of students' understanding of each sub concept of color

Color Concepts	Percentages of the Students' Understanding			
	Scientific Concept	Partial Scientific Concept	Alternative Conception	No Response
Color in white light	2	0	95	3
Color object in color light	10	48	38	4
Color by the filter	8	0	87	5
Seeing color	8	0	88	4

Concerning the concept of color in white light, two percent of the students had scientific conceptions about color in the white light because they knew that when someone sees the color black, light from the object doesn't reflect to his/ her eyes, and when someone sees the color white, the light rays from the object reflect all of it to his/her eyes. Ninety-five percent of the students had alternative conception regarding the concept that the color of an object is a physical property of that object and the color of an object is determined by the color of light it absorbs. Three percent of the students did not respond to the question.

Regarding the colored object in a colored light concept, the researcher let the students choose the answer and reason which explained what happened when the students wore striped T-shirts with white and red stripes, and green caps in a green spotlight. Ten percent of the students held the scientific concept that they would see themselves wearing striped T-shirts with green and black stripes, and a green cap in the green spotlight. Thirty-eight percent of the students held a alternative conception because they did not choose the right answer and reason. They thought that they would see themselves wearing a green T-shirt and a green cap in the green spotlight. Forty-eight percent of the students had partial scientific conceptions because they thought that it was a combination of two colors. Four percent of the students did not respond to the question.

Concerning the color by the filter concept, the researcher let the students choose the answer and reasons which explained how a color filter works. Eight percent of the students used a scientific concept because they chose the right answer and reason explaining how a color filter works. They thought that the color of an object is the color of the light that is reflected by that object. Eighty-seven percent of the students gave a wrong answer and a wrong reason about the way a color filter works. They thought that the function of a filter is to change the color of the transmitted light. Five percent of the students did not respond to the question.

Regarding the concept of seeing color, the researcher let the students choose an answer and a reason which explained what happened when the students looked at a green object for a long time and then looked at a white wall. Eight percent of the students held the scientific concept, stating that they would see the purple wall because they had seen a green object for a long time which caused the green cone cells in the fovea of the eye not to respond and the red and blue cone cells to respond. Eighty-eight percent of the students held alternative conceptions because they did not choose the right answer and reason. They thought that they would see a green wall because the brain would recognize the color they looked at the first time. Four percent of students did not respond to the question.

The common alternative conceptions on color are summarized as follows:

- The color of an object is a physical property of that object.

- The color of an object is determined by the color of the light it absorbs.

- The function of a filter is to change the color of transmitted light.

- When the students looked at a green object for a long time and then look at a white wall, they saw a green wall because the brain recognized the color they looked at the first time.

Optical Instrument

There are three sub concepts used to measure the concepts of optical instruments: telescopes, microscopes, and the comparison between a camera and the human eye. Table 4.6 shows students' understanding of each sub concept of optical instruments.

Table 4.6 Percentages of students' understanding of each sub concept of optical instruments

Optical Instrument Concepts	Percentages of Students' Understanding			
	Scientific Concept	Partial Scientific Concept	Alternative Conception	No Response
Telescope	17	0	68	15
Microscope	7	0	83	10
The comparison between camera and human's eyes	1	0	84	15

Concerning the concept of telescopes, the researcher let the students choose the answers and reasons which explain how a telescope works. Seventeen percent of the students held a scientific concept because they chose the right answer and reason. They thought that the objective lens of the telescope made the actual upside down image and that the eyepiece lens made the image bigger. Sixty-eight percent of the students gave a wrong answer and a wrong reason about how a telescope works. They thought that the objective lens of the telescope made the larger image. Fifteen percent of students did not respond to the question.

To test students' understanding of microscope concepts, the researcher let the students choose the answer and reason which explained how a microscope works. Seven percent of the students held a scientific concept because they chose the right answer and reason. They thought that the image from the microscope was big and the position of the actual image formed by the objective lens was less than the focal length of the eyepiece lens. Eighty-three percent of the students gave a wrong answer and a wrong reason about how a microscope works. They thought that the image from the microscope was big and the position of the actual image formed by the objective lens was more than two focal lengths of the eyepiece lens. Ten percent of the students did not respond to the question.

To determine the students' responses to a comparison between a camera and the human eye, the researcher let the students select an answer and a reason to explain whether there is a difference between the image from a camera and an image from the human eye. One percent of the students held a scientific concept because they chose the correct answer and reason. They thought that both the image from a camera and from the human eye are the actual image, and that both are smaller than the real object. Eighty-four percent of the students gave a wrong answer and a wrong reason. They thought that there is difference between the image from a camera and the image from the human eye. The image from the camera is the real image and smaller than the actual object, but the image a human eye is a virtual image and smaller than the actual object. Fifteen percent of the students did not respond to the question.

The common alternative conceptions regarding optical instruments are summarized as follows:

- The objective lens of a telescope makes a larger image.

- The image from a microscope is big and the position of the real image formed by the objective lens is more than two focal lengths of the eyepiece lens.

- There is difference between the image from a camera and an image from the human eye. The image from a camera is the real image and smaller than the actual object, but the image from a human eye is the virtual image and smaller than the actual object. Each point on a luminous object emits light in one direction.

Seeing

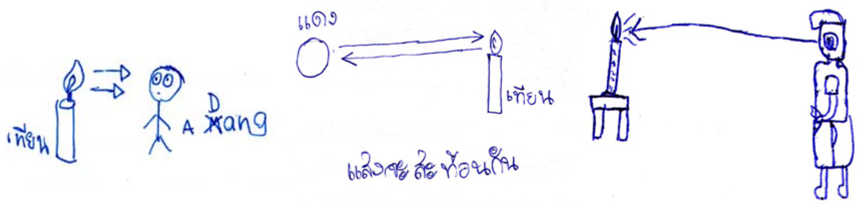
There are three sub concepts included within the concept of seeing: seeing a candle flame, a candle stick, and the eye problem. Table 4.7 shows the students' understanding of each sub concept of seeing.

Table 4.7 Percentages of students' understanding of each sub concept of seeing

Seeing Concepts	Percentages of Students' Understanding			
	Scientific Concept	Partial Scientific Concept	Alternative Conception	No Response
Seeing the candle flame	16	0	68	4
Seeing the candle stick	11	0	46	5
The eye problem	8	0	85	7

Regarding the concept of seeing the candle flame, the researcher let the students choose the answer that explained how they saw the candle flame in a dark room. They also sketched a picture to represent what they saw. Sixteen percent of the students held a scientific concept because they chose the right answer and the correct reason which explained how the light from the candle flame traveled to their eyes.

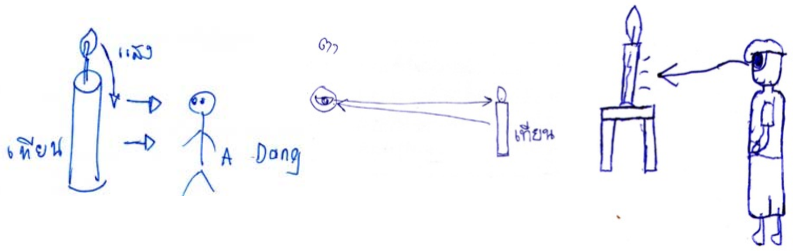
Sixty-eight percent of the students gave the wrong answer and the wrong explanation for the way they saw the candle flame. The students thought that the reflected light from the candle flame traveled to the their eyes, the light from their eyes traveled to the candle flame, and the light from the candle flame traveled to their eyes and then back to the candle flame again. Four percent of the students did not respond to the question. Figure 4.1 shows the students' drawings that express the correct scientific concept of seeing the candle flame)a) and their alternative conceptions in (b) and (c).



(a) (b) (c)

Figure 4.1 The students' drawings show their correct scientific conceptions about seeing the candle flame (a) and their alternative conceptions in (b) and (c)

Regarding the seeing candlestick concept, the researcher let the students choose the answer that explained how they saw the candlestick in a dark room and also asked them to draw a picture to represent what they had seen. Eleven percent of the students held a scientific concept because they chose the right answer and correct reason: that the light from the candle flame shined from the candlestick and then reflected to the students' eyes. Forty-six percent of the students gave the wrong answer and reason about the seeing the candlestick concept. They thought that the light from the candlestick traveled to their eyes, the light from their eyes traveled to the candlestick, and the light from the candlestick traveled to their eyes and then back to the candlestick again. Five percent of the students didn't respond to the question. Figure 4.2 shows the students' drawings which illustrate their correct scientific conceptions about seeing the candlestick (a) and their alternative conceptions in (b) and (c).



(a) (b) (c)

Figure 4.2 The students' drawings illustrated their correct scientific conceptions about seeing the candlestick (a) and their alternative conceptions in (b) and (c)

Concerning the eye problem concept, the researcher let the students choose the answer and reason that best explained what the eye problem was in the given picture. Eight percent of the students held the correct scientific concept because they chose the right answer and reason. They thought that the given picture illustrated nearsightedness. When the people become nearsighted, diverging eyeglass lenses are used to correct this condition. When the students put the diverging lens into the eyeglasses, the lens spread the light out before it reached the eye-lens, and when the eye-lens converged the light, the light then converged on the back of the eye to produce the proper focus. Eighty-five percent of the students responded with the wrong answer and wrong reason to the eye problem. They thought that the given picture showed nearsightedness. When the students put diverging lenses into the eyeglasses, the lens spread the light out before it reached the eye-lens, and when the eye-lens converged the light, the light then converged on the back of the eye to achieve proper focus. Seven percent of students did not respond to the question.

The common alternative conceptions regarding seeing are summarized as follows:

- The reflected light from the candle flame traveled to the students' eyes.

- The light from the eyes traveled to the candle flame.

- The light from the candle flame traveled to the students’ eyes and then back to the candle flame again.

- The light from the candlestick traveled to the students’ eyes.

- The light from the eyes traveled to the candlestick.

- The light from the candlestick traveled to the students’ eyes and then back to the candlestick again.

- When the students put a diverging lens into the eyeglasses, the lens spread the light out before it reached the eye-lens, and when the eye-lens converged the light, the light converged on the back of the eye to achieve the proper focus.

In summary, the majority of the students had alternative conceptions about the concept of color, refraction of light, and image formation by a mirror and lens. Many concepts about light are connected to each other. For example, the concept of optical instruments is connected to the concept of image formation by a mirror and lens. The concept of seeing is connected to the concept of the reflection of light. The students should understand the fundamental concept first, and then they will be able to understand more advanced or more complicated concepts.

Discussion

The majority of students had both scientific conception and misconception in all concepts about Light. In the concept of Nature of Light, The results found that the concepts that most students had misconception are light source, media of light, travel of light respectively. The students’ misconception about travel of light is consistent with the findings of Andersson and Karrqvist (1983) and Sangsupata (1995). These studies found that the students in these studies explained that light only travels as far as it is visible, light travels as far as it is possible, and light travels as far as it is out of energy. The same as the concept about light source, the students' misconception found is consistent with the finding of Sangsupata (1995) which is found that the students thought that light is an entity which is located in space (region around the light source), and light goes out only in radial direction. The students' misconceptions may come from the students used their experiences explained what they have seen. Moreover, the concept about the ray of light is the abstract concept (Donovan and Bransford, 2005). So, the imagination is required for understanding of this concept.

For the concept of the image formation by mirror and lens, the results found that the most students had misconceptions in plane mirror, lens, and Curve mirror respectively. The students' misconception about image formation by plane mirror is consistent with the findings of Goldberg and McDermott (1986) and Sangsupata (1995). The students in these studies explained that the image by plane mirror is on the mirror instead of behind it and also they did not understand about left-right reversal. All of misconceptions the students held may come from the instruction. So, the teacher should be careful when he/she explained the particular concept or the students used their experiences explained what they have seen. The same as the concept of image formation by lens, the students' misconception found similarly with the study of Goldberg and McDermott (1987).

For the concept of the refraction of light, the results found that most students had misconceptions in refraction of prism, refraction when the incident light ray perpendicular, and refraction respectively. The students' misconception about refraction of light found that the students did not understand when light travel one medium to another medium, the refraction occurs because refraction is a phenomenon that close to students and sometime they did not notice what is going on. For example, most of students thought that when they observe the fish, they see the image of fish is deeper than it should be.

For the concept of Color, the result found that most students had misconceptions in color in the white light, color by eye's problem, color by the filter and colored object in colored light respectively. The students' misconception about color is consistent with the findings of Salley (1996). The students thought that color is stimulated by the particular object to observer's eyes or color is come from object and also from light. The students held misconception because they used their experiences explained what they have seen and they did not understand the fundamental concept. The students did not understand the reflection of light and did not understand the connection between reflection of light and color. The reflected light ray may be an abstract concept.

For the concept of Optical Instrument, the result found that most students had misconceptions in the comparison between camera and human's eyes, microscope and telescope respectively. The students held misconception because the students used their experiences explained what they have seen and they did not understand the fundamental concept. For example, the students did not understand the concept of image formation by mirror and lens and the connection between image formation by mirror and lens and optical instrument.

For the concept of seeing, the result found that most students had misconception in the eye problem, candle stick, and seeing the flame candle respectively. The students held misconceptions because they did not understand the fundamental concept. For example, if the students do not understand the reflection of light, the students may not understand the concept of seeing. The students' misconception about seeing is consistent with the findings of Andersson and Karrqvist (1983), Ramadas and Driver, (1989) and Osborne, Smith, and Meadows (1993). The students in these studies thought that there is light from the eyes to the object instead of reflected light from that object bounce into the observer's eyes.

Implications of Two Survey Results for Designing the Unit

The students' misunderstanding of light might come from poor instruction. The survey about the current state of teaching and learning the concept of light revealed that the teachers didn't use social constructivist teaching methods. The teachers preferred to use lecturing, demonstrating, experimenting, and assigning the students to do a report and a group presentation. The teachers didn't use discussion and didn't give the students an opportunity to construct their learning.

The teaching strategies that the teachers had been using do not facilitate student understanding. These teaching strategies cause most of the students to hold alternative conceptions about all concepts, especially the concepts of color, refraction of light, and image formation by mirror and lens.

These students' alternative conceptions about light and the current state of teaching and learning about the concept of light will guide the researcher to plan activities that will promote these scientific concepts to students.

The next chapter will be a discussion on the design and development of the Light Leaning Unit (LLU) which will promote scientific understanding of the concept of light. The development of the Light Learning Unit (LLU) will be guided by the findings from the exploratory phase, students' difficulty understanding of the concept of light, the teachers' teaching methods, and teachers' needs when teaching and learning the concept of light.

CHAPTER V

THE DEVELPOMENT OF THE LIGHT LEARNING UNIT

Introduction

This chapter discusses the design and development of the Light Leaning Unit (LLU) which will be used to promote scientific understanding of the concept of light. The development of the Light Learning Unit (LLU) is guided by the findings from the exploratory phase and a review of literature on this subject. The process of the unit design and the development and the organization of content and activities of the Light Learning Unit (LLU) are then discussed. Moreover, the comparison of contents and activities between the Light Leaning Unit (LLU) and the former curriculum will be presented.

Design and Development of the Light Learning Unit (LLU)

The design and development of the Light Learning Unit were based on the Thai National Education Act and the social constructivist approach. The details of Thai National Education Act and the social constructivist approach were discussed in Chapter 2. Below is a summary of the Thai National Education Act and the social constructivist approach.

The learning process as discussed in the Thai National Education Act is based on the principle that all learners are capable of learning and development. This is regarded as being of great importance. The teaching methods detailed in the act aim to provide training in thinking processes, develop management skills, find ways to face various situations, teach students to apply knowledge for obviating and solving problems, organize activities to allow learners to draw from authentic experiences, provide practical work drills for complete mastery, enable learners to think critically and to acquire the habit of reading, and develop a continuous thirst for knowledge within students. So, it can say that learning has become more student-centered.

Learning science under a social constructivist framework requires students to make meanings of the world through both individual and social processes. Vygotsky proposed the term Zone of Proximal Development (ZPD). Zone of proximal development of learners is defined as the learner's range of ability with and without assistance. Thus, one end of the range is the student's ability level without assistance, and the other end of the range is the learner's ability level with assistance.

Two surveys in the exploratory phase revealed the state of teaching and learning the concepts of light, and along with the students' understanding of the concept of light, were used to design the light learning unit. The details of teaching and learning the concept of light, including the students' understanding of the concept of light, were discussed in chapter 4. This section presents only a summary of teaching and learning the concept of light and includes the students' understanding of the concept of light.

Teaching and Learning the Concept of Light in the Classroom

The results from the questionnaire reveal the big picture of the state of teaching and learning of the concept of light in schools under the Bangkok Metropolitan Administration (BMA) in the 2005 academic year. Most teachers normally use both lectures and experiments in their teaching and use various kinds of assessment.

The results from the interview showed that the teachers let the students be part of the teaching and learning processes, but they did not obviously focus on students' prior knowledge. They did not use social constructivist teaching. They preferred to use lecturing, demonstrating, experimenting, and assigning reports and group presentations. They didn't use discussion and didn't give the students an opportunity to construct their own knowledge. Teachers used various kinds of assessment including students' tasks, their performance during teaching and learning, and participation during teaching and learning.

Students' Understanding of the Concept of Light

The results of this study showed that the students held both scientific conceptions and misconceptions in each of the main concept areas. Most students had misconceptions about color, the refraction of light, and image formation by mirrors and lenses. The student held misconceptions about these concepts because light is an abstract concept. The imagination must be used to understand some concepts including the concept of light rays. Students did not have enough of an understanding of fundamental concepts to explain advanced concepts. For example, the reflection of light is a fundamental concept of sight. The image formation from mirrors and lenses is the fundamental concept of optical instruments. Moreover, the students usually only memorized the concepts without understanding or using their experiences to explain the situations they faced.

The research findings reported here and a review of the relevant literature were used as guiding principles for the design and construction of the light learning unit. There were 6 guiding principles used in the process of designing and constructing the concept of light unit:

1. The unit should address students' prior knowledge of the concept of light. Students come to the classroom with their own prior knowledge. The unit should build scientific understanding from the students' prior knowledge.

2. The unit should give students an opportunity to construct their own learning through interaction with their peers.

3. The unit should use a meaningful context to help students develop the concepts in the real world.

4. The unit should use thoughtful, open-ended questions to encourage students.

5. The unit should focus on students working cooperatively.

6. Assessment in the unit should be authentic and interwoven with teaching.

The Light Learning Unit (LLU) was designed in January 2007 (academic year 2006) and is based on the social constructivist approach. The Light Learning Unit is designed for grade 8 students. The unit consists of 8 lessons covering 20 hours. The unit will:

1. Analyze sources including the content of the National Science Education Standard provided by the IPST, and light and optics text books.

2. Study the constructivist teaching approaches from previous research, text books, and articles.

3. Be based on the light content section of the IPST science education in Thailand, social constructivist approaches, and the results from the exploratory phase.

4. Be designed using constructivist approach-based instructional units, including learning objectives, main concepts, instructional procedures, instructional materials, and assessment.

The unit will be implemented following four steps:

1. The first draft of the instructional unit will be sent to the committee to consider the aspects of teaching, learning, and content.

2. The unit will be revised following the committee's suggestions.

2. The second draft of the unit will be sent to the committee for reconsideration and revision for a second time.

4. The instructional unit will be implemented.

Light Learning Unit (LLU) was designed in January 2007 (Academic year 2006) which based on social constructivist approach. Light learning unit is the unit for grade 8 students. The unit consists of 8 lessons covering 20 hours. The followings are:

1. Analyze the content of the National Science Education Standard provide by IPST and from other sources such as light and optics text book.

2. Study constructivist teaching approaches from previous researches, and text books and articles

3. Based on the light content of the IPST science education in Thailand, social constructivist approaches and the result from the exploratory phase, design constructivist approach-based instructional units, including learning objectives, main concept, instructional procedure, and instructional materials and assessments.

4. Send the first draft of instructional unit to the committee to consider the unit both in aspect of teaching and learning and content.

5. Revise the instructional unit according to the committee suggestions.

6. Send the second draft of the unit to the committee to reconsider and revise for the second time.

7. Implement the instructional unit.

Content of Light Learning Unit (LLU)

The unit is comprised of lesson plans, a student manual, instructional materials and media, and is ready for use by teachers. Each lesson plan contains information about the main concept, learning outcomes, instructional procedures, instructional materials, worksheets, and suggestions on formative assessment. The content of each unit is according to the National Science Curriculum Standards (IPST, 2002). In the

IPST Textbook, the content of light is divided into 3 themes: light and seeing, the refraction of light and its application, and seeing and the intensity of light. However, the LLU content is divided into eight lessons on the topic of light: the nature of light, the reflection of light, curved mirrors, the refraction of light, image formation from lenses, optical instruments, color, and seeing and light intensity. The activities of all lessons used social interaction between teachers and students, and between students and students. Group work and whole class discussion are the main strategies of the unit. There are some differences between the contents of the light learning unit (LLU) and the IPST Textbook. A comparison of content between the light learning unit and the IPST Textbook is shown in Table 5.1

Table 5.1 Comparison of contents and the activities of the Light Learning Unit (LLU) and IPST Textbook

IPST Science Textbook	LLU
Theme 1: Light and seeing	
	Lesson 1*: The nature of light ▪ The meaning of light ▪ The importance of light ▪ The travel of light ▪ The types of media
The reflection of light by plane mirror ▪ The law of reflection of light ▪ The application of plane mirror **The image formation by plane mirror** ▪ The virtual image ▪ The ray diagram	**Lesson 2: The reflection of light** ▪ The law of reflection of light ▪ The characteristics of image formed by the plane mirror ▪ The ray diagram of the image formed by plane mirror.
The image formation by curved mirror ▪ The real image ▪ The virtual image ▪ The ray diagram ▪ The reflection of light by curved mirror	**Lesson 3: The curved mirror** ▪ The characteristics of curved mirrors (concave and convex mirrors) ▪ The characteristics of image formed and ray diagram by the curved mirror
Theme 2: The refraction of light and its application ▪ The refraction of light ▪ The formation of rainbow	**Lesson 4: The refraction of light** ▪ The refraction of light ▪ The rainbow ▪ The refraction of light in daily life ▪ The application of refraction of light

Table 5.1 (Continued)

IPST Science Textbook	LLU
Theme 2: The refraction of light and its application ▪ The refraction of light by lens ▪ The image formation by lens ▪ The ray diagram ▪ The internal total reflection	**Lesson 5: The image formation by lens** ▪The characteristics of lenses (converging and diverging lenses) ▪ The light ray when the light passes through the lenses ▪ The image formation by the lenses ▪ The total reflection of light
The optical instrument ▪ Microscope ▪ Telescope ▪ Camera	**Lesson 6: The optical instrument** ▪ Microscope ▪ Telescope ▪ Camera
Theme 3: seeing and the intensity of light Seeing	**Lesson 7*: The color** ▪ The combination of color light ▪ The color of colored object when shined the other colors to that object ▪ The application of the color combination
▪ The nearsightedness, farsightedness and the correction ▪ The intensity of light	**Lesson 8: seeing and light intensity** ▪ Seeing ▪ The eye problems and its correction ▪ The light intensity ▪ The eye care

Note: * is the lesson found only in LLU

For more understanding about the comparison between LLU and IPST Textbook, the conceptual framework of the topic of light in LLU and in IPST textbook is shown below.

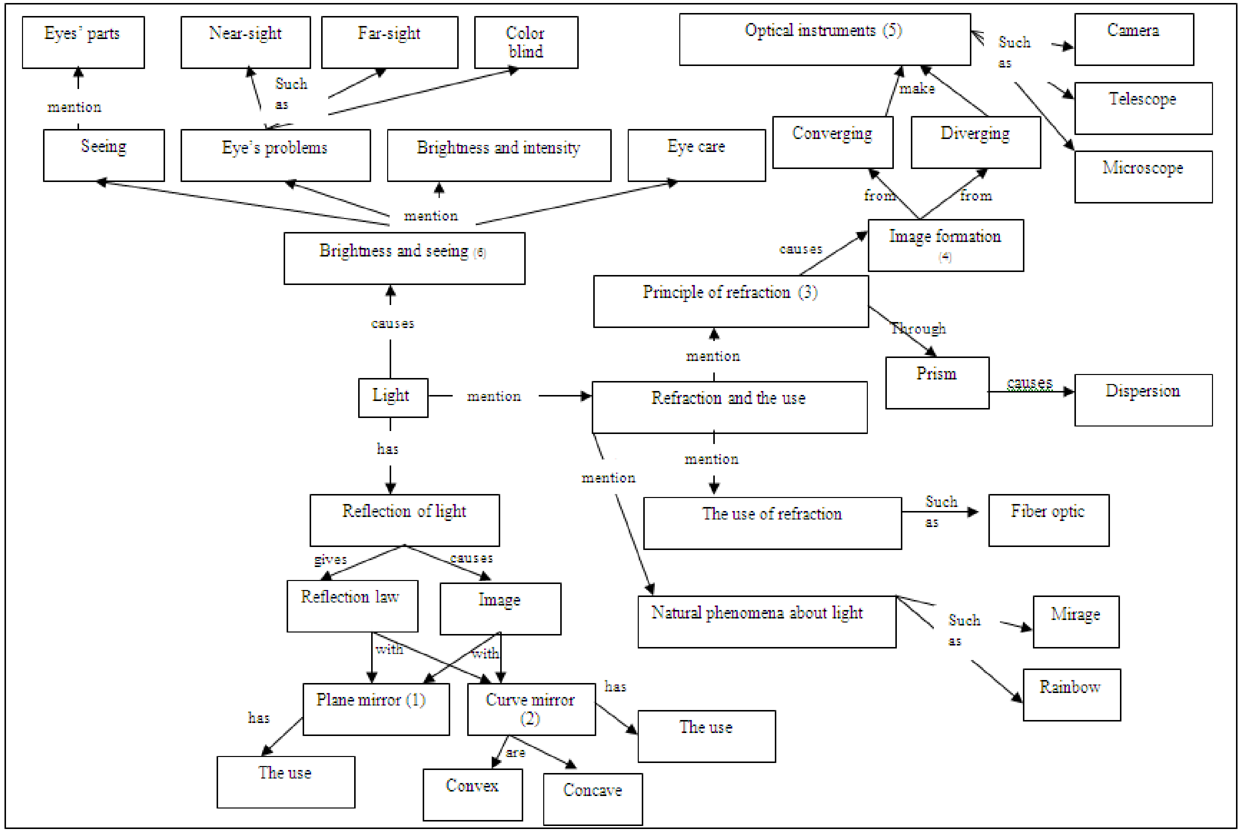


Figure 5.1 Conceptual framework of the topic of light in IPST Textbook

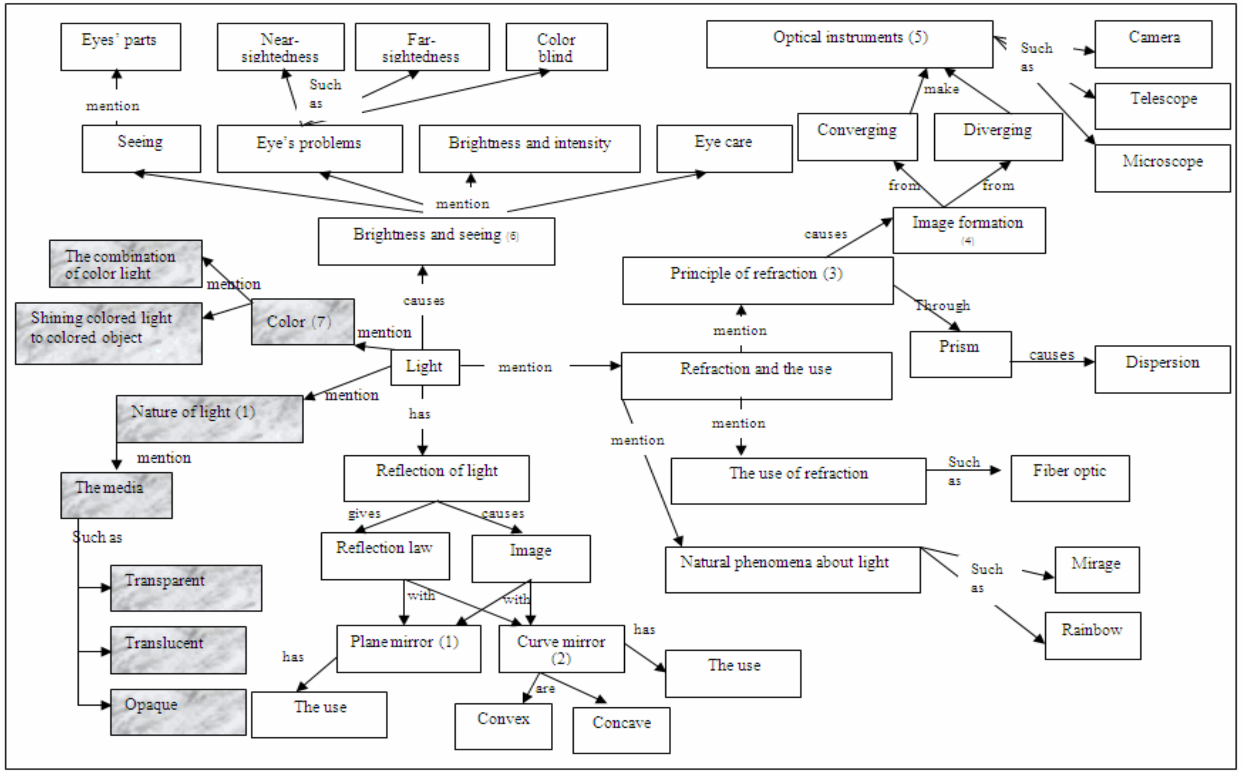


Figure 5.2 Conceptual framework of the topic of light in LLU

Activities of Light Learning Unit (LLU)

A description of the activities in each lesson is briefly outlined below.

Lesson 1: the Nature of Light

This lesson will introduce students to the nature of light. The lesson takes two hours to complete. The lesson begins by asking students to think and share ideas about the nature of light in their daily lives. Then, working in groups, the students share their ideas on the nature of light by constructing a concept map. The students are asked to design and do an experiment working in groups to verify that light travels in a straight line. In this activity, the students work collaboratively to design the experiment by using these materials: 2 paper cards, modeling clay, 2 straws, a ruler, and scissors. The students are free to design the experiment using higher-order thinking skills. Next, the students in each group present their design and explain it to the rest of the class. After that, the students are asked to classify the types of media by using the property of light as it passes through the media. The objects used for classification are objects which appear in students' daily lives. For example, a piece of paper, a glass plate, a wood plate, and a waxed sheet. The teachers ask the students to classify the media into three types: transparent, translucent, and opaque media. The nature of light concepts are then be identified by the students and their teacher.

Lesson 2: the Reflection of Light

Lesson 2 discusses the reflection of light. The students are asked to discuss their experiences with reflections from a plane mirror and then they are asked to use think-pair-share to discuss the plane mirror in given situations. The students are asked to do the experiment working in groups to verify the law of reflection and to investigate image formation using one mirror and two mirrors. Then, the students present and explain their results to the class. The students learn how to draw a ray diagram from the teachers' guide. Finally, the reflection of light concept is concluded by the students and their teacher.

Lesson 3: the Curved Mirror

Lesson 3 emphasizes the curved mirror. First, the students are asked to share their ideas about the differences between a plane mirror and a curved mirror. Then they are asked to use think-pair-share in a given situation to discuss image formation by a curved mirror. Second, the students are asked to do experiment involving image formation by a curved mirror working in groups. Then, the students present and explain their results to the rest of the class. Third, the students learn how to draw a ray diagram from the teachers' guide. Finally, the curved mirror concept is concluded by the students and their teacher.

Lesson 4: the Refraction of Light

Lesson 4 is about the refraction of light. First, the students are asked to share their ideas about phenomena involving the refraction of light that they have seen or known. Then, they share their ideas in groups and with the entire class while they are observing a teacher demonstration. Second, the students are asked to do a refraction of light experiment working in groups. After that, they present and explain their results to the class. Third, the students learn how to draw a ray diagram from the teachers' guide. Fourth, they are asked to share their ideas about phenomena that is related to the refraction of light including mirages and rainbows. Then they are asked to do an experiment which involves making a rainbow. After that, they present and explain their results to the class. Fifth, they are asked to design and do an experiment which examines ways to make internal total reflection. Finally, the refraction of light concept is concluded by the students and their teacher.

Lesson 5: Image Formation by Lens

Lesson 5 discusses image formation by a lens. First, the students are asked to share their ideas about the refraction of light that are related to a lens and then they are asked to use think-pair-share to discuss refraction by a lens in a given situation. Second, the students are asked to do a group experiment to verify the principals of refraction by a lens and image formation by a lens. Then, the students present and explain their results to the class. Third, the students learn to draw a ray diagram from the teachers' guide. After that, the students learn to calculate the qualities of lenses including the focal length, the image distance, and the image size. Finally, the image formation by a lens concept is concluded by the students and their teacher.

Lesson 6: Optical Instruments

Lesson 6 discusses optical instruments. Firstly, the students are asked to share their ideas and knowledge about optical instruments and then they are asked to use think-pair-share to discuss ideas about optical instruments. After that, the students and the teacher conclude the concept of optical instruments. Second, the students are asked to design and do a group experiment regarding a simple camera. Then, the students present and explain their design to the class. Third, the students are asked to do an experiment about image formation by telescopes and microscopes. Then, the students present and explain their results to the class. Finally, the optical instrument concept is concluded by the students and their teacher.

Lesson 7: Color

Lesson 7 emphasizes color. First, the students are asked to share their ideas about the different colors produced from the refraction of a prism and to use think-pair-share to discuss the idea of classifying the 7 colors. Second, the students are asked to do a group experiment about color. Then, the students present and explain their results to the rest of the class. Third, the students do an experiment about colored objects in colored light. Then, the students present and explain their results to the class. Finally, the color concept is concluded by the students and their teacher.

Lesson 8: Intensity and Seeing

Lesson 8 is about intensity and seeing. First, the students are asked about the essential principals regarding sight, and then they take a look into a friend's eyes and share their ideas about the characteristics of eyes with the whole class. Second, the students share their ideas about eye problems including farsightedness, nearsightedness, and corrections for these problems. Third, the students are asked to design and perform a group experiment about the effects of light intensity on living things. Then, the students present and explain their design to the class. Finally, the light intensity and seeing concepts are concluded by the students and their teacher.

The concepts and the activities of all lessons are summarized in table 5.2

Table 5.2 Concepts and activities of Light Learning Unit (LLU)

Lessons	Concepts	Activities	Duration (hours)
Lesson 1: The nature of light	▪ The meaning of light, nature of light ▪ The importance of light ▪ The travel of light ▪ The types of media by using the property of allowing light to pass through	▪ Identify prior knowledge about light ▪ Construct the concept map about the nature of light ▪ Design and do the experiment about the travel of light ▪ Identify types of media by using the property of allowing light to pass through	2
Lesson 2: The reflection of light	▪ The law of reflection of light ▪ The characteristics of image formed by the plane mirror ▪ The ray diagram of the image formed by plane mirror.	▪ Identify prior knowledge of reflection of light ▪ Discuss the reflection from mirror ▪ Do the experiment about the reflection of light ▪ Draw the ray diagram of the image formed by plane mirror	3
Lesson 3: The curve mirror	▪ The characteristics of curved mirrors (concave and convex mirrors) ▪ The characteristics of image formed by the curved mirror ▪ The ray diagram of the image formed by curved mirrors ▪ The use of the reflection by curved mirrors	▪ Use think-pair-share to discuss about the curve mirrors and the image formation by curve mirror ▪ Do the experiment about reflection ▪ Draw the ray diagram of the image formed by curved mirror	2

Table 5.2 (Continued)

Lessons	Concepts	Activities	Duration (hours)
Lesson 4: The refraction of light	▪ The refraction of light ▪ The light dispersion ▪ The refraction of light in daily life ▪ The application of refraction of light.	▪ Demonstrate refraction of light ▪ Do the experiment about refraction of light	3
Lesson 5: The image formation by the lenses	▪ The characteristics of lenses (converging and diverging lenses) ▪ The light ray when the light passes through the lenses ▪ The image formation by the lenses ▪ The total reflection of light	▪ Find out the prior knowledge about the image formations ▪ Do the experiment about the image formations from lenses ▪ Draw the ray diagram of the image formations from lenses	3
Lesson 6: The optical instruments	▪ The concept of optical instruments (camera, telescope and microscope)	▪ Identify student prior knowledge about the optical instruments ▪ Design and construct the simple camera ▪ Do experiment about the image formation from telescope and microscope	2

Table 5.2 (Continued)

Lessons	Concepts	Activities	Duration (hours)
Lesson 7: Color	▪ The combination of color light ▪ The color of colored object when shined the other colors to that object ▪ The application of the color combination	▪ Identify student prior knowledge about color using worksheets, questions ▪ Do the experiment about color	2
Lesson 8: Intensity and seeing	▪ Seeing ▪ The eye's problems ▪ The light intensity ▪ The eye care	▪ Identify student prior knowledge about the intensity and seeing ▪ Discuss about eye's problems such as nearsightedness, farsightedness and the eye correction ▪ Design the activity about light intensity and seeing	3

Summary

This chapter explained the design and development of the Light Learning Unit (LLU) using guiding principles. Schools can adopt or adapt the unit to suit their needs.

In the next chapter, the unit implementation and evaluation phase, the Light Learning Unit (LLU) was implemented in three schools to answer the last two research questions: how and to what degree are Thai science teachers able to implement the Light Learning Unit (LLU) and how does teacher implementation of the Light Learning Unit (LLU) influence students' scientific understanding of light?

CHAPTER VI

Unit Implementation and Evaluation

Introduction

This chapter discusses the implementation and evaluation of the Light Learning Unit (LLU). The chapter describes a workshop that was set up to train the teachers to implement the LLU and to gather their input for further improvements to the unit. The next section introduces the implementation of the Light Learning Unit (LLU) in three schools. Teachers' background information, students' background information, and school and classroom settings are also examined in this section. The implementation of the Light Learning Unit (LLU) is discussed separately for each school. The last two research questions are posed and investigated for each school in the study.

Participants and Settings

Three teachers from three schools were involved in implementing the LLU in the second semester of the 2006 academic year. They had all participated in the first exploratory phase of the study, as discussed in Chapter IV. Two schools are large (more than 1,500 students) and one school is medium sized (1,300 students). This research was conducted in schools under the Bangkok Metropolitan Administration. There were three schools used in this study and all were lower secondary schools. In all cases, pseudonyms were used to represent the schools' and teachers' names. Sompong was a teacher in Sara School, Pranee was a teacher in Pattana School, and Chaichana was a teacher in Charoen School. Sara and Pattana were in the same district. The distance between two schools was around 3 kilometers. Charoen is about 15 kilometers from Sara and Charoen is about 17 kilometers from Pattana.

Implementation of the Light Learning Unit (LLU)

Three teachers from three schools started their implementation by attending a workshop. This workshop was set up to discuss the Light Learning Unit (LLU), and how each teacher implemented it. The feedback and comments of the teachers on the LLU were used for the improvement of the LLU. Moreover, while they implemented the LLU, there were teacher support meetings which were established for to support and encourage the teachers while they implemented the unit. At the first meeting, the teachers were asked to reflect upon their teaching, their satisfaction with their teaching, how the students responded to their teaching, and the problems that the teachers faced in the classroom.

A workshop and teacher support meetings were set up to facilitate the teachers' reflections upon their teaching. The timing and focus of these workshops is summarized in table 6.1.

Table 6.1 Overview of the workshop

Workshop Topics		
Before Implementation	**During Implementation**	
Workshop (November,2006)	**Teacher Support Meeting 1 (January,2007)**	**Teacher Support Meeting 2 (February,2007)**
▪ Overview of the research study ▪ Teachers' teaching strategies for teaching the concepts of light in the last academic year ▪ The National Education Act B.E. 2542 (1999), National Science Curriculum Standards, and the findings from the exploratory phase ▪ Social constructivism ▪ The design and construct of LLU and a comparison of LLU and IPST ▪ Lesson plans and materials ▪ Demonstration of the lesson plans ▪ Roles of the researcher	▪ Reflect on their teaching (lesson plan 1-4) ▪ Students' responses ▪ Students' responses ▪ Problems with teaching ▪ Preparation of the next 4 lesson plans	▪ Reflect on their teaching (lesson plan 5-8) ▪ Students' responses ▪ Problems with teaching ▪ Evaluation of the LLU

The Workshop

This workshop was set up to discuss the Light Learning Unit (LLU), and how each teacher implemented the unit. The teachers' feedback and comments on the LLU were used to improve the LLU. Three teachers were given the LLU documents to read before the workshop to allow them to prepare for the meeting. The researcher started the workshop by presenting the following topics:

- An overview of the research study

- The National Education Act B.E. 2542 (1999) and the National Science Curriculum Standards statement about the learner-centered approach

- Findings from the exploratory phase including the current state of teaching and learning the concept of light and students' understanding of the concept of light

- Social constructivism underpins the teaching and learning process

- The importance of students' prior knowledge

- Teachers' teaching strategies for teaching the concepts of light in the last academic year

- The design and construction of the LLU

- A comparison of the LLU and the IPST

- Lesson plans and materials

- Demonstration of the lesson plans

- Roles of the researcher

The Light Learning Unit was introduced by comparing it to the current National Science Curriculum Standards (IPST, 2002). The researcher discussed ways to design and construct the LLU and also showed the teachers the process of designing and constructing the LLU. Then, the researcher compared the Light Learning Unit and The National Science Curriculum Standards in terms of content and activities for eighth graders. Next, the teachers were introduced to 8 lessons, lesson by lesson. The objectives, the concepts, teaching procedures, materials, and assessment of each lesson were discussed. After presenting each lesson, teachers were asked for comments or suggestions on the lesson.

Content

The content of the Light Learning Unit is divided into 8 main concepts: the nature of light, the reflection of light, the curve mirror, the refraction of light, image formation by a lens, color, and seeing and light intensity. The LLU covers all 6 concepts of light in the National Science Curriculum Standard (IPST, 2002) for eighth grade students. The researcher added more two concepts: the nature of light, and color in the LLU.

In lessons 1, 5, and 6 students are encouraged to design experiments by themselves. Each lesson emphasizes that the students build knowledge by themselves by working in groups.

All teachers accepted that the content of the LLU covers all concepts as suggested by the curriculum standards. All teachers thought that the content of the LLU was intensive and maybe difficult for their students in some parts.

Activities

Teachers believed that the LLU would help their students to better understand the concept of light. All activities in each lesson focused on group work. At first, the students were probed with questions from their teacher. They were allowed to discuss their explanations with other students which gave them the opportunity to share their ideas with other students. For example, in lesson 1, “The nature of light”, the students shared an idea which led to the construction of a concept map using 11 words that were related to the concept of light. The teachers were concerned about activities which allowed their students to design the experiments because the students had never done so before. They thought that these activities would take a lot of time. In an activity which discussed finding the critical angle that makes a total internal reflection, the teachers asked additional questions to help their students understand what a critical angle is. When discussing the concept of the refraction of light, the teachers asked students to use the real thing to demonstrate the refraction of light instead of using a picture. In an activity which involved calculating qualities of a lens, the teachers were concerned that they couldn’t teach the topic to their students because they had skipped teaching it for many years. And in an activity about color, the teachers suggested that a document describing this concept should be printed in color instead of in black and white.

Teacher Support Meetings

The teacher support meeting was established to support and encourage the teachers while they implemented the unit. At the first meeting, the teachers were asked to reflect upon their teaching, their satisfaction with their teaching, how the students responded to their teaching, and the problems that the teachers had faced in the classroom. All of this information would help the researcher to understand how the teachers implemented the LLU. The teachers and researcher found the best solution to answer all of the problems. The teachers implemented the LLU in the mid December 2006. There were two teacher support meetings. The first was held in late January 2007 and the second was held in late February 2007.

Themes from Teacher Support Meetings

Student Responses

All teachers had the same conclusions about their teaching, believing that the students enjoyed learning in the classroom and paid more attention to the lessons, especially when doing experiments in groups. The students performed the processes, along with the instructions, correctly. This means that the teaching was clear to them. One teacher said that the LLU enhanced his students' understanding of the concept of light because the students could explain the concept to their peers and they could apply the lessons to other situations. For example, in the study of the concept of a curved mirror, the students learned how to make a ray diagram from a curved mirror. After that, most students could correctly apply that idea to other problems. Moreover, the teachers said that the students enjoyed learning when they studied the concepts of lenses, optical instruments, and color because these concepts were studied using a computer program to help them to understand.

The teachers said that their students were happy to learn in groups because the students had to share their ideas and everyone in the group had their own responsibilities. The responsibilities were not the same as the students had experienced before. They knew that everyone in a group had a responsibility, for example, the president, vice president, secretary, and so on, but responsibility in the LLU required a person to do the experiments, a person to collect data, and a person to present the data.

Teacher Responses

The teacher responded to the intervention both during and after teaching each lesson. During the teaching, all teachers felt good because they had the confidence to teach concepts that they usually skipped or shortened. When they taught their lessons, they usually followed the steps that were suggested by the LLU. All teachers said that the LLU helped them a lot when teaching the concept of light and they were happy every time they finished the lesson. Moreover, one teacher said that the LLU changed his teaching technique from giving knowledge to the students to letting the students construct knowledge by themselves. The LLU helped him to understand the concepts as he learned with his students, performing the curved mirror experiments and doing lens calculations.

Difficulties of Teachers

Teacher Content Knowledge

Teacher content knowledge would be investigated during the workshop before the implementation of the LLU, and teachers' problems would be examined before and after they taught their students. All teachers lack some content knowledge. For example, one teacher had a problem with the concept of a curved mirror because he had never taught it before and he also had problems with calculations involving lenses such as the focal length and the image distance. The teacher explained this during the workshop.

> For the 2 years that I have taught the concept of light, I have felt that the content of this topic was very hard to understand, not only for students but also for the teacher. I can only say that I didn't want to teach the concept of light because I had almost no knowledge of the concept. (Ms. Pranee's meeting interview: January, 2007)

This section introduces three case studies of three lower secondary schools. In each case, school context, classroom setting, teachers' background information, and students' background information are described. The last two research questions are posed and answered in each case. The results are presented in terms of the teachers' teaching practices and their problems with teaching practices, their perceptions of the teachers regarding social constructivist teaching, students' perceptions of their teaching, and the student's understanding of concepts about light. In all cases, pseudonyms were used to represent the schools and teachers. Sompong was the teacher at Sara School, Pranee was the teacher at Pattana School, and Chaichana was the teacher at Charoen School.

Case I: Sara School

School Context

The school was established in 1943 in a suburban area of Bangkok. It is close to Pratumtani Province. It is a medium sized school with 1,335 students with thirty two classrooms. This school has kindergarten, primary, and secondary classrooms. There are 4 kindergarten classrooms with 40-45 students per class. In grades 1-4, each grade level has 4 classrooms with 40-45 students per class. In Grades 5-6, each grade has 3 classrooms with 40-45 students per class. In Grades 7-9, each grade has 2 classrooms with 25-35 students per class. One class consists of high ability students, and others contain students with mixed abilities. The school is surrounded by a field and a small community. Teaching hours begin at 8.30 a.m. and finish at 3.30 p.m. There are seven periods a day. Each period is 60 minutes long at the lower secondary level. The students have science class for 3 hours each week. One semester consists of eighteen weeks including seventeen weeks for the teaching and one week for the final examination.

Teacher's Background

Sompong was a male lower secondary school teacher. He usually taught the seventh and eighth grade. He had 10 years experience teaching science and 4 years experience teaching the concept of light. He had a teaching workload of 18 hours per week. He also was a classroom teacher and the teacher in charge of preventing and solving student problems. He was 35 years old. He had a bachelor degree in education and his major was biology. He participated in a workshop on the concepts of astronomy, but never participated in any workshops involving the concept of light or teaching the concept of light. For that reason, he sometimes skipped teaching some topics regarding the concept of light including curved mirrors, calculations about image formation such as the focus and distance of an image, and the drawing of ray diagrams from both mirrors and lenses. Even though he believed in constructivism, he usually taught science using teacher-centered learning. He explained a particular concept to his students and then he had them do an experiment. Sometimes he used textbooks or ready to use science lessons that he bought from a private publishing company. He believed that it is an important part of the teacher's role to offer all available knowledge to his students. He also said that his students don't pay attention; therefore, he often used a lecturing technique to teach his students. He believed that lectures can promote students' understanding of the subject matter and that lectures are more suitable for his students. He had no ideas regarding other teaching strategies. When the researcher asked him to participate in the study, he agreed to join immediately. He thought that this would be an opportunity to gain more teaching strategies and also new media materials to use with his students.

Students' Background

Most of the students were 14 years old and came from low socioeconomic families. They were average achieving students. There were 26 students in the class, 16 males and 10 females. Most of the students, 15, had moderate GPAs (2.0). Six students had high GPAs (3.5) and five had GPAs of 3.0. However, no students achieved the highest GPA (4.0). The students loved to do experiments. When they were doing experiments, they looked happy. This study focuses on three students who were purposely selected to be studied in depth concerning the development of their understanding of the concept of light. The selection was based on a students' personalities in terms of talkativeness. Pseudonyms, Soraya, Dongdao, and Pakphum, were used to represent the students' names. The details of these students are described below.

Soraya

Soraya was a fourteen year old girl. Her mother was a housewife, and her father owned a small business. Soraya liked to study science. She believed that science was necessary for her daily life. Her science achievement score was 3.0.

Dongdao

Dongdao was a thirteen year old girl. Her mother and father were laborers. She didn't like science because she thought that science was hard to understand. Her science achievement score was 2.0.

Pakphum

Pakphum was a fourteen year old boy. His mother and father were laborers. He liked science because he loved to do experiments. His science achievement score was 2.0.

Classroom Setting

Sompong's classroom was a laboratory room with 8 tables in the room and one for the teacher as shown in Figure 6.1. When the researcher looked at the classroom, it was crowded with tables and chairs and everything was dirty. There was a lot of dust on the tables in the room. A lot of equipment and material was unpacked and some was broken. Sompong taught in a science laboratory with insufficient equipment and material, including lenses, prisms, and optical instruments, that is necessary for the study of the concept of light.

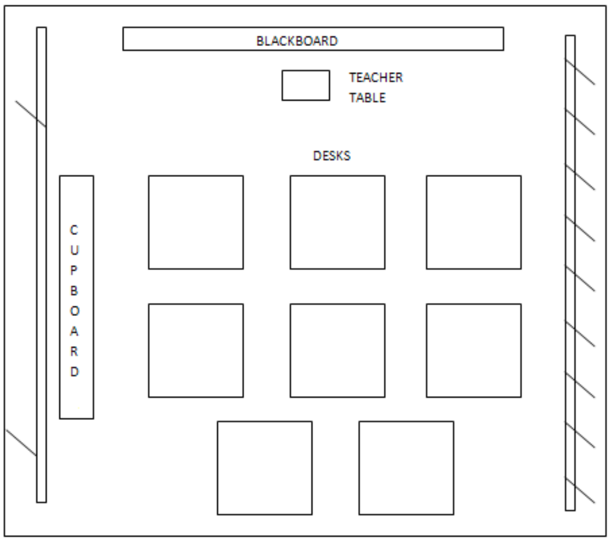


Figure 6.1 Sompong's classroom setting

Research Questions 3: How and to What Degree Are Thai Science Teachers Able to Implement the Light Learning Unit (LLU)?

To answer this research question, Sompong's teaching practices, including teaching and assessment strategies, are described. Moreover, the problems that he faced during the implementation the unit and the perceptions of Sompong and his students about the unit implementation were investigated as well. The in-depth information on the process of Sompong's implementation of the LLU is discussed below.

Sompong's Teaching Practices: Sompong Served in the Role of Facilitator.

Sompong was very worried about implementing the LLU, because he was not familiar with the teaching strategies in the LLU. The teaching strategies in LLU were different from his previous teaching styles. In the first week, he seems to have had some stress when he taught the lesson. Sompong made many efforts to ask students questions, and encouraged students to participate in the lessons. Sometimes, he read the teacher manual for two or three minutes to be sure that what he had taught was complete. However, in the later weeks, Sompong felt comfortable and free with teaching the LLU. He was able to adapt and felt more comfortable with the LLU. His students paid more attention, listened, thought, discussed, and shared their ideas with him and their peers. The details of Sompong's teaching practices are discussed in terms of teaching and assessment strategies below.

Sompong's Teaching Strategies

Sompong implemented the unit by following the guidelines in the teacher manual. He usually assessed students' prior knowledge by asking and discussing questions. His teaching strategies focused on cooperative group work. He also prepared hands-on and minds-on activities that allowed students to think and discuss with their peers in small groups. The classroom observations confirmed that students' understanding was enhanced by working in groups. The students were given time to discuss their findings and make conclusions within their group and within the whole class. This helped students to understand the concepts they studied. Sompong's teaching strategies are presented below.

Sompong Focused on Students' Prior Knowledge.

During the first week of the implementation, Sompong was nervous about teaching the lesson, but he followed the instructional unit step by step. He also used all of the instructional media and materials and he often used all of the questions to determine the students' prior knowledge. As time passed, he seemed to have more confidence in his teaching. Sometimes he added more questions in addition to the ones suggested in the lesson plan. To further investigate students' prior knowledge, he asked the students to give the reasons for their answers. This was evidenced by classroom observations. In the lesson one, the Nature of Light, the students were expected to explain the meaning, the nature, and the importance of light and to design, do experiments, and classify types of media by using the property of light as it passed through. Sompong first let the students close and then open the classroom doors and windows. Then he asked his students about the difference between these two situations to engage them and he let his students think and share their ideas. Then he asked, “What is the importance of light to humans?” and “Without light will humans still survive and why?” He was trying to pose more questions to increase the students’ prior knowledge. Sompong found that his students’ answers were not right, but he did not tell them that they were wrong. He then asked the students more questions including “Why do you think like that? Explain more about your understanding.” Moreover, he used group activities or concept maps to illustrate the students’ prior knowledge of the nature of light. He gave his students time to discuss and share ideas from their own understanding to construct concept maps and then the concept maps from each group were presented. Sompong and his students then made a conclusion from the students’ presentations. The following week, he used all of the questions to check the students’ understanding of the concepts. When the students could not answer the questions, he gave them time for discussion. He asked more questions including “Do you understand the question?” and “What do you think?”

Nevertheless, sometimes, he moved back to his old teaching style. He did not wait for the students’ answer to elicit their prior knowledge. For example, while explaining the concept of image formation by a plane mirror, he asked the students about the size of an image produced by a plane mirror. When the students answered that the size of the image would be smaller than the actual object, Sompong argued suddenly that it was not smaller but it was the same size. He asked the students to remember that the image size from a plane mirror is the same size as the actual object.

Sompong Used a Meaningful Context to Help Students Develop the Concepts in the Real World.

When Sompong taught the students the concept of the reflection of light, he used learning material which is related to the students’ lives. He helped his students to develop an understanding of the concept of the reflection of light by using a real life situation. This was evidenced by classroom observations. In lesson two, the reflection of light, Sompong first let the students look at a plane mirror and discussed what the students saw in the mirror, what the reflection looked like, and where reflection existed. Then, he asked the students to solve a real situation problem that was related to the reflection of light by a plane mirror. He helped the students to develop some ideas about the reflection of light. This was evidenced by classroom observations.

> The students in each group cooperatively talked and thought about the reflection of light and image formation by plane mirror. They used a real plane mirror to check their reflections. Then the teachers asked them more about how to draw a ray diagram of the situation. While the students worked cooperatively in groups, Sompong walked from group to group to help his students. He asked them more questions about the relationship between the angle of incident and reflected rays to stimulate his students' thinking on ways to draw the ray diagram. (Field note, December, 2006)

One more example of Sompong's use of a meaningful context was when he taught the concept of the curved mirror. Sompong asked the students to observe and touch shiny silver paper that can be bent. He asked the students about their reflection from that paper. Then, he asked more questions about ways to make your reflection to appear upside down, and ways to make their reflections shorter and shrunken, and taller and thinner than normal. The students answered that they had to bend the paper. The students then bent the paper and tried to make strange reflections. After that Sompong related the paper to a curved mirror and asked the students to do an experiment about image formation by curved mirror. Then, he asked the students about the use of the curved mirror in their lives.

Sompong Encouraged Students by Asking Thoughtful, Open-ended Questions.

In the first week of the implementation, Sompong used the questions to make students think and explain their ideas. For example, in lesson one, the Nature of Light, Sompong asked his students to think about how to investigate the reasons that light travels in a straight line, He used open-ended questions such as, "What do you think would happen if there was no light and how would you classify the types of media when using their properties of allowing light to pass through them?" He also gave his students time to think about the questions.

The following week, he still asked his students thoughtful and open-ended questions. For example, in lesson three, the Refraction of Light, Sompong asked his students to find ways to make internal total reflections and to use total internal reflections in their daily lives.

However, sometimes he used "yes" or "no" questions. For example, in the lesson on the concept of image formation by a plane mirror, after the students finished the experiment, he asked the students about the characteristics of an image formed by a plane mirror. Sompong asked "Is the image made by a plane mirror a virtual image? "Does it have the same size as the actual object?" He did not ask the students to explain the reasons behind their answers.

Sompong Gave the Students an Opportunity to Construct Their Learning Through Interaction with Their Peers.

In the first week of the implementation, Sompong usually gave his students an opportunity to learn as active learners and to work cooperatively. For example, in an activity, How Light Travels, Sompong asked the students about the nature of light by asking "how does light travel?" to encourage his students to think. He then asked them to demonstrate the travel of light using some objects (2 paper cards, modeling clay, 2 straws, ruler, and scissors). He asked each group of students to read the worksheet directions and then to explain how to do the activity. In this activity, Sompong gave the students time to work in groups to discuss and share their ideas about designing and doing the experiment. Sompong supported the students' active learning by encouraging them to think and to try to design the experiment. He said, "You should try to do it". The results in each group were presented and followed by Sompong's and the students' conclusions about this activity.

One more example of Sompong's students' study of the nature of light was when students were asked to classify types of media according to the properties which allowed light to pass through them. Sompong distributed twelve objects to each group of students. The objects that Sompong used were ones that appeared in the students' daily lives such as a piece of paper, a glass plate, a wooden plate, and a waxed sheet. Students observed the twelve objects in terms of three measures of their ability to allow light to pass through: transparent, translucent, and opaque. He asked the students to read the directions in the worksheet and then to explain how to do the activity. The students looked and touched each of twelve objects. To do the worksheet, the students in each group had an opportunity to interact with each other or with the teacher to classify each type of media according to its property of allowing light to pass through. After doing the experiment, the students helped each other to answer the questions. The results of the activity in each group were presented, and Sompong and the students made conclusions about the each type of media according to its property of allowing light to pass through. In the following week, Sompong's students were still active learners because he gave them the opportunity to construct their own knowledge by active doing.

Sompong Focused on the Students Working Cooperatively

He divided the students into groups. Each group consisted of five students. When forming the groups, Sompong explained the role and responsibility of each student in each group as a collector, a reporter, a presenter, and a supporter. Then, he explained how to do the activity. This activity was used to increase the students' prior knowledge by letting them construct a concept map from 11 given words. In this activity, Sompong gave time to the students to discuss and share their ideas on the construction of the concept map. Sompong walked from group to group to observe and give help when needed. He asked students questions to help them think. He gave praise and encouragement during in-class group work. He was also an extended participant and involved group member. After the presentation, he used peer assessment techniques to grade the students' experiment as suggested by the LLU.

Assessment Strategies

Sompong used various ways to assess the students' learning; test scores, presentations, worksheets, and participation in the classroom as suggested by LLU. He also focused on assessing students' prior knowledge. He asked the students to share their ideas. Students often presented the results of their experiments to the whole class. He usually observed while his students were doing the experiment or assignment. For example, while students were doing the "design an experiment about the travel of light" assignment, he observed the students working, asked them about their work, and sometimes gave suggestions. At the end of some lessons, he allowed students to conclude the concepts they had learned by having a class discussion. He also used peer assessment techniques to grade students' experiments.

Sompong's Problems Teaching

Time Constraints

Sompong felt that there were too many activities. He worried that he needed more time to finish all of the lessons. Unfortunately, he could not finish the last three lessons of the unit on time. He provided more time for these lessons and gave lectures to summarize the content and skipped the activities. There were many reasons that he could not finish the last three lessons. First, there were many days off which shortened the teaching time. The students had to attend the school sports competition day. They had to take the National Test for two days. Before taking the National Test, they had to prepare for one week. Second, the teacher was asked to attend a workshop for one week, so his students did not learn science that week. Last, Sompong was sick for a week, so his students did not learn science for another week.

Sompong's Perception of Teaching

During the implementation, Sompong had changed his teaching strategy from transmitting the knowledge to his students to letting his students construct their own knowledge from the group experiments. Sompong said,

> This unit made me changes my old teaching style. I was able to teach some topics that I had skipped in past years by reading and following the unit in the teacher's guide. I can say that when I finished my teaching, I felt happy. (Sompong, Interviewed in January, 2006)

Moreover, Sompong noticed that his students enjoyed doing some of the activities in the LLU unit including the nature of light, curved mirrors, and lenses. Students paid more attention when doing the activities. Sompong agreed that giving students an opportunity to do hands-on activities in groups could increase their attention and understanding. Sompong said,

> I felt like the students paid more attention when they learned by themselves through the activities and the group experiments. (Sompong, Interviewed in January, 2006)

Students' Perception of Sompong's Teaching

The students felt the changes in their teacher's teaching practices and thought that they had a chance to express their understanding and ideas when they were in the class. One student said,

> I felt that all the activities and the experiments about light helped me to understand the concept of light. We had unity in our working group. In the learning of light, we gained more knowledge of the reflection of light, refraction of light, image formation from mirrors and lenses, color, and other important topics. I can tell that I know it (the concept of light) better. We also

had a chance to present the results of the experimental data and I loved the questions before and after the experiment. Those questions can help and guide us to understand more. Finally, when we were in the classroom, we had a chance to express our thinking or ask something that we were curious about. (Soraya, Student reflection, February, 2006)

Research Questions 4: How Does the Implementation the Light Learning Unit (LLU) Enhance Students' Scientific Understanding of Concept about Light?

To answer this research question, this section presents the percentages of students choosing either scientific or partial scientific concepts, misconceptions, or no response to the concept of light from the Light Concept Test (LCT) after implementing the LLU. Next, this section presents the conceptions of three focused students before and after the implementation.

The Students' Conceptions of the Concept of Light

Students were asked to complete a light concept test (LCT) after the implementation of the LLU. The LCT was like the light diagnostic test (LDT), divided into six concepts: nature of light, image formation by plane mirror and lens, curved mirrors, refraction of light, optical instruments, color, and seeing. The students' responses and explanations related to light concepts were analyzed and placed into four categories: scientific conceptions (SC), partial scientific conceptions (PSC), Misconceptions (MC), and No response (NR). The percentage of students choosing scientific concepts, partial scientific concepts, misconceptions, and no response to the concept of light from the Light Concept Test (LCT) before (pretest) and after (posttest) implementing the LLU are included as well. The students' conceptions of light are presented below.

The Nature of Light

There are three sub-concepts used to determine the concepts of the nature of light: the travel of light, light sources, and the media of light. The percentages of Sara school students in each category of nature of light before (pretest) and after (posttest) implementing the LLU is shown in Table 6.2.

Table 6.2 Percentages of Sara school students in each category of nature of light before (pretest) and after (posttest) implementing the LLU

Nature of Light Concepts	Test	Percentages of Students			
		Scientific Concept	Partial Scientific Concept	Misconception	No Response
Travel of light	Pre	27	0	73	0
	Post	57.6	0	42.4	0
Light source	Pre	15	0	85	0
	Post	73.1	0	26.9	0
Media of light	Pre	15	19	66	0
	Post	53.8	15.4	30.8	0

For the travel of light concept, the researcher let the students choose the sentence which explained how far light goes and why. A total of 57.6 percent of the students held the scientific concept that light can go further until it is blocked by something. A full 42.4 percent of the students held the misconceptions that light only travels as far as it is visible, light travels as far as possible, and light travels until it is out of energy.

For the light source concept, 73.1 percent of the students held the scientific concept that light emanates from each point of the light source and propagates, diverging in all spatial directions. On the other hand, most of students, 26.9 percent, held a misconception by explaining that light is an entity which is located in space (region around the light source), light from a luminous object travels only as far as it can illuminate the area surrounding the luminous object, light fades away with distance from the source, light goes out only in a radial direction, or each point on a luminous object emits light in one direction.

For the media of Light concept, the researcher gave the students a situation where three media show the amount of light that can pass through and asked students to classify which one is transparent, translucent, or opaque media. Fifty three percent of the students used a scientific concept to classify the media because they chose the correct answer and they called an object that can block light an opaque object, they called an object a transparent object if light can totally pass through it, and they called an object a translucent object if light can partially pass through it. A total of 30.8 percent of the students held a misconception because they could not choose the correct answer and some of them thought that light can pass through an opaque object. Only 15.4 percent of the students used partial scientific concepts because they thought that light can pass through both transparent and translucent objects, but that there is no difference between transparent and translucent objects.

Image Formation

The concept of image formation can be divided into three sub concepts: image formation by a plane mirror, curved mirrors, and lenses. The percentages of Sara school students in each category of image formation before (pretest) and after (posttest) implementing the LLU is shown in Table 6.3.

Table 6.3 Percentages of Sara school students in each category of image formation before (pretest) and after (posttest) implementing the LLU

Image Formation Concepts	Test	Percentages of the Students			
		Scientific Concept	**Partial Scientific Concept**	**Misconception**	**No Response**
Image formation by plane mirror lies behind the mirror	Pre	4	0	96	0
	Post	65.4	0	34.6	0

Table 6.3 (Continued)

Image Formation Concepts	Test	Percentages of the Students: Scientific Concept	Partial Scientific Concept	Misconception	No Response
Image is a left-right reversal	Pre	19	0	81	0
	Post	60.4	0	38.4	1.2
Curve mirror 1	Pre	0	0	96	4
	Post	11.6	0	84.6	3.8
Curve mirror 2	Pre	0	0	89	11
	Post	15.4	0	84.6	0
Image formation by lens 1	Pre	0	0	85	15
	Post	50	0	50	0
Image formation by lens 2	Pre	0	0	96	4
	Post	46.1	0	53.9	0

For the image formation by plane mirror concept, 65.4 percent of the students held the scientific concept that the image lies behind the mirror and it is just as far behind the mirror as the actual object is in front of the mirror. A total of 34.6 percent of the students held a misconception because they thought that an object has its image behind the surface of a mirror in a position that is in front of the observer.

The other question about the image formation by a plane mirror is a left-right reversal. A total of 60.4 percent of the students held the scientific concept, while 38.4 percent held a misconception because they thought that an object has its image behind the surface of the mirror in a position that is in front of the observer. Just 1.2 percent of the students didn't respond to the question.

For the image formation by a curved mirror concept, the researcher let the students explain where the image exists, asked them to find the size of the image and to calculate the focal length of the concave mirror when the researcher put the object between the focal point (f) and 2f of the concave mirror. Only 11.6 percent of the students held a scientific conception because they knew that the image existed between 2f to infinity and the image would be bigger than the actual object. A total of 84.6 percent of the students had a misconception because they thought that the image existed between the focal point (f) and 2f and the image would be the same size as the actual object. Just 3.8 percent of the students didn't respond to the question.

The other question was about image formation by a curved mirror. The researcher created a situation where an object was placed 0.05 meters in front of a curved mirror and the virtual image existed 0.1 meter behind the mirror. The researcher asked the students if the curved mirror was concave or convex and asked them to calculate the focal length of the curved mirror. Only 15.4 percent of the students were able to calculate the focal length of 0.1 meter and they were able to identify the type of curved mirror (which was a concave mirror). A total of 84.6 percent of the students held a misconception because they chose the wrong answer.

To investigate the image formation by a lens concept, the researcher placed an object 0.18 meters in front of a lens. The image existed 0.06 meters in front of the lens. The researcher asked the students if the curved mirror was concave or convex, and asked them to calculate the focal length and the magnification of the lens. Fifty percent of the students calculated a focal length of 0.09 meters, knew that the lens was a converging lens, and that the magnificent of the lens was 1/3. Fifty percent of the students held a misconception because they chose the wrong answer.

Regarding the second question about image formation by a lens, the researcher placed the object 0.1 meters in front of the converging lens which had a focal length of 0.05 meters. The researcher asked the students to identify the type of image, the image distance, and the magnification of the lens. Forty six percent of the students calculated the correct image distance of 0.1 meters and they knew that the image was a real image with a lens magnification of 1. Another 53.9 percent of the students held a misconception because they chose the wrong answer.

The Refraction of Light

The refraction of light can be divided into three sub concepts: refraction, the refraction of a prism, and refraction when the incident light ray travels perpendicular to two media. The percentages of Sara school students in each category of refraction of light before (pretest) and after (posttest) implementing the LLU is shown in Table 6.4.

Table 6.4 Percentages of Sara school students in each category of refraction of light before (pretest) and after (posttest) implementing the LLU

Refraction of Light Concepts	Test	Percentages of Students			
		Scientific Concept	Partial Scientific Concept	Misconception	No Response
The refraction of light 1	Pre	7	0	93	0
	Post	69.2	0	30.8	0
The refraction of light 2	Pre	4	0	96	0
	Post	77	0	23	0
The refraction from a prism	Pre	8	8	84	0
	Post	15.4	23	61.6	1
The refraction occurs when the incident light ray travels perpendicular to two media	Pre	23	0	77	0
	Post	15.4	7.7	76.9	0

To test the refraction of light concept, the researcher let the students choose the possible refracted rays that can express the refraction of light when light travels from oil into water. A total of 69.2 percent of the students chose the correct refracted ray which expressed the refraction of light when light travels from oil into water. Another 30.8 percent of the students held a misconception because they could not choose the correct refracted ray.

The students were given an additional problem. They were asked about the location of the image of a fish when seen by an observer on the bank. A total of 77 percent of the students chose the correct answer and reason. They thought that the image of the fish was shallower than it should have been because of the refraction of light. Only 23 percent of the students held a misconception when they saw the fish. They thought that the image of the fish was deeper than it should have been because the speed of light through the water is faster than the speed of light through the air.

To study the refraction of a prism concept, the research let the students choose a picture and reason that could express the refraction of light when light travels into a prism. Just 15.4 percent of the students chose the right picture and the right reason which correctly showed the refraction of light when light travels into prism. They thought that when white light travels through a prism, the angle of refraction is different for different colors of light. The purple is refracted the most and the red is refracted the least. A total of 61.6 percent of the students held a misconception because they could not choose the right picture and chose the incorrect answer which stated that purple is the least refracted and the red is the most refracted color. Only 23 percent of the students held a partial scientific conception because they chose the correct picture, which expressed the refraction of light, but they thought that the spectrum of a rainbow by a prism is continuous and each color has its own exact boundary. Only 1 percent of the students had no answer.

For the refraction when the incident light ray travels perpendicular to two media concept, the researcher let the students choose the answer and reason which explained what happens when light passes from one medium into another medium if it hits the second medium at right angles to its surface. Only 15.4 percent of the students held the scientific concept that light will not change direction when passing from one transparent material into the other medium if it hits the second material at right angles to its surface. Because front waves of the incident light incident the medium at the same time, the refraction of light does not occur. A total of 76.9 percent of the students held the misconception that refraction still occurs because light travels from one medium to the other medium or there is just a transmission of light from one medium to the other medium. Just 7.7 percent of the students had a partial scientific conception because they thought that the refraction of light does not occur, but that the light will reflect to the incident light.

Color

The concept of color can be divided into four sub concepts: color in white light, colored objects in color light, color using a filter, and seeing color. The percentages of Sara school students in each category of color before (pretest) and after (posttest) implementing the LLU is shown in Table 6.5.

Table 6.5 Percentages of Sara school students in each category of color before (pretest) and after (posttest) implementing the LLU

Color Concepts	Test	Percentages of the Students			
		Scientific Concept	Partial Scientific Concept	Misconception	No Response
Color in white light	Pre	0	0	100	0
	Post	11.5	0	88.5	0
Colored object in colored light	Pre	0	0	92	8
	Post	27	0	73	0
Color using a filter	Pre	0	0	100	0
	Post	15.4	0	84.6	0
Seeing color	Pre	8	0	92	0
	Post	53.8	0	46.2	0

For the color in white light concept, 11.5 percent of the students had a scientific conception about color in white light because they knew that when someone sees black, light from the black object didn't reflect to his/ her eyes, and when someone sees white, the light rays from the object reflect all of the rays to his/her eyes. A total of 88.5 percent of the students had a misconception about color because they did not understand that the color of an object is a physical property of that object and the color of an object is determined by what color of light it absorbs.

For the colored object in a colored light concept, the researcher let the students choose the answer and reason which best explained what happened when the students wore red and white striped T-shirts with green caps in a green spotlight. Twenty seven percent of the students held the scientific concept that they would see themselves wearing a striped T-shirt with green and black stripes and a green cap in the green spotlight. A total of 73 percent of the students held a misconception because they could not choose the right answer and reason. They thought that they would see themselves wearing a green T-shirt with and a green cap in the green spotlight.

For the color by filter concept, the researcher let the students choose the answer and reason which best explained how a color filter works. Only 15.4 percent of the students used a scientific concept because they chose the right answer and reason about how a color filter works. They thought that the color of an object is the color of the light that is reflected by the object. A total of 84.6 percent of the students gave the wrong answer and reason about how a color filter works. They thought that the function of a filter is to change the color of the transmitted light.

For the seeing color concept, the researcher let the students choose the answer and reason which best explained what happened when the students looked at a green object for a long time and then looked at a white wall and why. A total of 53.8 percent of the students had the scientific concept that they would see a purple wall because they had stared at the green object for a long time, and it made the green cone cells in the fovea of the eye unresponsive while the other cells responded (red and blue cone cells). A total of 46.2 percent of the students held a misconception because they could not choose the right answer and reason. They thought that they would see a green wall because the brain would recognize the color they had looked at the first time.

Optical Instruments

The concept of optical instruments can be divided into three sub concepts: telescopes, microscopes, and a comparison between a camera and the human eye. The percentages of Sara school students in each category of optical instrument before (pretest) and after (posttest) implementing the LLU is shown in Table 6.6.

Table 6.6 Percentages of Sara school students in each category of optical instruments before (pretest) and after (posttest) implementing the LLU

Optical Instrument Concepts	Test	Percentages of Students			
		Scientific Concept	**Partial Scientific Concept**	**Misconception**	**No Response**
Telescopes	Pre	0	0	96	4
	Post	30	0	70	0
Microscopes	Pre	0	0	96	4
	Post	30	0	62	8
A comparison between a camera and the human eye	Pre	0	0	96	4
	Post	50	0	50	0

For the telescope concept, the researcher let the students choose the answer and reason which best explained how a telescope works. Thirty percent of the students had a scientific concept because they chose the right answer and reason. They thought that the objective lens of the telescope made the real upside down image and then the eyepiece lens made the image bigger. Seventy percent of the students gave the wrong answer and reason about how a telescope works. They thought that the objective lens of a telescope makes a bigger image.

For the microscope concept, the researcher let the students choose the answer and reason which best explained how a microscope works. Thirty percent of the students held a scientific concept because they chose the right answer and reason. They thought that the image from a microscope is big and the position of the real image formed by the objective lens is less than the focal length of the eyepiece lens. Sixty two percent of the students gave the wrong answer and reason about how a microscope works. They thought that the image from the microscope is big and the position of the real image formed by the objective lens is more than two focal lengths of the eyepiece lens. Eight percent of the students did not respond to the question.

For the comparison between a camera and the human eye concept, the researcher let the students choose the answer and reason to a question about the difference between an image from a camera and an image from the human eye and why. Fifty percent of the students held a scientific concept because they chose the right answer and reason. They thought that both the image from a camera and from the human eye were the real images, and smaller than the actual object. Fifty percent of the students gave a wrong answer and reason about how a microscope works. They thought that there is a difference between the image from a camera and the image in the human eye. The image from the camera is the real image, and smaller than the actual object, but the image from the human eye is a virtual image and smaller than the actual object.

Seeing

The concept of seeing can be divided into three sub concepts: seeing the candle flame, the candle stick, and eye problems. The percentages of Sara school students in each category of seeing before (pretest) and after (posttest) implementing the LLU is shown in Table 6.7.

Table 6.7 Percentages of Sara school students in each category of seeing before (pretest) and after (posttest) implementing the LLU

Seeing Concepts	Test	Percentages of the Students			
		Scientific Concept	**Partial Scientific Concept**	**Misconception**	**No Response**
Seeing the candle flame	Pre	8	0	84	8
	Post	15.4	0	84.6	0
Seeing the candle stick	Pre	8	0	88	4
	Post	30	0	70	0
Eye problems	Pre	8	0	82	0
	Post	34.6	0	65.4	0

For the concept of seeing the candle flame, the researcher let the students choose the answer that explained how the students saw the candle flame in a dark room and asked them to draw a picture to represent it. Just 15.4 percent of the students held a scientific concept because they chose the right answer and reason to explain how the light from the candle flame traveled to their eyes. Eighty four percent of the students gave the wrong answer and reason about seeing the candle flame. They thought that the reflected light from the candle flame traveled to their eyes, the light from their eyes traveled to the candle flame, and the light from the candle flame traveled to their eyes and then to the candle flame again.

For the seeing the candle stick concept, the researcher let the students choose the answer that best explained how the students saw the candle stick in the dark room and asked them to draw a picture to represent it. Thirty percent of the students held a scientific concept because they chose the right answer and reason: the light from the candle flame shined to the candle stick and then reflected to the students' eyes. Seventy percent of the students gave the wrong answer and reason about seeing the candle stick. They thought that the reflected light from the candle stick traveled to their eyes, the light from the eyes traveled to the candle stick, and the light from the candle stick traveled to the students' eyes and then to the candle stick again.

For the eye problem concept, the researcher let the students choose the answer and reason that best explained what the eye problem was in a picture that was given to them. A total of 34.6 percent of the students held a scientific concept because they chose the right answer and reason. They thought that the given picture showed nearsightedness. When people become nearsighted, a diverging eyeglass lens is used to correct this condition. When the students put a diverging lens into the eyeglasses, the lens spread the light out before it got to the eye-lens. When the eye lens converged the light, the light converged at the back of the eye for proper focus. A total of 65.4 percent of the students gave a wrong answer and reason about the eye problem. They thought that the given picture showed nearsightedness. When the students put a diverging lens into the eyeglasses, this lens spread the light out before it got to the eye-lens, and when the eye lens converged the light, the light converged on the back of the eye for proper focus.

In conclusion, these findings indicate that most of Sompong's students were classified as having scientific conceptions of light. Students' understanding could result from the learning activities provided in the teaching unit. Sompong's students received opportunities to construct their learning through interaction with their peers. Sompong encouraged the students by asking many questions. He often used thoughtful, open-ended questions to stimulate the students. He also used a meaningful context to help students develop the concept in the real world. However, these findings also show that some students retained misconceptions. Some concepts appeared more difficult for students to understand, especially the curved mirror and lens, refraction of light, color, optical instruments, and seeing.

Three Focused Students' Conceptions about Light before (pretest) and after (posttest) Implementing the Light Learning Unit (LLU)

The three students' responses and explanations related to light concepts were divided into four categories and analyzed. The categories include scientific conception (SC), partial scientific conception (PSC), Misconception (MC), and No response (NR). The details of each student's conception of light are shown below.

Soraya's Conception of Light before (pretest) and after (posttest) Implementing the LLU

Table 6.8 shows Soraya's conception of light before (pretest) and after (posttest) implementing the LLU.

Table 6.8 Soraya's conception of light before (pretest) and after (posttest) implementing the LLU

Concepts of Light	Sub Concepts	The Pre-Instruction Conceptions	The Post-Instruction Conceptions
Nature of light	Travel of light	Light can travel until it is blocked by something.(SC)	Light can travel until it is blocked by something.(SC)
	Light source	Light from a luminous object travels only as far as it can illuminate the object	Light emanates from an object leaving each point of the light source and

Table 6.8 (Continued)

Concepts of Light	Sub Concepts	The Pre-Instruction Conceptions	The Post-Instruction Conceptions
Nature of light	Light source	area surrounding the luminous object.(MC)	propagates diverging in all spatial directions.(SC)
	Media of light	Light can totally pass through a transparent object and light can partially pass through a translucent object, but light cannot pass through an opaque object.(SC)	Light can totally pass through a transparent object and light can partially pass through a translucent object, but light cannot pass through an opaque object (SC)
The image formation	Image lies behind the mirror	The image of an object is on the mirrored surface.(MC)	The image lies behind the mirror and it is just as far behind the mirror as the actual object is in front of the mirror.(SC)
	Image is a left-right reversal	The image is a left-right reversal.(SC)	The image is a left-right reversal.(SC)
	Curve mirror 1	The image existed between the focal point (f) and 2f and the image would be the same size as the actual object.(MC)	The image existed between the focal point (f) and 2f and the image would be the same size as the actual object.(MC)
	Curve mirror 2	The focal length is 0.1 meters and they can tell that the curved mirror is a concave mirror.(SC)	The focal length is 0.03 meters and they can tell that the curved mirror is a convex mirror.(MC)
	Image formation by lens 1	The focal length is 0.09 meters and they can tell that the lens is a converging lens and the magnification of the lens is 1/3.(SC)	The focal length is 0.09 meters and they can tell that the lens is a converging lens and the magnification of the lens is 1/3.(SC)
	Image formation by lens 2	The image distance is 0.1 meters, and they can tell that the image is a real image and the magnification of the lens is 2.(MC)	The image distance is 0.05 meters and they can tell that the image is a real image and the magnification of the lens is 2.(MC)

Table 6.8 (Continued)

Concepts of Light	Sub Concepts	The Pre-Instruction Conceptions	The Post-Instruction Conceptions
The refraction of light	The refraction of light 1	The refracted ray that correctly expresses the refraction of light when light travels from oil into water bends toward the normal line. (MC)	The refracted ray that correctly expresses the refraction of light when light travels from oil into water bends away from the normal line. (SC)
	The refraction of light 2	The image of a fish is shallower than it should be because the speed of light through the water is slower than the speed of light through the air. (SC)	The image of a fish is shallower than it should be because the speed of light through the water is slower than the speed of light through the air. (SC)
	The refraction of a prism	Purple is the least refracted and the red is the most refracted. (MC)	Purple is the most refracted and red is the least refracted and the spectrum of a rainbow made by a prism is continuous and each color has its own exact boundary. (PSC)
	Refraction when an incident light ray travels perpendicular to two media	The refraction of light does not occur but the light will reflect to the opposite. (MC)	The refraction of light does not occur but the light will reflect to the opposite. (MC)
Color	Color in white light	The color of an object is a physical property of that object. (MC)	When someone sees black color, light from the object doesn't reflect to his/ her eyes and when someone sees white color, the light rays from the object reflects all of it to his/her eyes. (SC)
	Colored object in colored light	No response (NR)	The students would see themselves wearing striped T-shirts with green and black stripes and green caps in the green spotlight. (SC)

Table 6.8 (Continued)

Concepts of Light	Sub Concepts	The Pre-Instruction Conceptions	The Post-Instruction Conceptions
Color	Color using a filter	The function of a filter is to change the color of the transmitted light. (MC)	The color of an object is the color of the light that is reflected by that object. (SC)
	Seeing color	The students would see a green wall because the brain would recognize the color they had looked at the first time. (MC)	The students would see the green wall because the brain would recognize the color they had looked at the first time. (MC)
Optical Instrument	Telescope	The objective lens of the telescope makes a bigger image. (MC)	The objective lens of the telescope makes the real upside down image and the eyepiece lens makes the image bigger. (SC)
	Microscope	The image from a microscope is big and the position of a real image formed by the objective lens is less than two focal lengths of the eyepiece lens. (SC)	The image from a microscope is big and the position of a real image formed by the objective lens is less than two focal lengths of the eyepiece lens. (SC)
	A comparison between a camera and the human eye	The image from a camera is the real image and is smaller than the actual object, but the image from a human eye is the virtual image and smaller than the actual object. (MC)	Both the image from a camera and from the human eye are real images, and smaller than the actual object. (SC)
Seeing	Seeing the candle flame	The reflected light from the candle flame travels to the students' eyes. (MC)	The light from the candle flame travels to students' eyes. (SC)
	Seeing the candle stick	The light from the candle stick travels to the students' eyes. (MC)	The light from the candle flame shines on the candle stick and then is reflected to the students' eyes. (SC)

Table 6.8 (Continued)

Concepts of Light	Sub Concepts	The Pre-Instruction Conceptions	The Post-Instruction Conceptions
Seeing	The eye problem	The given picture is nearsightedness. When the students put a converging lens into the eyeglasses, this lens spreads the light out before it gets to the eye-lens, and when the eye-lens converges the light, the light will converge on the back of the eye for proper focus. (MC)	The given picture is nearsightedness. When the students put a converging lens into the eyeglasses, this lens spreads the light out before it gets to the eye-lens, and when the eye-lens converges the light, the light will converge on the back of the eye for proper focus. (MC)

While Soraya showed evidence of holding a misconception of light in the pre-instruction phase for several concepts, she did have a scientific conception of the nature of light (travel of light and media of light), image formation by a plane, curved mirror, and lens (image is a left-right reversal, convex mirror, image formation by a lens), the refraction of light, and the optical instrument (microscope). After the instruction, many of Soraya's pre-instruction misconceptions were no longer apparent. Soraya’s conception changed from misconceptions to scientific conceptions regarding the concept of the nature of light (light source), image formation by plane, curved mirror, and lens (the image formation by plan mirror lies behind the mirror), the refraction of light, color (color in white light, color using a filter), optical instrument (telescope, the comparison between a camera and the human eye), seeing (seeing the candle flame and seeing the candle stick). This was supported by Soraya’s worksheet that showed her understanding about the image formation by a plane mirror. She wrote that “the image by a plane mirror is behind the mirror and the distances of object and image are the same.” However, as Table 6.8 shows, Soraya still had misconceptions about some sub concepts of the nature of light.

Dongdao's Conception of Light before and after the Implementation

Table 6.9 shows Dongdao's conception of light before and after implementing the LLU.

Table 6.9 Dongdao's conception of light before and after implementing the LLU

Concepts of Light	Sub Concepts	The Pre-Instruction Conceptions	The Post-Instruction Conceptions
Nature of light	Travel of light	Light only travel as far as it is visible. (MC)	Light can travel until it is blocked by something.(SC)
	Light source	Light from a luminous object travels only as far as it can illuminate the area surrounding the luminous object.(MC)	Light emanates from each point of the light source and propagates, diverging in all spatial directions.(SC)
	Media of light	Light can totally pass through a transparent object, and light can partially pass through a translucent object, but light cannot pass through an opaque object. (SC)	Light can totally pass through a transparent object, and light can partially pass through a translucent object, but light cannot pass through an opaque object. (SC)
The image formation	Image lies behind the mirror	The image of an object is on the mirror surface.(MC)	The image lies behind the mirror and it is just as far behind the mirror as the actual object is in front of the mirror.(SC)
	Image is a left-right reversal	The image of an object was exactly the same as the actual object. (MC)	The image is a left-right reversal.(SC)
	Curve mirror 1	The image existed between the focal point (f) and 2f and the image would be the same size as the actual object.(MC)	The image existed between the focal point (f) and 2f and the image would be the same size as the actual object.(MC)

Table 6.9 (Continued)

Concepts of Light	Sub Concepts	The Pre-Instruction Conceptions	The Post-Instruction Conceptions
The image formation	Curved mirror 2	The focal length is 0.1 meter and they identify the curved mirror as a concave mirror.(SC)	The focal length is 0.03 meters and they identify the curved mirror as a convex mirror.(MC)
	Image formation by a lens 1	No response (NR)	The focal length is 0.09 meters and they state that the lens is a converging lens and the magnification of the lens is 1/3.(SC)
	Image formation by a lens 2	No response (NR)	The image distance is 0.05 meters and they state that the image is a real image and the magnification of the lens is 2.(MC)
The refraction of light	The refraction of light 1	The refracted ray that correctly expresses the refraction of light when light travels from oil into water bends toward the normal line. (MC)	The refracted ray that correctly expresses the refraction of light when light travels from oil into water bends toward the normal line. (MC)
	The refraction of light 2	The image of a fish is deeper than it should be because the speed of light through the water is faster than the speed of light through the air. (MC)	The image of a fish is shallower than it should be because the speed of light through the water is slower than the speed of light through the air. (SC)
	The refraction of a prism	Purple is the least refracted and red is the most refracted. (MC)	Purple is most refracted and red is the least refracted and the spectrum of a rainbow made by a prism is continuous and each color has its own exact boundary. (PSC)

Table 6.9 (Continued)

Concepts of Light	Sub Concepts	The Pre-Instruction Conceptions	The Post-Instruction Conceptions
The refraction of light	Refraction when the incident light ray travels perpendicular to two media	The refraction of light does not occur because front waves of the incident light travel to the medium at the same time. (SC)	The refraction of light does not occur, but the light will reflect to the opposite direction. (MC)
Color	Color in white light	The color of an object is a physical property of that object. (MC)	Black is the least refracted and white is the most reflected. (MC)
	Color object in color light	The students see themselves wearing striped T-shirts with green and yellow stripes and a green cap using a green spotlight. (MC)	The students would see themselves wearing striped T-shirts with green and yellow stripes and a green cap using a green spotlight. (MC)
	Color by the filter	The filter reflects the color red to the eyes. (MC)	The color of an object is the color of the light that is reflected by that object. (SC)
	Seeing color	The students see a purple wall because the students saw a green object for a long time, and it made the green cone cells in the fovea of the eye not responsive while the red and blue cone cells responded. (SC)	The students would see a purple wall because the students saw a green object for a long time, it made the green cone cells in fovea of the eye not responsive while the red and blue cone cells responded. (SC)
Optical Instruments	Telescope	The objective lens of the telescope makes a bigger image. (MC)	The objective lens of the telescope makes a real upside down image and then the eyepiece lens makes the image bigger. (SC)

Table 6.9 (Continued)

Concepts of Light	Sub Concepts	The Pre-Instruction Conceptions	The Post-Instruction Conceptions
Optical Instruments	Microscopes	The image from a microscope is big and the position of the real image formed by the objective lens is less than two focal lengths of the eyepiece lens. (SC)	The image from the microscope is big and the position of the real image formed by the objective lens is less than two focal lengths of the eyepiece lens. (SC)
	A comparison between a camera and the human eye	The image from the camera is a real image and smaller than the actual object, but the image from the human eye is a virtual image and smaller than the actual object. (MC)	The image from the camera is a real image and smaller than the actual object. The image from the human eye is a virtual image and is the same the size as the actual object. (MC)
Seeing	Seeing the candle flame	The reflected light from the candle flame travels to the students' eyes. (MC)	The reflected light from the candle flame travels to the students' eyes. (MC)
	Seeing the candle stick	The light from the candle flame shines to the candle stick and then reflects to the students' eyes. (SC)	The light from the candle stick travels to the students' eyes. (MC)
	The eye problem	The given picture showed near-sightedness. When the students put a converging lens into the eyeglasses, this lens spread the light out before it got to the eye-lens, and when the eye-lens converged the light, the light converged on the back of the eye for proper focus. (MC)	The given picture showed nearsightedness. When the students put a converging lens into the eyeglasses, this lens spread the light out before it got to the eye-lens, and when the eye-lens converged the light, the light converged on the back of the eye for proper focus. (MC)

Dongdao showed evidence of holding pre-instruction misconceptions about several concepts concerning light. For example, the nature of light (travel of light, light source), image formation by a plane mirror, curved mirror and lens (image formation by a plane mirror lies behind the mirror, image is a left-right reversal, concave mirror), the refraction of light (the refraction of light 1, the refraction of light 2, the refraction of a prism), color (color in white light, a colored object in colored light, color using a filter), optical instruments (telescopes and a comparison between the camera and the human eye), and seeing (seeing a candle flame, the eye problem).

Throughout the implementation phase of the study, Dongdao's conceptions changed from misconceptions to scientific conceptions regarding the concepts of the nature of light (travel of light and light source), image formation by a plane mirror, curved mirror and lens (image formation by a plane mirror lies behind the mirror, image is a left-right reversal, and image formation by lens 1, the refraction of light (the refraction of light 2 and refraction using a prism), color (color using a filter), and optical instruments (telescope). This was supported by Dongdao's worksheet that showed her understanding about the image formation by a plane mirror. She wrote that "the image by a plane mirror is a left-right reversal."

Pakphum's Conception of Light before and after the Implementation

Table 6.10 shows Pakphum's conception of light before and after implementing the LLU.

Table 6.10 Pakphum's conception of light before and after implementing the LLU

Concepts of Light	Sub Concepts	The Pre-Instruction Conceptions	The Post-Instruction Conceptions
Nature of light	Travel of light	Light travels until it is blocked by something.(SC)	Light travels until it is out of energy. (MC)

Table 6.10 (Continued)

Concepts of Light	Sub Concepts	The Pre-Instruction Conceptions	The Post-Instruction Conceptions
Nature of light	Light source	Light from a luminous object travels only as far as it illuminates the area surrounding the luminous object.(MC)	Light emanates from each point of the light source and propagates, diverging in all spatial directions.(SC)
	Media of light	Light can pass through both transparent and translucent objects, but there is no difference between transparent and translucent objects. (PSC)	Light can totally pass through transparent objects and light can partially pass through translucent objects, but light cannot pass through opaque objects(SC)
The image formation	Image lies behind the mirror	The image of an object is on the mirror surface.(MC)	The image lies behind the mirror and it is just as far behind the mirror as the actual object is in front of the mirror.(SC)
	Image is a left-right reversal	The image is a left-right reversal.(SC)	The image is a left-right reversal.(SC)
	Curved mirror 1	The image existed between the focal point (f) and 2f and the image is the same size as the actual object.(MC)	The image existed between the focal point (f) and 2f and the image is the same size as the actual object.(MC)
	Curved mirror 2	The focal length is 0.1 meters and students identify the curved mirror as a concave mirror.(SC)	The focal length is 0.03 meter and students can identify the curved mirror as a convex mirror.(MC)
	Image formation by lens 1	The focal length is 0.09 meters and students can tell that the lens is a converging lens and the magnification of the lens is 1/3.(SC)	The focal length is 0.09 meters and students can tell that the lens is a converging lens and the magnification of the lens is 1/3.(SC)

Table 6.10 (Continued)

Concepts of Light	Sub Concepts	The Pre-Instruction Conceptions	The Post-Instruction Conceptions
Image formation	Image formation by a lens 2	The image distance is 0.05 meters and students can tell that the image is a real image and the magnification of the lens is 2.(MC)	The image distance is 0.05 meters and students can tell that the image is a real image and the magnification of the lens is 2.(MC)
The refraction of light	The refraction of light 1	The refracted ray that correctly expresses the refraction of light when light travels from oil into water bends toward the normal line. (MC)	The refracted ray that correctly expresses the refraction of light when light travels from oil into water bends away from the normal line. (SC)
	The refraction of light 2	The image of a fish is shallower than it should be because the speed of light through the water is slower than the speed of light through the air. (SC)	The image of a fish is shallower than it should be because the speed of light through the water is slower than the speed of light through the air. (SC)
	Refraction from a prism	Purple is the least refracted color and red is the most refracted color. (MC)	Purple is most refracted color and red is the least refracted color. The spectrum of a rainbow made by a prism is continuous and each color has its own exact boundary. (PSC)
	Refraction when an incident light ray travels perpendicular to two media	Refraction of light does not occur but the light will reflect in the opposite direction. (MC)	Refraction of light does not occur, but the light will reflect in the opposite direction. (MC)
Color	Color in white light	The color of an object is a physical property of that object. (MC)	When someone sees the color black, light from the object does not reflect to his/ her eyes, and when someone sees white the light rays from the object reflect all of the light to his/her eyes.(SC)

Table 6.10 (Continued)

Concepts of Light	Sub Concepts	The Pre-Instruction Conceptions	The Post-Instruction Conceptions
Color	Colored object in colored light	No response (NR)	The students see themselves wearing a T-shirt with green and black stripes and a green cap under the green spotlight. (SC)
	Color using a filter	The function of a filter is to change the color of the transmitted light. (MC)	The color of an object is the color of the light that is reflected by that object. (SC)
	Seeing color	The students see a green wall because the brain would recognize the color they looked at the first time. (MC)	The students see a green wall because the brain would recognize the color they looked at the first time. (MC)
Optical Instrument	Telescope	The objective lens of a telescope makes a bigger image. (MC)	The objective lens of a telescope makes the real upside down image and then the eyepiece lens makes the image bigger. (SC)
	Microscope	The image from a microscope is big and the position of the real image formed by the objective lens is less than two focal lengths of the eyepiece lens. (SC)	The image from a microscope is big and the position of the real image formed by the objective lens is less than two focal lengths of the eyepiece lens. (SC)
	A comparison between a camera and the human eye	The image from the camera is the real image and smaller than the actual object, but the image from the human eyes is a virtual image and smaller than the actual object. (MC)	Both the image from a camera and the human eye are real images, and smaller than the actual object. (SC)

Table 6.10 (Continued)

Concepts of Light	Sub Concepts	The Pre-Instruction Conceptions	The Post-Instruction Conceptions
	Seeing the candle flame	The reflected light from the candle flame travels to the students' eyes. (MC)	The light from the candle flame travels to the students' eyes. (SC)
	Seeing the candle stick	The light from the candle stick travels to the students' eyes. (MC)	The light from the candle flame shines on the candle stick and then reflects to the students' eyes. (SC)
Seeing	The eye problem	The picture illustrates nearsightedness. When the students put a converging lens into the eyeglasses, the lens spreads the light out before it gets to the eye-lens, and when the eye-lens converges the light, the light converges on the back of the eye for proper focus. (MC)	The picture illustrates nearsightedness. When the students put a converging lens into the eyeglasses, the lens spreads the light out before it gets to the eye-lens, and when the eye-lens converges the light, the light will now converge on the back of the eye for proper focus. (MC)

Before teaching the concepts of light, Pakphum showed evidence of holding misconceptions regarding several concepts, except for the concept of the nature of light (travel of light), image formation by plane, curved mirror (image is a left-right reversal, convex mirror, and image formation by lens 1), the refraction of light (the refraction of light 2), and optical instruments (microscope).

Many of the pre-instructional misconceptions were no longer apparent and they became scientific conceptions. This was supported by Pakphum's worksheet that showed his understanding about the refraction of light. He wrote that "the refraction of light when light travels from oil into water bends away from the normal line because the speed of light in water is less than that in water.” However, Pakphum still retained some misconceptions.

In conclusion, students showed scientific conceptions about light in all six concepts: the nature of light, image formation by a plane mirror and lens, curved mirrors, refraction of light, optical instruments, color, and seeing. These findings imply that the implementation the Light Learning Unit (LLU) enhanced students’ scientific understanding of the concepts of light.

Summary of Sompong’s Case

Sompong taught the concepts of light following the teacher manual of the Light Learning Unit (LLU). He attempted to follow the teacher manual step by step. He used various kinds of teaching strategies in his teaching practice. For example, he focused on students’ prior knowledge, used a meaningful context to help students to understand the concepts in the real world, encouraged students by asking thoughtful, open-ended questions, gave the students an opportunity to construct their learning through interaction with their peers, and focused on the students’ cooperative work.

He employed many assessment strategies. He thought that the unit was useful for his students. His students were encouraged by asking questions. They learned by doing hands-on and mind-on activities. Moreover, they had opportunities to share their ideas with their teacher and peers in their group. Consequently, students’ conceptions were improved. Most of the students had scientific conceptions on the concept of light. Many of the misconceptions were no longer apparent. Nevertheless, some students showed misconceptions regarding the concept of light. However, Sompong could not finish the last three lessons of the unit because of time constraints. To solve this problem, he provided more time for these lessons and gave a lecture to summarize the content, but skipped the activity.

Case II: Pattana School

School Context

The school was established in 1941 at a suburban site in Bangkok. It is close to Phatumtani Province. It is a large school with 1,507 students and thirty-seven classrooms. The school is near the community and also near the community temple. The school has a kindergarten, primary, and secondary classrooms. There were four kindergarten classrooms with 40-45 students per class. In grades 1-4, each grade has four classrooms with 40-45 students per class. In grades 5-6, each grade has 4 classrooms with 40-45 students per class. In Grades 7-9, each grade has three classrooms with 45-50 students per class. One class consists of students with high abilities, and the others were made up of students with mixed abilities. The teaching day begins at 8.30 a.m. and finishes at 3.30 p.m. At the lower secondary level, there are seven periods a day and each period is 60 minutes long. The students have a science class for three hours a week. One semester consists of eighteen weeks including seventeen weeks for teaching and one week for final examinations.

Teacher’s Background

Pranee was a female lower secondary school teacher. In the last two years, she taught primary school, but now she teaches eighth grade. She had fifteen years of science teaching experience, and two years of experience teaching the concept of light to eighth grade students. She taught eighth grade science and health science. She had a teaching workload of sixteen hours per week. She also was a classroom teacher and school activity teacher. She was 40 years old. She had a bachelor’s degree in education and her major was biology. She had never participated in any workshop on the concept of light or taught the concept of light. She admitted that she had no confidence teaching the concept of light. Sometimes, she eliminated some concept of light topics from her teaching including curved mirrors, calculations about image formation including focus and the distance of an image, and the drawing of a ray diagram from both mirrors and lenses. Sometimes, she invited other teachers to teach specialized, intensive concepts to her students. Pranee usually has her students write a report before they learn a concept. Then, she lets her students do an experiment and asks them to find similarities and differences between the report and the results from the experiment. Additionally, she usually blames her students when they express the wrong answer. Therefore, some of her students seem quiet and sometimes they are afraid to answer. Most of the time, she did not wait for the students' answer, but answered the questions by herself. Pranee loved attending the workshop. When the researcher asked her to participate in the study, she agreed to join the study immediately.

Students' Background

The students were from one grade eight classroom. There were forty-six students in this class with twelve boys and thirty-four girls. Their ages were between thirteen and fourteen years old. Most of them came from low and medium socioeconomic families. Seventeen students achieved moderate GPAs of 2.0. Fourteen students had high GPAs of 3.5, and twelve students had GPAs of 3.0. However, there were only four students who achieved the highest GPA of 4.0. The students loved to do experiments. When they were doing experiments, they looked happy. This study focuses on three students who were selected to be studied in depth concerning the development of their understanding of the concept of light. The selection was based on a student's personality in terms of his or her talkativeness. Pseudonyms were used to represent the students' names: Pimpa, Pasinee, and Apirom. The details of these students are described below.

Pimpa

Pimpa was a fourteen year old girl. Her mother and father owned a small business. Pimpa liked to study science and learn science. Her science achievement score was 4.0.

Pasinee

Pasinee was a thirteen year old girl. Her mother and father were laborers. She did not like science because she thought that science was hard to understand. Her science learning achievement score was 2.0.

Apirom

Apirom was a fourteen year old girl. Her mother and her father were laborers. She liked science because she loved to do experiments. Her science learning achievement score was 3.0.

Classroom Setting

Pranee's classroom was a normal classroom. When the researcher looked at the classroom, it was crowded with tables and chairs. Her classroom was next to the laboratory, but she could not do experiments in the laboratory because the laboratory was not available. Pranee taught in a science laboratory with insufficient equipment and materials, especially equipment and material necessary for studying the concept of light including lenses, prisms, and optical instruments. There was some equipment, but it was broken or could not be used at all. Sometimes, the equipment and materials were not available because they were being used by other teachers. In the classroom, there were seven student's tables. Each table consisted of six desks. There was also one table for the teacher. Pranee's classroom setting is shown in Figure 6.2.

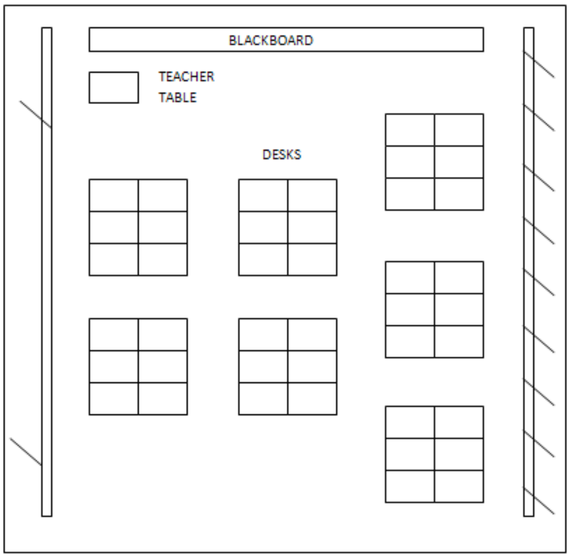


Figure 6.2 Pranee's classroom setting

Research Questions 3: How and to What Degree Are Thai Science Teachers Able to Implement Light Learning Unit (LLU)?

To answer this research question, Pranee's teaching practice, including teaching strategies, and assessment strategies, is described. Moreover, the problems that she faced during the implementation of the unit and the perception of Pranee and her students about the unit implementation were investigated. In-depth information on the process of Pranee's implementation of the LLU is discussed below.

Pranee's Teaching Practice: Pranee still Played the Role of a Teller.

Pranee was not worried about implementing the LLU. In the first week, she skipped asking suggested questions to assess students' prior knowledge and skipped an explanation to the students about how to do the activity. She started the lesson by letting students do the activity. She let her students read the instructions themselves. She let her students work on the activity and then she asked her students to present the results. She usually told the students the conclusion of the experiment or activity. However, in the following weeks, she seemed to follow the teacher manual more often. She started to use all of the suggested questions to determine the students' prior knowledge, but she still did not explain to the students how to do an experiment or activity. The details of Pranee's teaching practices are discussed in terms of her teaching and assessment strategies below.

Pranee's Teaching Strategies

Pranee often implemented the unit following the teacher manual, but she sometimes skipped asking suggested questions to assess students' prior knowledge. She often asked the students yes-no questions. She also had some problems with some concepts because she was unclear about the concepts and the activities. Even though her teaching strategies focused on cooperative group work and she prepared hands-on activities that allowed students to think and discuss their work with their peers in small groups, she never explained the procedure of the experiment to her students. She often told the students the conclusions of the experiment or activities more often than she asked them to figure out the conclusions on their own in their groups. Pranee's teaching strategies are presented below.

Pranee Asked for Her Students' Prior Knowledge, but She Did Not Ask for More Detail or Give Time for Discussion.

During the first week of the implementation, Pranee started the lesson by letting the students do an activity to elicit the students' prior knowledge, but she skipped all probing questions and discussion as suggested in the lesson plan. This was observed during classroom observation. In lesson one, the Nature of Light, the students were asked to construct a concept map about the nature of light. Before doing the activity, Pranee did not explain how to do the activity. She let her students read the instructions by themselves. During student group work, she gave her students time to discuss and share ideas to construct a concept map from their own understanding. Then the concept maps from each group wear presented to the whole class. During the presentation, one student in each group described his/her understanding of light from the concept map the group had constructed. After the students' presentation, Pranee asked the students, “Light travels in a straight line, doesn’t it? and “You can prove it in the next activity”. In the following week, she started to use all of the suggested questions to determine the students’ prior knowledge. For example, in lesson four, the refraction of light, Pranee started the by letting the students in each group observe a pen in a glass filled with water. She asked one student from each group to describe and share what they had seen. She then asked the students to do an experiment to check their understanding.

Pranee Rarely Used a Meaningful Context to Help Students Understand the Concept in the Real World.

When Pranee taught lesson four, the refraction of light, she started the lesson by letting the students in each group observe a pen in a glass filled with water. She asked one student from each group to describe and share what they had seen. She just waited for the students’ answers. When the students answered, she asked the next question. She rarely helped the students to develop the concept or encouraged the students to relate the concept to a real life situation. When students in each group cooperatively did an experiment about the refraction of light, Pranee rarely walked around from group to group to help her students.

Pranee Usually Asked Students Simple or Yes / No Questions.

During the first week of the implementation, Pranee skipped questions and classroom discussion as suggested in the lesson plans. In the next lesson, she asked the students questions and the students answered. Then she moved to other questions without talking or asking the reasons behind the students’ answers. The students gave responses students and Pranee did not ask the students about the main concepts. This was evidenced by classroom observations. In lesson four, the refraction of light, Pranee let the students in each group observe a pen in a glass filled with water. She asked one student from each group to describe and share what they had seen. The following dialogue illustrates how Pranee used questions while students were studying the refraction of light.

Pranee:	Student 1, describe this pen in a glass filled with water.
Student 1:	It looks bigger.
Pranee:	Is that right, student 2? Explain.
Student 2:	It looks broken.
Pranee:	How about you, student 3?
Student 3:	It's looks bigger.
Pranee:	How about you, student 4?
Student 4:	It looks broken.
Pranee:	Does anyone see anything different?
Students:	No.
Pranee:	What are phenomena that are related to this activity and appear in your daily lives?
Students:	A swimming pool (speak quietly)
Pranee:	Write in your notebook.
Pranee:	Ok, a representative from each group needs to draw a ray diagram on the blackboard.

As seen in this dialogue, Pranee elicited responses from her students. She pointed at one student and asked for an answer to her questions. She did not give the student time to discuss the topic before answering the questions. More importantly, she did not ask her students about the cause of the situation, called the refraction of light, which occurs because light travels from one media to the other media.

Moreover, she sometimes used yes / no questions and she did not wait for the students to answer. When the students did not respond to her questions, she did not repeat, rephrase, or add more questions. For example, during a discussion of the concept of the refraction of light, she asked the students about the direction of a refracted ray. Pranee asked, "Is the light bending toward or away from the normal line? "Is it caused by the light traveling through different media?" She also used leading questions as illustrated in the dialogue below.

Pranee:	Do you remember what happens when light travels from one medium to another?
Students:	Refraction.
Pranee:	As you were doing the experiment, what did the refracted ray express about the refraction of light when light travels from air into plastic? Was it bending toward the normal line?
Students:	Yes.
Pranee:	And what happens when light travels from plastic into air?
Students:	It is bending away from the normal line.

Pranee Gave the Students an Opportunity to Construct Their Learning Through Interaction with Their Peers.

Pranee asked the students to do an experiment about multiple reflections from two plane mirrors. Pranee distributed two plane mirrors and an object to each group of students. This experiment was used to determine the relationship between the number of images formed by two plane mirrors and the value of the angle between these two mirrors. Pranee did not explain how to do the activity. She asked the students to read the directions on the worksheet themselves. In group work, the students observed images formed by two plane mirrors with different angles between the two mirrors. To do the worksheet, the students in each group had the opportunity to interact with each other. After doing the experiment, the students helped each other to answer the questions. The results of the activity in each group were presented and Pranee told the students the right answers and conclusions about multiple reflections from two plane mirrors. In following weeks, Pranee's students were still active learners because she gave them the opportunity to construct their own knowledge through active learning.

Pranee Focused on the Students' Cooperative Work.

Pranee divided the students into groups of mixed ability and mixed gender with six to seven students in each group. She explained the role and responsibility of each student in the group: a collector, a reporter, a presenter, and a supporter. She didn't always explain how to do the activity. She let the students read the instructions by themselves. In all activities, even though Pranee gave the students time to discuss and share ideas, Pranee rarely walked around from group to group to help her students. At the end of lesson, she asked the students "Are you done?" then she asked her students to present the results of the experiment. After that, Pranee asked the students to make a conclusion. If the students could not make a conclusion themselves, she told them the conclusion.

Assessment Strategies

Pranee employed many strategies to assess the students' learning outcomes throughout the implementation of the unit. Students often presented their work to the whole class. Before the presentation, she asked the students to score each presentation group. Pranee collected and marked student worksheets regularly and returned the documents to students. However, she did not discuss their work with the class as a whole. Pranee emphasized participation in the classroom and scores on tests. At the end of some lessons, she used peer assessment techniques to grade students' experiments as suggested by the LLU.

Pranee's Teaching Problems

Time Constraints

Pranee said that there were many activities in the Light Learning Unit (LLU). This was one of the obstacles to finishing all of the lessons on time. She thought that there were too many students in her classroom and that it was hard to manage her students. She usually skipped some activities and some student presentations. She did not teach lesson 8 to the students because she thought that she had taught it before.

She skipped some activities and student presentations because she was afraid that she would not finish all of the lessons on time. There were many days off which shortened the teaching time and there were many school activities. For example, the students had to attend the school sport competition day and had to parade to ban drugs and parade to raise AIDS awareness. Moreover, they had to take two days off to complete the National Test and before taking the National Test, they had to prepare for the test for one week.

Teachers' Difficulties with Content Knowledge

Pranee had difficulties teaching some concepts. During the discussion of the concepts of reflection of light, Pranee was not aware of using misconceptions in her explanations of the reflection of light. She used the wrong explanations to the students as shown in the following dialogue.

Pranee:	How do you see yourself in the silver shiny paper? Is it the same as you see in a plane mirror?
Students:	It's different.
Pranee:	Your image seems blurred, right? Why? Is it the paper?
Students:	Yes.
Pranee:	Why is the paper different from a plane mirror?
Students:	(Silent)
Pranee:	It is because there is less incident light.

Pranee did not understand the refraction of light. She told the students that the activity is about refraction when light travels from air to water. Then, she asked students whether a ray diagram of the refraction of light is different when light travels from water to air. She asked the students to observe a pen in a glass filled with water from the bottom. Some students answered there was a difference and some groups answered that there was no difference. She gave the students time to observe the pen in a glass filled with water. Then, she let a representative from each group draw a ray diagram on the blackboard in front of the class.

In addition, Pranee was not aware of using incorrect terms to ask or explain concepts to her students. For example, when discussing image formation from a plane mirror, she and her students used the word "shadow" to refer to "the image or reflection". For example, "Have you ever looked at yourself in a plane mirror? Do you see your shadow in the mirror? How do you describe what you see?"

Pranee's Perception of Teaching

Pranee noticed that the students were happy when they were doing some activities in the LLU unit including the nature of light, curved mirrors and lenses, and color. Students paid more attention when doing the activities. Pranee said that the students understood more while they were learning and Pranee herself found it easy to teach.

Students' Perception on Pranee's Teaching

The students loved to learn and gained more knowledge when they were in the class. One student said,

> When the teacher taught, I felt it was easy to understand and gained more knowledge about light such as reflection of light, refraction of light, image formation from mirror and lens, color, and the rainbow. From those topics, I loved to learn the concept of color because the teacher took me to the computer room and taught me about color using a simulation. I will use the knowledge for higher level study and in my real life. (Pimpa, Student reflection, February, 2006)

In Summary, Pranee followed some activities in the LLU. She tended to be teacher-centered because she did not give the students a chance to discuss. She usually asked the students for an answer, but then she moved on to other questions without talking or asking the reason behind the students' answers. In addition, she usually asked students yes / no or plain questions. She hardly ever allowed students to present their reports, because there was not enough time in class and she usually made a conclusion of the experiment by herself if the students could not make the conclusion themselves. When students in groups cooperatively did the experiment about the refraction of light, she rarely walked around from group to group to help her students and she never explained the procedure for the experiment to her students at all. She often told the students the conclusions of the experiments or activities rather than asking them to figure out the conclusions on their own or in groups. She had many ways to assess the students' learning during the implementation of the unit. She had difficulties with content knowledge regarding reflection and refraction of light. In spite of these problems, Pranee and her students enjoyed teaching and learning the concept of light using the LLU.

Research Questions 4: How Does the Implementation the Light Learning Unit (LLU) Enhance Students' Scientific Understanding of Concept about Light?

To answer this research question, this section presents the percentage of students having a scientific concept, a partial scientific concept, a misconception, and no response to the concept of light from the Light Concept Test (LCT) before and after implementing the LLU. Then this section presents the conceptions of three students before and after the implementation of the LLU.

The Students' Conception of the Concept of Light

Students were asked to complete a light concept test (LCT) after the implementation of the LLU. The LCT was like the light diagnostic test (LDT), divided into six concepts: the nature of light, image formation by a plane mirror and lens, curved mirrors, the refraction of light, optical instruments, color, and seeing. The students' responses and explanations related to light concepts were analyzed and divided into four categories: scientific conception (SC), partial scientific conception (PSC), misconception (MC), and no response (NR). The table shows the percentage of students choosing scientific conception, partial scientific conception, misconception, and no response to the concept of light from the Light Concept Test (LCT) before (pretest) and after (posttest) implementing the LLU.

Nature of Light

The Nature of Light can be divided into three sub concepts: the travel of light, light sources, and media of light. The percentages of Pattana school students in each category of nature of light before (pretest) and after (posttest) implementing the LLU is shown in Table 6.11.

Table 6.11 Percentages of Pattana school students in each category of nature of light before (pretest) and after (posttest) implementing the LLU

Nature of Light Concepts	Test	Percentages of the Students			
		Scientific Concept	Partial Scientific Concept	Misconception	No Response
Travel of light	Pre	33	0	62	5
	Post	82	0	15	3
Light source	Pre	0	0	94	6
	Post	5	0	90	5
Media of light	Pre	6	94	0	0
	Post	65	23	12	0

For the travel of light concept, the researcher let the students choose the sentence which best explained how far light goes and why. There is an increase in the percentage of scientific conceptions in this concept. The percentage of scientific conceptions increases from 33 percent in the pretest to 82 percent in the posttest. However, 15 percent of the students still held misconceptions, that light only travels as far as it is visible, light travels as far as it is possible, and light travels until it is out of energy, after the LLU implementation.

For the light source concept, the percentage of scientific conceptions increases from 0 percent in the pretest to 5 percent in the posttest. The students had scientific conceptions: that light emanates leaving each point of the light source and propagates, diverging in all spatial directions. However, after the LLU implementation, most of the students, 90 %, still held some misconceptions: that light is an entity which is located in space (region around the light source), light from a luminous object travels only as far as it can illuminate the area surrounding the luminous object, light fades with distance from the source, light goes out only in a radial direction, or each point on a luminous object emits light in one direction.

Regarding the media of light concept, the researcher gave the students three media, which showed the amount of light that could pass through each one, to students to classify, asking them which one was transparent, translucent, or opaque. The percentage of scientific conceptions increased from 6 percent in the pretest to 65 percent in the posttest. The students had scientific conceptions because they called objects that can block light opaque objects, they called an object transparent if light totally passed through it, and they called an object translucent if light partially passed through it. Only 12 percent of the students held misconceptions because they thought that light can pass partially through an opaque object. A total of 23 percent of the students held a partial scientific conception because they thought that light could pass through both transparent and translucent objects, but that there was no difference between transparent and translucent objects.

Image Formation

The concept of image formation can be divided into three sub concepts: image formation by a plane mirror, a curved mirror, and a lens. The percentages of Pattana school students in each category of image formation before (pretest) and after (posttest) implementing the LLU is shown in Table 6.12.

Table 6.12 Percentages of Pattana school students in each category of image formation before (pretest) and after (posttest) implementing the LLU

Image Formation Concepts	Test	Percentages of the Students			
		Scientific Concept	Partial Scientific Concept	Misconception	No Response
Image formation by a plane mirror lies behind the mirror	Pre	3	0	80	17
	Post	23	0	71	6
Image is a left-right reversal	Pre	7	0	89	4
	Post	63	0	34	3
Concave mirror	Pre	42	0	26	32
	Post	28	0	70	12
Convex mirror	Pre	28	0	39	33
	Post	23	0	71	6
Image formation by a lens 1	Pre	32	0	14	54
	Post	28	0	63	9
Image formation by a lens 2	Pre	27	0	23	50
	Post	40	0	48	12

Regarding the image formation by a plane mirror concept, there is an increase in the percentage of scientific conceptions in this concept. The percentage of scientific conceptions increased from 3 percent in the pretest to 23 percent in posttest. The students held the scientific conception that the image lay behind the mirror and it is just as far behind the mirror as the actual object is in front of the mirror. A total of 71 percent of the students held a misconception because they thought that an object has its image behind the surface of the mirror in a position that is in front of the observer.

The other question about the image formation by a plane mirror is a left-right reversal. There was an increase in the percentage of scientific conceptions in this concept, from 7 percent in the pretest to 63 percent in the posttest. A total of 34 percent of the students held misconceptions because they thought that an object has its image behind the surface of the mirror in a position that is in front of the observer. Only 3 percent of the students did not respond to the question.

Regarding the image formation by curved mirror concept, the researcher let the students explain where the image exists, had them find the size of the image, and asked them to calculate the focal length of the concave mirror when the researcher put an object between the focal point (f) and 2f of the concave mirror. There was a decrease in the percentage of scientific conceptions concerning this concept, from 42 percent in the pretest to 28 percent in the posttest. The students held scientific conceptions because they knew that the image existed between 2f to infinity and the image would be bigger than the actual object. A total of 70 percent of the students held misconceptions because they thought that the image existed between the focal point (f) and 2f and the image would be the same size as the actual object. Just 12 percent of the students did not respond to the question.

The other question asked concerned image formation by a curved mirror. The object in this situation was 0.05 meters in front of the curved mirror and the virtual image existed 0.1 meters behind the mirror. The researcher asked the students whether the curved mirror was concave or convex, and asked them to calculate the focal length of the curved mirror. There was a decrease in the percentage of scientific conceptions regarding this concept, from 28 percent in the pretest to 23 percent in the posttest. The students held scientific conceptions because they were able to calculate the focal length, which was 0.1 meters, and they could identify the types of curved mirrors that were concave. A total of 71 percent of the students held a misconception because they chose the wrong answer. Only 6 percent of the students did not respond to the question.

Concerning the image formation by a lens concept, the object was 0.18 meters in front of the lens and the image existed 0.06 meters in front of the lens. The researcher asked the students whether the curved mirror was concave or convex and asked them to calculate the focal length and the magnification of the lens. There was a decrease in the percentage of scientific conceptions held regarding this concept, from 32 percent in the pretest to 28 percent in the posttest. The students held scientific conceptions because they correctly calculated a focal length of 0.09 meters, and identified the lens as converging with a magnification 1/3. A total of 63 percent of the students held a misconception because they chose the wrong answer. Only 9 percent of the students did not respond to the question.

The second question was about an image formation by a lens. The object was in 0.1 meters front of the converging lens. The lens had a focal length of 0.05 meters. The researcher asked the students to find the types of images, the image distance, and the magnification of the lens. There was an increase in the percentage of scientific conceptions held regarding this concept, from 27 percent in the pretest to 40 percent in the posttest. The students held scientific conceptions because they correctly calculated the image distance of 0.1 meters, they identified the image as a real image, and they calculated that the magnification of the lens was 1. A total of 48 percent of the students held a misconception because they chose the wrong answer. Just 12 percent of the students did not respond to the question.

The Refraction of Light

The concept of the refraction of light can be divided into three sub concepts: refraction, the refraction from a prism, and refraction when the incident light ray travels perpendicular to two media. The percentages of Pattana school students in each category of refraction of light before (pretest) and after (posttest) implementing the LLU is shown in Table 6.13.

Table 6.13 Percentages of Pattana school students in each category of refraction of light before (pretest) and after (posttest) implementing the LLU

Refraction of Light Concepts	Test	Percentages of the Students			
		Scientific Concept	Partial Scientific Concept	Misconception	No Response
The refraction of light 1	Pre	7	0	92	1
	Post	7	0	88	5
The refraction of light 2	Pre	8	0	92	0
	Post	8	0	87	5
The refraction from a prism	Pre	0	10	90	0
	Post	10	5	85	0

Table 6.13 (Continued)

Refraction of Light Concepts	Test	Percentages of the Students			
		Scientific Concept	Partial Scientific Concept	Misconception	No Response
Refraction occurs when the incident light ray travels perpendicular to two media	Pre	11	17	60	12
	Post	9	0	76	15

Regarding the refraction of light concept, the researcher let the students choose the possible refracted ray that expressed the refraction of light when light travels from oil into water. The same percentage of students in the pre and posttests chose the correct refracted ray that expressed the refraction of light when light travels from oil into water. A total of 88 percent of the students held misconceptions because they did not choose the correct refracted ray. Only 5 percent of the students did not respond to the question.

In an additional problem, the students were asked about the location of an image of a fish when the observer stands on the bank. The same percentage of students in pre and posttests chose the correct choice and reason when they observed the fish. They thought that the image of fish was shallower than it should have been because of the refraction of light. A total of 87 percent of the students held misconceptions when they saw the fish. They thought that the image of the fish was deeper than it should have been because the speed of light through the water was faster than the speed of light through the air. Just 5 percent of the students did not respond to the question.

Regarding the refraction of a prism concept, the researcher let the students choose a picture and reason that best expressed the refraction of light when light travels into a prism. There was an increase in the percentage of scientific conceptions in this concept, from 0 percent in the pretest to 10 percent in the posttest. The students held scientific conceptions because they chose the picture and the reason which correctly expressed the refraction of light when light travels into a prism. They thought that when white light travels through a prism, the angle of refraction is different for different colors of light, with purple being the most refracted and red the least refracted. A total of 85 percent of the students held a misconception because they did not choose the correct picture and reason where purple is the least refracted and red is the most refracted. Only 5 percent of the students held partial scientific conceptions because they correctly chose the picture which expressed the refraction of light, but they thought that the spectrum of a rainbow created by a prism is continuous and that each color has its own exact boundaries.

Concerning the refraction when an incident light ray travels perpendicular to two media concept, the researcher let the students choose the answer and reason which best explained what happened when light passing from one medium into the another medium hit the second medium at right angles to its surface. There was a decrease in the percentage of scientific conceptions regarding this concept, from 11 percent in the pretest to 9 percent in the posttest. The students held the scientific conceptions that light will not change direction when passing from one transparent material into another medium if it hits the second material at right angles to its surface. Because front waves of the incident light incident the medium at the same time, the refraction of light does not occur. A total of 76 percent of the students held the misconception that refraction still occurs because light travels from one medium to another medium or that there is transmission of light from one medium to the other medium. A total of 15 percent of the students did not respond to the question.

Color

The concept of color can be divided into for sub concepts: color in white light, a colored object in colored light, color using a filter, and seeing color. The percentages of Pattana school students in each category of color before (pretest) and after (posttest) implementing the LLU is shown in Table 6.14.

Table 6.14 Percentages of Pattana school students in each category of color before (pretest) and after (posttest) implementing the LLU

Color Concepts	Test	Percentages of the Students			
		Scientific Concept	Partial Scientific Concept	Misconception	No Response
Color in white light	Pre	4	0	89	7
	Post	25	0	70	5
Color object in color light	Pre	17	0	88	5
	Post	50	0	46	4
Color by the filter	Pre	6	0	83	11
	Post	20	0	72	8
Seeing color	Pre	14	0	80	6
	Post	10	0	90	0

Regarding the color in white light concept, there was an increase in the percentage of scientific conceptions from 4 percent in the pretest to 25 percent in the posttest. The students held scientific conceptions about color in white light because they knew that when someone sees the color black, light from the object does not reflect to his/ her eyes and when someone sees the color white, the light rays from the object reflect all of it to his/her eyes. A total of 70 percent of the students had misconceptions about color because they believed that the color of an object is a physical property of that object and the color of an object is determined by what the color of light it absorbs. Only 5 percent of the students didn't respond to the question.

Regarding the colored object in colored light concept, the researcher let the students choose the answer and reason which best explained what happened when the students wore white and red striped T-shirts with green caps in a green spotlight. The percentage of scientific conceptions increased from 17 percent in the pretest to 50 percent in the posttest. The students had the scientific conception that they would see themselves wearing green and black striped T-shirts with green caps in the green spotlight. A total of 46 percent of the students held misconceptions because they could not choose the right answer and reason. These students thought that they would see themselves wearing green T-shirts with green caps in the green spotlight. Just 4 percent of the students did not respond to the question.

Concerning the color by the filter concept, the researcher let the students choose the answer and reason which best explained how a color filter works. There was an increase in the percentage of scientific conceptions in this concept from 6 percent in the pretest to 20 percent in the posttest. The students held scientific conceptions because they correctly chose the answer and reason describing how a color filter works. They thought that the color of an object is the color of the light that is reflected by the object. Seventy two percent of the students gave a wrong answer and reason about how a color filter works. They thought that the function of a filter is to change the color of the transmitted light. Eight percent of the students did not respond to the question.

For the seeing color concept, the researcher let the students choose the answer and reason which best explained what happened when the students looked at a green object for a long time and then looked at the white wall and why this happened. There was a decrease in the percentage of scientific conceptions in this concept from 14 percent in the pretest to 10 percent in the posttest. The students held the scientific conception that they would see a purple wall because they had looked at a green object for a long time, which made the green cone cells in the fovea of the eye not responsive while the red and blue cone cells did respond. A total of 90 percent of the students held misconceptions because they did not choose the right answer and reason. They thought that they would see a green wall because the brain would recognize the color they had looked at the first time.

Optical Instruments

The concept of optical instruments can be divided into three sub concepts: telescopes, microscopes, and a comparison between a camera and the human eye. The percentages of Pattana school students in each category of optical instrument before (pretest) and after (posttest) implementing the LLU is shown in Table 6.15.

Table 6.15 Percentages of Pattana school students in each category of optical instruments before (pretest) and after (posttest) implementing the LLU

Optical Instrument Concepts	Test	Percentages of the Students			
		Scientific Concept	Partial Scientific Concept	Misconception	No Response
Telescopes	Pre	53	0	23	24
	Post	10	0	80	10
Microscopes	Pre	22	0	60	12
	Post	13	0	77	10
A comparison between a camera and the human eye	Pre	1	0	64	35
	Post	85	0	15	0

Concerning the telescope concept, the researcher let the students choose the answer and reason which best explained how telescopes work. There was a decrease in the percentage of scientific conceptions regarding this concept from 53 percent in the pretest to 10 percent in the posttest. The students held a scientific conception because they chose the correct answer and reason. They thought that the objective lens of the telescope made a real upside down image and then the eyepiece lens made the image bigger. Eighty percent of the students gave the wrong answer and reason to describe how a telescope works. They understood that the objective lens of the telescope made a bigger image. Only 10 percent of the students did not respond to the question.

For the microscope concept, the researcher let the students choose the answer and reason which best explained how a microscope works. There was a decrease in the percentage of scientific conceptions concerning this concept from 22 percent in the pretest to 13 percent in the posttest. The students had scientific conceptions because they chose the right answer and reason. They thought that the image from the microscope was big and the position of the real image formed by the objective lens was less than the focal length of the eyepiece lens. Seventy seven percent of the students gave the wrong answer and reason about how a microscope works. They thought that the image formed by the microscope was big and the position of the real image formed by the objective lens was more than two focal lengths of the eyepiece lens. A total of 10 percent of the students did not respond to the question.

For a comparison between a camera and the human eye concept, the researcher let the students choose the answer and reason which described the difference between an image from a camera and an image from the human eye. There was an increase the percentage of scientific conceptions in this concept from 1 percent in the pretest to 85 percent in the posttest. The students held scientific conceptions because they can chose the right answer and reason. They thought that both the image from a camera and from the human eye are real images and smaller than the actual object. Fifteen percent of the students gave a wrong answer and reason about how a microscope works. They thought that there is a difference between the image from a camera and from the human eye. The image from a camera is the real image and smaller than the actual object, but the image from the human eye is a virtual image and smaller than the actual object.

Seeing

The concepts of seeing can be divided into three sub concepts: seeing the candle flame, the candle stick, and the eye problem. The percentages of Pattana school students in each category of seeing before (pretest) and after (posttest) implementing the LLU is shown in Table 6.16.

Table 6.16 Percentages of Pattana school students in each category of seeing before (pretest) and after (posttest) implementing the LLU

Seeing Concepts	Test	Percentages of the Students			
		Scientific Concept	Partial Scientific Concept	Misconception	No Response
Seeing the candle flame	Pre	34	0	38	28
	Post	10	0	85	5
Seeing the candle stick	Pre	19	0	71	10
	Post	53	0	42	5
The eye problem	Pre	3	0	91	6
	Post	18	0	82	0

For the seeing the candle flame concept, the researcher let the students choose the answer that best explained how the students see the candle flame in a dark room and also asked them to draw a picture to represent what they had seen. There was a decrease in the percentage of scientific conceptions in this concept from 34 percent in the pretest to 10 percent in the posttest. The students held scientific conceptions when they chose the right answer, the light from the candle flame travels to students' eyes, and the correct reason. Eighty five percent of the students gave the wrong answer and reason about seeing the candle flame. They thought that the reflected light from the candle flame traveled to the their eyes, the light from their eyes traveled to the candle flame, and the light from the candle flame traveled to their eyes and then back to the candle flame again. Five percent of the students did not respond to the question.

For the seeing candle stick concept, the researcher let the students choose the answer that best explained how the students saw a candle stick in a dark room and asked them to draw a picture to represent it. There was an increase in the percentage of scientific conceptions in this concept from 19 percent in the pretest to 53 percent in the posttest. The students held scientific conceptions when they chose the right answer and reason: the light from the candle flame shines to the candle stick and then reflects to the students' eyes. Forty two percent of the students gave the wrong answer and reason about seeing the candle stick. They thought that the reflected light from the candle stick traveled to their eyes, the light from their eyes traveled to the candle stick, and the light from the candle stick traveled to their eyes and then back to the candle stick again. Five percent of the students did not respond to the question.

For the eye problem concept, the researcher let the students choose the answer and reason that best explained what the eye problem was in a given picture. There was an increase the percentage of scientific conceptions in this concept from 3 percent in the pretest to 18 percent in the posttest. The students held scientific conceptions because they chose the right answer and reason. They thought that the given picture showed nearsightedness. When people get nearsighted, a diverging eyeglass lens is used to correct this condition. When the students put a diverging lens into the eyeglasses, this lens spreads the light out before it got to the eye-lens, and when the eye lens converged the light, the light converged on the back of the eye for proper focus. Eighty two percent of the students gave a wrong answer and reason about the eye problem. They thought that the given picture showed nearsightedness. When the students put a converging lens into the eyeglasses, this lens spread the light out before it got to the eye-lens, and when the eye lens converged the light, the light converged on the back of the eye for proper focus.

In conclusion, these findings indicate that there is an increase in the percentage of scientific conceptions in many concepts of light. However, most of Pranee's students were classified as having misconceptions about some of the concepts of light. Student understanding could result from the learning activities provided in the teaching unit. Even though Pranee's students received opportunities to construct their learning through interaction with their peers, she rarely used a meaningful context to help students develop the light concept in the real world. Moreover, she did not encourage her students by asking them thoughtful, open-ended questions, and she did not give them time for discussion or time to ask for more details.

Three Focused Students' Conceptions about Light before (pretest) and after (posttest) Implementation of the Light Learning Unit (LLU)

The three students' responses and explanations related to light concepts were analyzed and divided into four categories: scientific conception (SC), partial scientific conception (PSC), Misconception (MC), and No response (NR). The details of each student's conception of light are shown below.

Pimpa's Conception of Light before (pretest) and after (posttest) Implementing the LLU

Table 6.17 shows Pimpa's conception of light before and after implementing.

Table 6.17 Pimpa's conception of light before (pretest) and after (posttest) implementing the LLU

Concepts of Light	Sub Concepts	The Pre-Instruction Conceptions	The Post-Instruction Conceptions
Nature of light	Travel of light	Light can travel until it is blocked by something.(SC)	Light can travel until it is blocked by something.(SC)
	Light source	Light from a luminous object travels only as far as it can illuminate the area surrounding the luminous object.(MC)	Light emanates leaving each point of the light source and propagates, diverging in all spatial directions.(SC)
	Media of light	Light can totally pass through a transparent object and light can partially pass through a translucent object, but light cannot pass through an opaque object.(SC)	Light can totally pass through a transparent object and light can partially pass through a translucent object but light cannot pass through an opaque object.(SC)
The image formation	The image lies behind the mirror	The image of an object is on the mirror surface.(MC)	The image lies behind the mirror and it is just as far behind the mirror as the actual object is in front of the mirror.(SC)
	The image is a left-right reversal	The image of an object was exactly the same as the actual object. (MC)	The image is a left-right reversal.(SC)
	Curved mirror 1	The image exists between 2f to infinity and the image is larger than the actual object. (SC)	The image existed between the focal point (f) and 2f and the image is the same size as the actual object.(MC)
	Curved mirror 2	No Response.(NR)	The focal length is 0.03 meters and they can tell that the curved mirror is convex.(MC)
	Image formation by lens 1	No Response.(NR)	The focal length is 0.09 meters and they can tell that the lens is converging and the magnification of the lens is 1/3.(SC)

Table 6.17 (Continued)

Concepts of Light	Sub Concepts	The Pre-Instruction Conceptions	The Post-Instruction Conceptions
The image formation	Image formation by lens 2	The image distance is 0.1 meters and they can tell that the image is a real image and the magnification of the lens is 2.(MC)	The image distance is 0.05 meters and they can tell that the image is a real image and the magnification of the lens is 2.(MC)
The refraction of light	The refraction of light 1	The corrected refracted ray that can express the refraction of light when light travels from oil into water is bending toward the normal line. (MC)	The correct refracted ray that can express the refraction of light when light travels from oil into water is bending toward the normal line. (MC)
	The refraction of light 2	The image of a fish appears deeper than it should be because the speed of light through the water is faster than the speed of light through the air.(MC)	The image of fish appears shallower than it should be because the speed of light through the water is slower than the speed of light through the air. (SC)
	The refraction of a prism	Purple is the least refracted and the red is the most refracted color. (MC)	When white light travels through a prism, the angle of refraction is different for different colors of light. Purple is the most refracted and the red is the least refracted color. (SC)
	Refraction when an incident light ray travels perpendicular to two media	The refraction of light does not occur, but the light will reflect in the opposite direction. (MC)	The refraction of light does not occur, but the light will reflect in the opposite direction. (MC)
Color	Color in white light	The color of an object is a physical property of that object. (MC)	When someone sees black, light from the object doesn't reflect to his/ her eyes and when someone sees white, the light rays from the object reflect all of it to his/her eyes. (SC)

Table 6.17 (Continued)

Concepts of Light	Sub Concepts	The Pre-Instruction Conceptions	The Post-Instruction Conceptions
Color	Colored object in colored light	The students would see themselves wearing striped T-shirts with green and black stripes and green caps under a green spotlight. (SC)	The students would see themselves wearing striped T-shirts with green and black stripes and green caps under a green spotlight. (SC)
	Color using a filter	The function of a filter is to change the color of the transmitted light. (MC)	The color of an object is the color of the light that is reflected by that object. (SC)
	Seeing color	The students would see a green wall because the brain would recognize the color they had looked at the first time. (MC)	The students would see a green wall because the brain would recognize the color they had looked at the first time. (MC)
Optical Instrument	Telescope	The objective lens of a telescope makes a bigger image. (MC)	The objective lens of a telescope makes a bigger image. (MC)
	Microscope	The image from a microscope is big and the position of a real image formed by the objective lens is more than two focal lengths of the eyepiece lens. (MC)	The image from the microscope is big and the position of a real image formed by the objective lens is less than two focal lengths of the eyepiece lens. (SC)
	The comparison between camera and human's eyes	The image from the camera is a real image and is smaller than the actual object, but the image from the human eye is a virtual image and smaller than the actual object. (MC)	Both the image from a camera and the human eye are real images, and smaller than the actual object. (SC)
Seeing	Seeing the candle flame	The light from a candle flame travels to the students' eyes. (SC)	The reflected light from the candle flame travels to the students' eyes. (MC)
	Seeing the candle stick	The light from the candle stick travels to the students' eyes. (MC)	The light from the candle stick travels to the students' eyes. (MC)

Table 6.17 (Continued)

Concepts of Light	Sub Concepts	The Pre-Instruction Conceptions	The Post-Instruction Conceptions
Seeing	The eye problem	The given picture shows nearsightedness. When the students put a converging lens into the eyeglasses, the lens spreads the light out before it gets to the eye-lens, and when the eye-lens converges the light, the light will converge on the back of the eye for proper focus. (MC)	The given picture shows nearsightedness. When the students put a diverging lens into the eyeglasses, the lens spreads the light out before it gets to the eye-lens, and when the eye-lens converges the light, the light will converge on the back of the eye for proper focus. (SC)

While Pimpa showed evidence of holding a misconception of the concept of light in pre-instruction in several areas, she did have a scientific conception of the nature of light (light source), image formation by plane, curved mirror, and lens (image formation by a plane mirror lies behind the mirror, the image is a left-right reversal, image formation by lens 2), the refraction of light, color, optical instruments and seeing (seeing the candle stick, the eye problem). After instruction, many of Pimpa's pre-instruction misconceptions were no longer apparent. Pimpa’s conceptions changed from misconceptions to scientific conceptions in the concepts of image formation by plane, curved mirror, and lens (the image formation by plane mirror lies behind the mirror and the image is a left-right reversal), the refraction of light (the refraction of light 2 and the refraction from a prism), color (color in white light and color using a filter), optical instruments (a microscope and the comparison between a camera and the human eye), and seeing (the eye problem). This was supported by Pimpa’s worksheet that showed her understanding about the image formation by a plane mirror. She wrote that “the image by a plane mirror is a left-right reversal.” However, as Table 6.17 shows, Pimpa still had some misconceptions concerning some sub concepts of light.

Pasinee's Conception of Light before (pretest) and after (posttest) Implementing the LLU

Table 6.18 shows Pasinee's conception of light before (pretest) and after (posttest) implementing the LLU

Table 6.18 Pasinee's conception of light before (pretest) and after (posttest) implementing the LLU

Concepts of Light	Sub Concepts	The Pre-Instruction Conceptions	The Post-Instruction Conceptions
Nature of light	Travel of light	Light only travels as far as it is visible.(MC)	Light can travel until it is blocked by something.(SC)
	Light source	Light from a luminous object travels only as far as it can illuminate the area surrounding the luminous object.(MC)	Light from a luminous object travels only as far as it can illuminate the area surrounding the luminous object.(MC)
	Media of light	Light can pass through both transparent and translucent objects, but there is no difference between transparent and translucent objects.(PSC)	Light can pass through both transparent and translucent objects, but there is no difference between transparent and translucent objects.(PSC)
Image formation	Image formation by a plane mirror lies behind the mirror	The image of an object lies on the mirror's surface.(MC)	The image lies behind the mirror and it is as far behind the mirror as the actual object is in front of the mirror.(SC)
	Image is a left-right reversal	The image of an object was exactly the same as the actual object. (MC)	The image is a left-right reversal.(SC)
	Curved mirror 1	The image existed between the focal point (f) and 2f and the image was the same size as the actual object.(MC)	The image existed between the focal point (f) and 2f and the image was the same size as the actual object.(MC)
	Curved mirror 2	The focal length is 0.1 meters and they identified the curved mirror as a concave mirror (SC)	The focal length is 0.03 meters and they identified the curved mirror as a convex mirror.(MC)

Table 6.18 (Continued)

Concepts of Light	Sub Concepts	The Pre-Instruction Conceptions	The Post-Instruction Conceptions
Image formation	Image formation by a lens 1	No response (NR)	No response (NR)
	Image formation by a lens 2	No response (NR)	No response (NR)
The refraction of light	The refraction of light 1	The correct refracted ray that expresses the refraction of light when light travels from oil into water is bending toward the normal line. (MC)	The correct refracted ray that expresses the refraction of light when light travels from oil into water is bending toward the normal line. (MC)
	The refraction of light 2	The image of a fish appears deeper than it should be because the speed of light through the water is faster than the speed of light through the air. (MC)	The image of a fish appears deeper than it should be because the speed of light through the water is faster than the speed of light through the air. (MC)
	The refraction from a prism	Purple is the least refracted color and red is the most refracted color. (MC)	Purple is the least refracted color and red is the most refracted color. (MC)
	The refraction when of light when the incident light ray travels perpendicular to two media	The refraction of light does not occur because the front waves of the incident light travel to the medium at the same time. (SC)	The refraction of light does not occur because the front waves of the incident light travel to the medium at the same time. (SC)
Color	Color in white light	The color of an object is a physical property of that object. (MC)	Black is the least refracted color and white is the most reflected color. (MC)
	Colored object in colored light	The students would see themselves wearing green and yellow striped T-shirts and green caps under a green spotlight. (MC)	The students would see themselves wearing green and black striped T-shirts and green caps under a green spotlight. (SC)
	Color using a filter	The filter reflects the color red to the eyes. (MC)	The color of an object is the color of the light that is reflected by that object. (SC)

Table 6.18 (Continued)

Concepts of Light	Sub Concepts	The Pre-Instruction Conceptions	The Post-Instruction Conceptions
Color	Seeing color	The students would see a green wall because the brain would recognize the color they had looked at the first time. (MC)	The students would see a green wall because the brain would recognize the color they had looked at the first time. (MC)
Optical Instrument	Telescope	The objective lens of a telescope makes a bigger image. (MC)	The objective lens of a telescope makes a bigger image. (MC)
	Microscope	The image from a microscope is big and the position of a real image formed by the objective lens is smaller than the focal length of the eyepiece lens. (SC)	The image from a microscope is big and the position of real image formed by the objective lens is more than two focal lengths of the eyepiece lens. (MC)
	The comparison between a camera and the human eye	The image from a camera is the real image and smaller than the actual object, but the image from the human eye is a virtual image and is smaller than the actual object. (MC)	Images from both a camera and from the human eye are the real images, and smaller than the actual object. (SC)
Seeing	Seeing the candle flame	The reflected light from a candle flame travels to the students' eyes. (MC)	The reflected light from a candle flame travels to the students' eyes. (MC)
	Seeing the candle stick	The light from a candle flame shines to a candle stick and then reflects back to the students' eyes. (SC)	The light from a candle flame shines to a candle stick and then reflects back to the students' eyes. (SC)
	The eye problem	The picture shows nearsightedness. When the students put a converging lens into the eyeglasses, the lens spreads the light out before it gets to the eye-lens, and when the eye-lens converges the light, the light will converge on the back of the eye for proper focus. (MC)	The given picture shows farsightedness. When the students put a converging lens into the eyeglasses, this lens spreads the light out before it gets to the eye-lens, and when the eye-lens converges the light, the light will converge on the back of the eye for proper focus. (MC)

Pasinee showed evidence of holding several pre-instruction misconceptions about light. For example, she misunderstood the nature of light (travel of light, light source), image formation by a plane mirror, curved mirror and lens (image formation by a plane mirror lies behind the mirror, the image is a left-right reversal, concave mirror), the refraction of light (the refraction of light 1, the refraction of light 2, the refraction from a prism), color (color in white light, colored object in colored light, color using a filter), optical instruments (telescopes and a comparison between a camera and the human eye), and seeing (seeing the candle flame, eye problems). Throughout the implementation phase of the study, Pasinee's conceptions changed from misconceptions to scientific conceptions in the concepts of the nature of light (travel of light), image formation by plane mirror, curved mirror, and lens (image formation by a plane mirror lies behind the mirror, the image is a left-right reversal), color (colored object in colored light), and optical instruments (a comparison between a camera and the human eye). This was supported by Pasinee's worksheet that showed her understanding about the image formation by a plane mirror. She wrote that "the image by a plane mirror is a left-right reversal."

Apirom's conception of light before (pretest) and after (posttest) implementing the LLU.

Table 6.19 shows Apirom's conception of light before (pretest) and after (posttest) implementing the LLU

Table 6.19 Apirom's conception of light before (pretest) and after (posttest) implementing the LLU

Concepts of Light	Sub Concepts	The Pre-Instruction Conceptions	The Post-Instruction Conceptions
The Nature of light	Travel of light	Light continues to travel until it is blocked by something.(SC)	Light travels until it is out of energy. (MC)
	Light source	Light from a luminous object travels only as far as it can illuminate the area surrounding the luminous object.(MC)	Light emanates from each point of the light source and propagates, diverging in all spatial directions.(SC)

Table 6.19 (Continued)

Concepts of Light	Sub Concepts	The Pre-Instruction Conceptions	The Post-Instruction Conceptions
Nature of light	Media of light	Light can pass through both transparent and translucent objects, but there is no difference between transparent and translucent objects. (PSC)	Light can totally pass through transparent objects and light can partially pass through translucent objects, but light cannot pass through opaque objects (SC)
Image formation	Image formation by a plane mirror lies behind the mirror	The image of an object is on the mirror surface.(MC)	The image lies behind the mirror and it is just as far behind the mirror as the actual object is in front of the mirror.(SC)
	Image is a left-right reversal	The image is a left-right reversal.(SC)	The image is a left-right reversal.(SC)
	Curve mirror 1	The image existed between the focal point (f) and 2f and the image was the same size as the actual object.(MC)	The image existed between the focal point (f) and 2f and the image was the same size as the actual object.(MC)
	Curve mirror 2	The focal length is 0.1 meters and students know that the curved mirror is a concave mirror.(SC)	The focal length is 0.03 meters and students know that the curved mirror is a convex mirror.(MC)
	Image formation by lens 1	The focal length is 0.09 meters and students know that the lens is a diverging lens with a magnification of 1/3.(MC)	The focal length is 0.09 meters and students know that the lens is a converging lens with a magnification of 1/3.(SC)
	Image formation by lens 2	The image distance is 0.1 meters and students know that the image is a real image and the magnification of the lens is 2(MC)	The image distance is 0.05 meters and students know that the image is a real image and the magnification of the lens is 2(MC)
The refraction of light	The refraction of light 1	The correct refracted ray that expresses the refraction of light when light travels from oil into water is bending toward the normal line. (MC)	The correct refracted ray that expresses the refraction of light when light travels from oil into water is bending away from the normal line. (SC)

Table 6.19 (Continued)

Concepts of Light	Sub Concepts	The Pre-Instruction Conceptions	The Post-Instruction Conceptions
The refraction of light	The refraction of light 2	The image of a fish appears shallower than it should be because the speed of light through the water is slower than the speed of light through the air.(SC)	The image of fish appears shallower than it should be because the speed of light through the water is slower than the speed of light through the air. (SC)
	The refraction from a prism	Purple is the least refracted color and red is the most refracted color. (MC)	Purple is the most refracted color, red is the least refracted color, and the spectrum of the rainbow made by a prism is continuous and each color has its own exact boundary. (PSC)
	Refraction when the incident light ray travels perpendicular to two media	The refraction of light does not occur, but the light will reflect to the opposite side. (MC)	The refraction of light does not occur but the light will reflect to the opposite side. (MC)
Color	Color in white light	The color of an object is a physical property of that object. (MC)	When someone sees the color black, light from the object doesn’t reflect to his/ her eyes and when someone sees the color white, the light rays from the object reflect all of it to his/her eyes. (SC)
	Colored object in colored light	No response (NR)	The students see themselves wearing green and black striped T-shirts and green caps under a green spotlight. (SC)
	Color using a filter	The function of a filter is to change the color of the transmitted light. (MC)	The color of an object is the color of the light that is reflected by that object. (SC)

Table 6.19 (Continued)

Concepts of Light	Sub Concepts	The Pre-Instruction Conceptions	The Post-Instruction Conceptions
Color	Seeing color	The students see a green wall because the brain recognizes the color they had looked at the first time. (MC)	The students see a green wall because the brain recognizes the color they had looked at the first time. (MC)
The Optical instrument	Telescope	The objective lens of a telescope makes a bigger image. (MC)	The objective lens of a telescope makes the real upside down image and the eyepiece lens makes the image bigger. (SC)
	Microscope	The image from the microscope is big and the position of the real image formed by the objective lens is more than two focal lengths of the eyepiece lens. (SC)	The image from the microscope is big and the position of the real image formed by the objective lens is more than two focal lengths of the eyepiece lens. (SC)
	The comparison between a camera and the human eye	The image from the camera is the real image and smaller than the actual object, but the image from the human eye is a virtual image and smaller than the actual object. (MC)	Both the image from a camera and from the human eye are real images, and smaller than the actual object. (SC)
Seeing	Seeing the flame candle	The reflected light from the candle flame travels to the students' eyes. (MC)	The light from the candle flame travels to the students' eyes. (SC)
	Seeing the candle stick	The light from the candle stick travels to the students' eyes. (MC)	The light from the candle flame shines on the candle stick and then reflects to the students' eyes. (SC)
	The eye problem	The given picture shows nearsightedness. When the students put a converging lens into the eyeglasses, this lens spreads the light out before it gets to the eye-lens, and when the eye-lens converges the light, the light will converge on the back of the eye for proper focus. (MC)	The given picture shows nearsightedness. When the students put a converging lens into the eyeglasses, this lens spreads the light out before it gets to the eye-lens, and when the eye-lens converges the light, the light will converge on the back of the eye for proper focus. (MC)

Before teaching of the concepts of light, Apirom showed evidence of holding misconceptions about several concepts except the concept of the nature of light (travel of light), image formation by a plane, curved mirror (image is a left-right reversal, convex mirror, and image formation by lens 1), the refraction of light (the refraction of light 2), and optical instrument (microscope). Many of the pre-instructional misconceptions were no longer apparent and they became scientific conceptions. This was supported by Apirom's worksheet that showed her understanding about the image formation by a plane mirror. She wrote that "the image by a plane mirror is behind the mirror and the distances of object and image are the same." However, Apirom still had some misconceptions.

In conclusion, students showed scientific conceptions about light in all six categories: the nature of light, image formation by plan mirror and lens, curved mirrors, refraction of light, optical instruments, color, and seeing. These findings imply that the implementation the Light Learning Unit (LLU) can enhance students' scientific understanding of light concepts.

Summary of Pranee's Case

Pranee often implemented the unit following the Light Learning Unit (LLU). She rarely used a meaningful context to help students develop concepts in the real world, but she gave the students an opportunity to construct their learning through interaction with their peers, focused on having the students' work cooperatively, and used various kinds of teaching strategies in her teaching practice. She did not focus on students' prior knowledge, but encouraged students by asking thoughtful and open-ended questions. However, she usually asked the students for answers, and then moved on to other questions without talking or asking for the reasons behind the students' answers. She usually made a conclusion of the experiment by herself if the students could not make their own conclusion. Consequently, some student's conceptions were improved, but most of the students still had misconceptions about the concept of light. Pranee herself also had difficulty with the content knowledge regarding the reflection and refraction of light. She could not finish the last lesson of the unit because of time constraints. She skipped the lesson because she used to teach it before.

Case III: Charoen School

School Context

The school was established in 1977 at a suburban site in Bangkok. It is close to Nontaburi Province and located near a market area. It is a large size school with 1,800 students. The school has two levels, level 3 (Grade 7-9) and level 4 (Grade 10-12). Level 3 had twenty four classrooms and Level 4 had twenty one classrooms. Each grade 7-9 classroom had 40-45 students, and each grade 10-12 classroom had 40-45 students. In grades 7-9, one class consisted of high ability students, and the others were made up of mixed ability students. The school is famous, so every parent wanted their child to study there. Every day from 7.40 – 8.20 a.m., students and teachers sang the national anthem, and clasped their hands and to give thanks to the country, to Buddha, and to the King. Teaching hours began at 8.30 a.m. and finished at 15.30 p.m. Each day, there were seven periods of sixty minutes each at the lower secondary school level. The students had science class three hours a week. One semester consisted of eighteen weeks including sixteen weeks for teaching and two weeks for the midterm and final examinations.

Teacher Background

Chaichana was a male lower secondary and high school teacher. He usually taught the seventh, eighth, and eleventh grade students. He had sixteen years of experience teaching science and had six years experience teaching the concept of light. He had a workload of twenty teaching hours per week. He also had responsibility for Army Reserve Force students. He was forty five years old. He had a bachelor’s degree in education with a major in biology and he also had a master’s degree in botany. He loved to participate in workshops that helped him to develop his career but he had never participated in any workshop involving the concept of light or teaching the concept of light. Chaichana usually taught the students by giving them some knowledge, and then he let his students do an experiment and give a presentation. In teaching science, he was concerned about students' prior knowledge and he was also concerned that the students should learn cooperatively. He used various kinds of assessment methods including pretests and posttests, the student presentations, assignments and reports, and student tasks. He usually used an observation record to check student participation while doing activities, both individually and in groups, and he also used peer assessment. He usually gave praise to his students when they answered questions correctly. Chaichana had a problem when he taught the concept of light. Chaichana said that "the concept of light is difficult for both teacher and students. To understand this concept, the students have to understand the basic concept first and they should have appropriate mathematical skills." When the researcher asked him to participate in the study, he agreed to join in the immediately because he needed to develop his concept of light teaching skills.

Student Background

The students were from one grade 8 classroom. There were 42 students in this class with 11 boys and 31 girls. The students were 13-14 years old. Most of the students (14 students) had a moderate GPA (2.0). Twelve students had a GPA of 3.5 and eleven had a GPA of 3.0. Only five students achieved the highest GPA (4.0). Most of the students looked happy when they were learning science. They loved to do the experiments. This study focuses on three students. Pseudonyms were used to represent the students' names, Chadaporn, Chalerm, and Chai. The details of each student are described below.

Chadaporn

Chadaporn was a fourteen year old girl. Her mother was a housewife, and her father owned a small business. Chadaporn liked to study science. She believed that science was necessary for her everyday life. Her science learning achievement score was 3.0.

Chalerm

Chalerm was a thirteen year old boy. His mother was a nurse and his father owned a small business. He didn’t like science because he thought that it was hard to understand. His science learning achievement score was 2.0.

Chai

Chai was fourteen year old boy. His mother and father were laborers. He liked science because he loved to do experiments. His science learning achievement score was 3.0.

Chaichana’s Classroom Setting

Chaichana’s classroom was a big and was also a laboratory. There were nine tables for the students and one for the teacher. There was a lot of equipment and material there, but some was unpacked and some was broken. When the researcher looked at the classroom, it was very dirty. Although Chaichana’s classroom had a lot of equipment and materials, but they were not suitable for the concept of light unit. Chaichana taught in a science laboratory with insufficient equipment and materials, especially, the equipment and materials needed to study the concept of light including lenses, prisms, and optical instruments. Each table in the classroom consisted of five groups of students. Figure 6.3 shows Chaichana’s classroom setting.

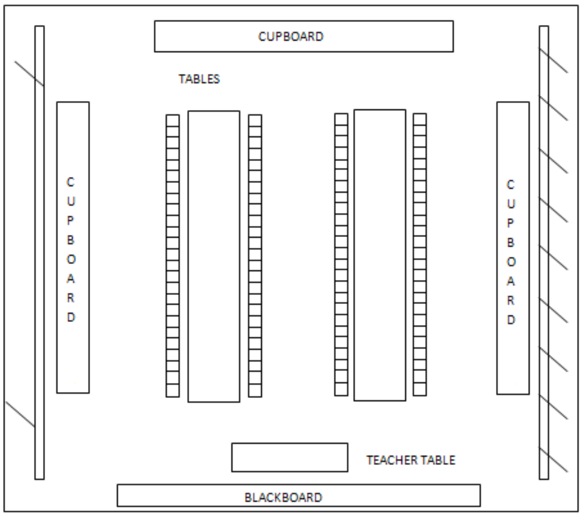


Figure 6.3 Chaichana's classroom setting

Research Questions 3: How and to What Degree Are Thai Science Teachers Able to Implement Light Learning Unit (LLU)?

To answer this research question, Chaichana's teaching practices, including teaching strategies and assessment strategies, are described. Moreover, the problems that he faced during the implementation the LLU and the perception of Chaichana and his students about the unit implementation were investigated too. The in-depth information on the process of Chaichana's implementation of the LLU is discussed below.

Chaichana's Teaching Practices

Chaichana was not worried about implementing the LLU. In the first week, he skipped asking the suggested questions to assess students' prior knowledge. He started the lesson by letting students do an activity. He explained how to do the activity to the students, and then he let his students work on the activity and asked them to present the results. During the presentation, he gave the students an opportunity to ask the presenter of each group questions after he or she finished the presentation. In the following weeks, he seemed to follow the teacher manual more closely. He used all of the suggested questions to determine the students' understanding. The details of Chaichana's teaching practices are discussed, in terms of his teaching and assessment strategies, below.

Chaichana's Teaching Strategies

Chaichana implemented the LLU by following the teacher manual. He asked the students to think, but many times he answered the questions by himself because his students did not respond to his questions. His teaching strategies focused on cooperative group work, and also prepared hands-on activities that allowed students to think about and discuss concepts with their peers in small groups. He also explained the experiment procedures to the students. He let the students make conclusions from the experiment or the activities first, and then made his own conclusion. He used a meaningful context to help students to develop the concept in the real world. He gave the students an opportunity to construct their learning through interaction with their peers, and while the students did the experiment, he walked from group to group to help the students. Chaichana's teaching strategies are illustrated below.

Chaichana Increasingly Developed the Students' Prior Knowledge.

During the first week of the implementation, Chaichana started the lesson by letting his students do the activity without using the suggested questions to assess the students' prior knowledge. This was evidenced by classroom observation. In lesson one, the Nature of Light, the students were asked to construct a concept map about the nature of light. Chaichana explained how to do the activity and then let his students read the instructions. During student group work periods, he gave his students time to discuss and share their ideas and asked them to construct concept maps which reflected their own understanding of topics. Then, the concept maps from each group were presented. He gave the students' time to ask the presenter of each group questions after the presentation was finished which resulted in discussions among the students. In the following weeks, he started to use all of the suggested questions to determine the students' prior knowledge. For example, in lesson four, the refraction of light, Chaichana started the lesson by letting the students in each group observe a pen in a glass filled with water. He asked students in each group to describe and share what they had seen, and he asked one student in each group to share their ideas. Then he asked them to describe the reasons behind their answers to gain a better understanding of their prior knowledge.

Chaichana Used a Meaningful Context to Help Students to Develop the Concept of Light in the Real World.

When Chaichana taught lesson three, the curved mirror, he started the lesson by encouraging the students in each group to observe and touch some shiny silver paper that can be bent. He asked the students to compare the reflection on the paper with a reflection from a plane mirror. He asked the students to bend the silver paper. After that, he compared the paper to the curved mirror and asked the students to do an experiment concerning image formation by a curved mirror. Then he asked the students about the use of curved mirrors in their lives.

Chaichana Encouraged Students by Asking Thoughtful, Open-Ended Questions.

During the first week of the implementation, Chaichana skipped questions and classroom discussion as suggested in the lesson plans. In the next lesson, he asked questions and had classroom discussions as suggested in the lesson plans. He shared thoughtful and open-ended questions with his students. Chaichana asked the students about the multiple reflections of two plane mirrors when an object is placed in front of those two mirrors. He tried to help the students to understand the relationship between the number of reflections and the angle between the two plane mirrors. The following was evidenced by classroom observation.

> While the students in each group cooperatively talked, thought, and made conclusions about multiple reflections from two plane mirrors, Chaichana

> asked the students to think about the relationship between the number of reflections and the angle between two plane mirrors. He first asked the students about the number of reflections when the angle between two plane mirrors is zero degrees, and then the number of reflections when the angle between the two mirrors is increased. During the time that the students worked cooperatively in groups, Chaichana walked around from group to group to help his students. He asked students questions to help them to think about the relationship between the number of reflections and the angle between two plane mirrors. (Field note, December, 2006)

Moreover, when the students did not respond to his questions, he did Repeated, rearranged, or added more details to the question. For example, when discussing the concept of the refraction of light, he asked the students about the cause of the refraction of light. “What do you think happens when light travels from one medium to another medium?” “Have you ever seen a fish in the water? What did the fish look like? What happened there?

Chaichana Gave the Students an Opportunity to Construct Their Learning Through Interaction with Their Peers, and Through Extended Participation and Involvement as Group Members.

During the first week of the implementation, Chaichana gave the students an opportunity to construct their learning through interaction with their peers. He let his students share an idea about the media of light. The students had a chance to interact through the experiment and talk with each other in groups. This was evidenced by classroom observation. During the students’ presentation, he gave the students time to ask the presenter of each group questions after he or she finished the presentation.

While the students in each group cooperatively talked about, thought about, and made conclusions about the media of light, Chaichana extended participation and involved group members and he defined the three types of media which had the property of allowing light to pass through them, as transparent, translucent, and opaque media.

The teacher and the students talked about the media as the following dialogue illustrates.

Chaichana: What is the purpose of this activity?

Student 1: I know. It is to classify the types of media according to the way light passes through them.

Chaichana: Yes, that's right. First, you learn the three types of media according to the way light to passes through them. Do you know what are they?

Student 2: Transparent, translucent, and opaque media.

Chaichana: How do you know which one is transparent, or translucent, or opaque media?

Student 1: We need to see through the objects. If light can travel through, it's transparent, if some light can travel through, it's translucent, and if no light can travel through, it's opaque.

Student 2: This is a candle paper.

Student 1: Some light can pass through.

Chaichana: So, what type of media is candle paper?

Student 2: Translucent.

Student 2: How about plastic?

Student 1: Plastic? Light can't pass through. So, it is opaque.

Chaichana asked students more questions to think about to help them to understand about the media of light. Then, he walked around from group to group to help his students when they had problems.

Chaichana Focused on the Students' Cooperative Work.

In the first lesson, Chaichana asked the students to form groups composed of six to seven students. During this time, there was a chaos because the students wanted to join a group with their best friends. Some groups had only girls or boys. So, Chaichana had to assign the students to mixed ability and mixed gender groups. After that, he gave each group member a responsibility which included collecting data, making a report, presenting the results of the experiment, and providing support. He also explained the procedure of the experiment to the students. He walked from group to group to help the students.

At the end of lesson, he asked his students to present the results of the experiment. After that, he asked the students to make a conclusion. Then he summarized the conclusion to the students. He used peer assessment techniques to grade the students' experiment as suggested by the LLU.

Assessment Strategies

Chaichana used many methods to assess the students' learning during the implementation of the LLU. He obviously observed the students while they were working in groups. He observed the students and then gave the students a score based upon their performance in their group. He also collected and marked student worksheets regularly and returned those to the students. Students usually had a chance to present their work to the whole class. This shows that Chaichana emphasized participation in the classroom and scores on tests. At the end of the lessons, he used peer assessment techniques to grade students' experiments as suggested by the LLU.

Chaichana's Teaching Problems

The Time Constraints

Chaichana said that there were too many activities in each lesson and some of the activities took too much time. He worried about finishing all of the lessons on time. So, he also skipped Lesson 6, Optical Instruments, because he thought that the activity in this lesson took too much time. The students were asked to do a group report about optical instruments instead of doing a group experiment. Even though he skipped Lesson 6, he still could not finish the last lesson. He could not finish the last lesson for many reasons. First, every Monday, teaching time was shortened by the singing of the national anthem, the clasping of hands and giving thanks to the country, to Buddha, and to the King. Moreover, the principal and other teachers announced the school news and activities and some days the teachers disciplined the students about their roles and stated the school rules. These activities were supposed to finish at 8.20, but sometimes took more than 10-20 minutes. Second, there were many days off which shortened the teaching time. The students had to attend the school sports competition day. They had to take the National Test which took two days. Before taking the National Test, they had to prepare for the test for one week. Finally, the teacher was asked to attend a workshop for a week, so his students did not learn science while he was gone.

Teachers' Difficulties with Content Knowledge

Chaichana had difficulties teaching some concepts of light. During a discussion about a ray diagram of a concave mirror, Chaichana did not understand how to draw the diagram because he did not understand the property of concave mirrors when light from the object travels to the mirror and the reflected ray is diverted from the mirror.

In addition, Chaichana did not clearly explain the specific word, the critical angle, or the total internal reflection. In the activity, the students were asked to find the angle that made the total internal reflection of the plastic plate and Chaichana did not discuss what a critical angle means before starting the activity. He did not link the previous activity to make his students understand the words “critical angle and the total internal reflection”. The students started to ask Chaichana what critical angle meant. So, he incorrectly told the students that the critical angle is the angle that makes a total internal reflection instead of increasing the angle of incidence above the critical angle which will result in a total internal reflection.

Moreover, Chaichana was not aware of a student’s incorrect explanation of the media of light while the student was presenting his results in front of the classroom. He did not clarify the student’s explanation. The student gave the wrong explanation about types of media. The student said “There are three types of media which have the property of allowing light to pass through them. They are transparent, translucent, and opaque media.” The student seemed so confused about the difference between transparent and translucent media. The student said that light can travel through translucent media and some light can travel through transparent media.

Chaichana’s Perception of His Teaching

During the implementation, Chaichana thought that the students enjoyed doing some activities in the LLU unit including the nature of light, curved mirrors and lenses, and color. Students paid more attention when they were doing the activities. Chaichana agreed that the students’ prior knowledge was important to the students when they constructed their own understanding of the unit. Chaichana said,

> My students looked happy when they learned by themselves through the activities and group experiments. I thought that their prior knowledge and reinforcement were very important. So, I always gave them prior knowledge and praised them. (Chaichana, interviewed in January, 2006)

However, Chaichana did not agree with the activities which involved the design of an experiment. He thought they took too much time. Moreover, the students did not have any experience in designing an experiment. So, these activities seemed hard to the students.

Students' Perceptions of Chaichana's Teaching

The students loved to learn and gain more knowledge when they were in the class. The student said,

> Learning about the concept of light was good because I understood it and had fun. I gained knowledge from doing the experiment and I also gained much experience. I loved that the teachers gave me the opportunity to share my ideas. My favorite concept was multiple reflections of two plane mirrors because I gained knowledge about the making the multiple reflections and I also had the responsibility of doing the experiment working within a group. (Chadaporn, Student reflection, February, 2006)

In Summary, Chaichana followed the guidelines of the LLU. He increasingly developed a concern for the students' prior knowledge. He gave time to his students to discuss and share their ideas. In most of the activities, he used a meaningful context to help students to develop the concepts in the real world. He also encouraged students by asking thoughtful and open-ended questions. When the students did not respond to his questions, he repeated, rearranged, or added more questions. He gave the students a chance to construct their own learning through interaction with their peers. Chaichana focused on the students' cooperative work. He used many methods to assess the students' learning during the implementation of the LLU. He had difficulty with the content knowledge regarding the drawing of a ray diagram of a concave mirror and understanding the critical angle and the total internal reflection. Chaichana and his students enjoyed teaching and learning the concept of light using the LLU even though he did not agree with letting the students design the experiment.

Research Questions 4: How Does the Implementation the Light Learning Unit (LLU) Enhance Students' Scientific Understanding of Concept about Light?

To answer this research question, this section first presents the percentage of students choosing scientific conceptions, partial scientific conceptions, misconceptions, and no response to the concept of light from the Light Concept Test (LCT) before and after implementing the LLU. Second, this section presents the conceptions of three students before and after the LLU implementation.

The Students' Conceptions about the Concepts of Light

Students were asked to complete a light concept test (LCT) after the implementation of the LLU. The LCT was like the light diagnostic test (LDT), and was divided into six concepts: the nature of light, image formation by a plane mirror and lens, curved mirrors, refraction of light, optical instruments, color, and seeing. The students' responses and explanations related to the concepts of light were divided into four categories and analyzed: scientific conceptions (SC), partial scientific conceptions (PSC), misconceptions (MC), and no response (NR). The students' conceptions of the concept of light are presented below.

The Nature of Light

The Nature of Light can be divided into three sub concepts: the travel of light, light sources, and the media of light. The percentages of Charoen school students in each category of nature of light before (pretest) and after (posttest) implementing the LLU is shown in Table 6.20.

Table 6.20 Percentages of Charoen school students in each category of nature of light before (pretest) and after (posttest) implementing the LLU

Nature of Light Concepts	Test	Percentages of Students			
		Scientific Concept	Partial Scientific Concept	Misconception	No Response
Travel of light	Pre	69	0	31	0
	Post	64	0	36	0
Light source	Pre	0	0	100	0
	Post	2	0	98	0
Media of light	Pre	7	2	91	0
	Post	36	0	64	0

For the travel of light concept, the researcher let the students choose the sentence which explained how far light goes and why. There is a decrease in the percentage of scientific conceptions that states that light can travel until it is blocked by something. The percentages of scientific conceptions decreased from 69 percent in the pretest to 64 percent in the posttest. However, 36 percent of students held the misconceptions that light travels as far as it is visible, light travels as far as possible and light travels until it is out of energy.

For the concept of light sources, there was an increase in the percentage of scientific conceptions that states that light emanates by leaving each point of the light source and propagates, diverging in all spatial directions. The percentage of scientific conceptions increased from 0 percent in the pretest to 2 percent in the posttest. Even though most of students, 98 percent, still held misconceptions because they explained that light is an entity which is located in space (the region around the light source), light from a luminous object travels only as far as it can illuminate the area surrounding the luminous object, light fades with distance from the source, light goes out only in a radial direction, or each point on a luminous object emits light in one direction.

For the media of light concept, the researcher created a situation which included three media. He asked the students to classify which media was transparent, translucent, or opaque. There was an increase in the percentage of scientific conceptions because the students chose the correct answer when they identified an object that could block light as an opaque object, they called an object transparent if light could totally pass through the object, and they called an object translucent if light could partially pass through the object. The percentage of scientific conceptions increased from 7 percent in the pretest to 36 percent in the posttest. Sixty four percent of the students held misconceptions because they could not choose the correct answer and some of them thought that light could pass partially through an opaque object.

Image Formation

Image formation can be divided into three sub concepts: image formation by plane mirror, curved mirror, and lens. The percentages of Charoen school students in each category of image formation before (pretest) and after (posttest) implementing the LLU is shown in Table 6.21.

Table 6.21 Percentages of Charoen school students in each category of image formation before (pretest) and after (posttest) implementing the LLU

Image formation Concepts	Test	Percentages of Students			
		Scientific Conceptions	Partial Scientific Conceptions	Misconceptions	No Response
The image formed in a plane mirror lies behind the mirror	Pre	10	0	90	0
	Post	22	0	78	0
The image is a left-right reversal	Pre	50	0	50	0
	Post	74	0	26	0
Curved mirror 1	Pre	33	0	77	0
	Post	17	0	81	2
Curved mirror 2	Pre	26	0	67	7
	Post	5	0	95	0
Image formation by a lens 1	Pre	38	0	57	5
	Post	5	0	90	5
Image formation by a lens 2	Pre	17	0	78	5
	Post	5	0	90	5

For the image formation by a plane mirror concept, there was an increase in the percentage of scientific conceptions which stated that the image lies behind the mirror and is just as far behind the mirror as the actual object is in front of the mirror. The percentage of scientific conceptions increased from 10 percent in the pretest to 22 percent in the posttest. Seventy eight percent of the students held misconceptions because they thought that an object has its image behind the surface of the mirror in a position that is in front of the observer.

The other question about the image formation by a plane mirror is a left-right reversal. There is an increase in the percentage of scientific conceptions which state that the image lies behind the mirror and it is just as far behind the mirror as the actual object is in front of the mirror. The percentage of scientific conceptions increased from 50 percent in the pretest to 74 percent in the posttest. Twenty six percent of the students held misconceptions because they thought that the image of the object was exactly the same as the actual object.

For the image formation by a curved mirror concept, the researcher asked the students to explain where the image exists, to find the size of the image, and to calculate the focal length of the concave mirror when the researcher put the object between the focal point (f) and 2f of the concave mirror. There was a decrease in the percentage of scientific conceptions that stated that the image existed between 2f to infinity and the image was larger than the actual object. The percentage of scientific conceptions decreased from 33 percent in the pretest to 17 percent in the posttest. However, 81 percent of the students had misconceptions because they thought that the image existed between the focal point (f) and 2f, and that the image would be the same size as the actual object.

The other question concerns image formation by a curve mirror. The researcher created a situation where the researcher put an object 0.05 meters in front of a curved mirror and the virtual image existed 0.1 meters behind the mirror. The researcher asked the students if the curved mirror was concave or convex and asked them to calculate the focal length of the curved mirror. There was a decrease in the percentage of scientific conceptions where students were asked to calculate the focal length, which was 0.1 meters, and if they could determine if the curved mirror was a concave mirror. The percentage of scientific conceptions decreased from 26 percent in the pretest to 5 percent in the posttest. Ninety five percent of the students had misconceptions because they chose the wrong answer.

For the image formation by lens concept, the researcher created a situation where the object was place 0.18 meters in front of lens and the image existed 0.06 meters in front of the lens. The researcher asked the students whether the curved mirror was a concave or convex mirror and asked them to calculate the focal length and the magnification of the lens. There was a decrease in the percentage of scientific conceptions where students could not calculate the focal length, which is 0.09 meters, and they could not identify the lens as a converging lens with a magnification of 1/3. The percentage of scientific conceptions decreased from 38 percent in the pretest to 5 percent in the posttest. Ninety percent of the students held misconceptions because they chose the wrong answer.

The second question concerned image formation by a lens.
The researcher created a situation where the object was put 0.1 meters in front of the converging lens that had a focal length of 0.05 meters, and the researcher asked the students to find the type of image, the image distance, and the magnification of the lens. There was a decrease in the percentage of scientific conceptions. Students could not calculate the image distance of 0.1 meters and they could not identify the image as a real image where the magnification of the lens was 1. The percentage of scientific conceptions decreased from 38 percent in the pretest to 5 percent in the posttest. Ninety percent of the students held misconceptions because they chose the wrong answer.

The Refraction of Light

The concept of the refraction of light can be divided into three sub concepts: refraction, refraction of a prism, and refraction when the incident light ray travels perpendicular to two media. The percentages of Charoen school students in each category of refraction of light before (pretest) and after (posttest) implementing the LLU is shown in Table 6.22.

Table 6.22 Percentages of Charoen school students in each category of refraction of light before (pretest) and after (posttest) implementing the LLU

Refraction of Light Concepts	Test	Percentages of Students			
		Scientific Conceptions	**Partial Scientific Conceptions**	**Misconceptions**	**No Response**
The refraction of light 1	Pre	36	0	64	0
	Post	48	0	52	0
The refraction of light 2	Pre	33	0	67	0
	Post	48	0	52	0
The refraction of a prism	Pre	17	0	83	0
	Post	14	0	86	0
The refraction that occurs when the incident light ray travels perpendicular to two media	Pre	5	0	95	0
	Post	10	0	90	0

For the refraction of light concept, the researcher let the students choose the possible refracted ray that illustrated the refraction of light when light travels from oil into water. There was an increase in the percentage of scientific conceptions because students chose the refracted ray that correctly expressed the refraction of light when light travels from oil into water. The percentage of scientific conceptions increased from 36 percent in the pretest to 48 percent in the posttest. Fifty two percent of the students held misconceptions because they could not choose the correct refracted ray.

In another problem, the students were asked about the location of the image of a fish when the observer sees it from the bank. There was an increase in the percentage of scientific conceptions because students were able to choose the right answer and explanation when they observed the fish. They thought that the image of the fish was shallower than it should have been because of the refraction of light. The percentage of scientific conceptions increased from 33 percent in the pretest to 48 percent in the posttest. Fifty two percent of the students had misconceptions when they saw the fish. They thought that the image of the fish was deeper than it should have been because the speed of light through the water is faster than the speed of light through the air.

For the refraction of a prism concept, the researcher let the students choose the picture and reason that best expressed the refraction of light when light travels into a prism. There was a decrease in the percentage of scientific conceptions where students had to choose the right picture and the right explanation which expressed the refraction of light when light travels into prism. They thought that when white light travels through a prism, the angle of refraction is different for different colors of light. The percentage of scientific conceptions decreased from 17 percent in the pretest to 14 percent in the posttest. Eighty six percent of the students held misconceptions. They could not choose the correct picture and reason because purple is the least refracted color and red is the most refracted color.

For the refraction when the incident light ray travels perpendicular to two media concept, the researcher let the students choose the answer and reason which best explained what happened when light passed from one medium to another medium and it hit the second medium at right angles to its surface. There was an increase in the percentage of scientific conceptions which stated that light will not change direction when passing from one transparent material into another medium if it hits the second material at right angles to its surface. The refraction of light does not occur because front waves of the incident light incident the medium at the same time. The percentage of scientific conceptions increased from 5 percent in the pretest to 10 percent in the posttest. Ninety percent of the students held the misconception that refraction still occurs because light travels from one medium to another medium, or there is only the transmission of light from one medium to another medium.

Color

There are four sub concepts used to measure the concepts of color: color in white light, colored object in colored light, color using a filter, and seeing color. The percentages of Charoen school students in each category of color before (pretest) and after (posttest) implementing the LLU is shown in Table 6.23.

Table 6.23 Percentages of Charoen school students in each category of color before (pretest) and after (posttest) implementing the LLU

Color Concepts	Test	Percentages of Students			
		Scientific Conceptions	Partial Scientific Conceptions	Misconceptions	No Response
Color in white light	Pre	2	0	98	0
	Post	7	0	93	0
Colored object in colored light	Pre	12	0	88	0
	Post	17	0	83	0
Color using a filter	Pre	17	0	83	0
	Post	19	0	81	0
Seeing color	Pre	5	0	95	0
	Post	10	0	90	0

For the color in white light concept, there was an increase in the percentage of scientific conceptions. The students knew that when someone sees the color black, light from the object does not reflect to his/ her eyes and when someone sees the color white, the light rays from the object reflect all of it to his/her eyes. The percentage of scientific conceptions increased from 2 percent in the pretest to 7 percent in the posttest. However, 93 percent of the students had misconceptions about color. They believed that the color of an object is a physical property of that object and the color of an object is determined by the color of light it absorbs.

For the colored object in colored light concept, the researcher let the students choose the answer and reason which best explained what happened when the students wore white and red striped T-shirts and green caps under a green spotlight. There was an increase in the percentage of scientific conceptions. The students thought they would see themselves wearing striped T-shirts with green and black stripes and green caps under the green spotlight. The percentage of scientific conceptions increased from 12 percent in the pretest to 17 percent in the posttest. However, 83 percent of the students held misconceptions because they could not choose the right answer and reason. They thought that they would see themselves wearing green T-shirts with and green caps under a green spotlight.

For the color using a filter concept, the researcher let the students choose the answer and reason which best explained how a color filter works. There was an increase in the percentage of scientific conceptions where students choose the right answer and reason to explain how a color filter works. They thought that the color of an object is the color of the light that is reflected by the object. The percentage of scientific conceptions increased from 17 percent in the pretest to 19 percent in the posttest. However, 81 percent of the students gave the wrong answer and reason about how a color filter works. They thought that the function of a filter is to change the color of the transmitted light.

For the seeing color concept, the researcher let the students choose the answer and reason which best explained what happened when the students looked at a green object for a long time and then looked at a white wall and why this happened. There was an increase in the percentage of scientific conceptions. The students said they would see a purple wall because they had seen a green object for a long time. This made the green cone cells in the fovea of the eye not as responsive as the red and blue cone cells. The percentage of scientific conceptions increased from 5 percent in the pretest to 10 percent in the posttest. However, 90 percent of the students held misconceptions because they could not choose the right answer and reason. They thought that they would see a green wall because the brain would recognize the color they had looked at the first time.

Optical Instruments

There are three sub concepts used to measure the concepts of optical instruments: telescopes, microscopes, and a comparison between the camera and the human eye. The percentages of Charoen school students in each category of optical instrument before (pretest) and after (posttest) implementing the LLU is shown in Table 6.24.

Table 6.24 Percentages of Charoen school students in each category of optical instrument before (pretest) and after (posttest) implementing the LLU

Optical Instrument Concepts	Test	Percentages of Students			
		Scientific Conceptions	Partial Scientific Conceptions	Misconceptions	No Response
Telescope	Pre	0	0	100	0
	Post	0	0	100	0
Microscope	Pre	0	0	100	0
	Post	2	0	98	5
The comparison between a camera and the human eye	Pre	2	0	98	0
	Post	12	0	88	0

For the telescope concept, the researcher let the students choose the answer and reason which best explained how a telescope works. The students still held misconceptions because they gave the wrong answer and reason about how a telescope works. They understood that the objective lens of the telescope makes a bigger image.

For the microscope concept, the researcher let the students choose the answer and reason which best explained how a microscope works. There is an increase in the percentage of scientific conceptions because the students chose the right answer and reason. They thought that the image from the microscope is big and the position of the real image formed by the objective lens is less than the focal length of the eyepiece lens. The percentage of scientific conceptions increased from 0 percent in the pretest to 2 percent in the posttest. However, 98 percent of the students gave the wrong answer and reason about how a microscope works. They thought that the image from a microscope is big and the position of the real image formed by the objective lens is more than two focal lengths of the eyepiece lens.

For the comparison between a camera and the human eye concept, the researcher let the students choose the answer and reason which described the difference between the image from a camera and the human eye and why. There was an increase the percentage of scientific conceptions because the students could choose the right answer and reason. They thought that the image from both a camera and from the human eye are real images, and smaller than the actual object. The percentage of scientific conceptions increased from 2 percent in the pretest to 12 percent in the posttest. However, 88 percent of the students gave the wrong answer and reason to describe how a microscope works. They thought that there was a difference between the image from a camera and from the human eye. The image from the camera is the real image, and smaller than the actual object, but the image from the human eye is a virtual image and smaller than the actual object.

Seeing

There are three sub concepts used to measure the concepts of seeing: seeing a candle flame, the candle stick, and the eye problem. The percentages of Charoen school students in each category of seeing before (pretest) and after (posttest) implementing the LLU is shown in Table 6.25.

Table 6.25 Percentages of Charoen school students in each category of seeing before (pretest) and after (posttest) implementing the LLU

Seeing Concepts	Test	Percentage of Students			
		Scientific conceptions	Partial scientific conceptions	Misconceptions	No response
Seeing the candle flame	Pre	9	0	91	0
	Post	12	0	88	0
Seeing the candle stick	Pre	9	0	91	0
	Post	17	0	83	0
The eye problem	Pre	14	0	86	5
	Post	48	0	52	0

For the seeing the candle flame concept, the researcher let the students choose the answer that best explained how the students would see a candle flame in a dark room and also asked them to draw a picture to represent what they might see. There was an increase in the percentage of scientific conceptions because the students chose the right answer and reason: the light from the candle flame travels to the students' eyes. The percentage of scientific conceptions increased from 9 percent in the pretest to12 percent in the posttest. However, 88 percent of the students gave the wrong answer and reason about seeing the candle flame. They thought that the reflected light from the candle flame traveled to their eyes, the light from their eyes traveled to the candle flame, and the light from the candle flame traveled to their eyes and then back to the candle flame again.

For the seeing candle stick concept, the researcher let the students choose the answer that best explained how the students saw a candle stick in a dark room and also asked them to draw a picture to represent it. There was an increase in the percentage of scientific conceptions because they chose the right answer and reason: the light from the candle flame shines to the candle stick and then reflects to the students' eyes. The percentage of scientific conceptions increased from 9 percent in the pretest to 17 percent in the posttest. However, 83 percent of the students gave the wrong answer and reason about seeing the candle stick. They thought that the reflected light from the candle stick travels to the students' eyes, the light from the eyes travels to the candle stick, and the light from the candle stick travels to students' eyes and then back to the candle stick again.

For the eye problem concept, the researcher let the students choose the answer and reason that could best explain what the eye problem was in the given picture. There was an increase in the percentage of scientific conceptions because students chose the right answer and reason. They thought that the eye problem in the picture was nearsightedness. When people get nearsighted, a diverging eyeglass lens is used to correct the condition. When the students put a diverging lens into the eyeglasses, this lens spread the light out before it got to the eye-lens. When the eye lens converged the light, the light converged on the back of the eye for proper focus. The percentage of scientific conceptions increased from 14 percent in the pretest to 48 percent in the posttest. However, fifty two percent of the students gave the wrong answer and reason about the eye problem. They thought that the given picture showed nearsightedness. When the students put a converging lens into the eyeglasses, this lens spread the light out before it got to the eye-lens, and when the eye lens converges the light, the light will now converge on the back of the eye for proper focus.

In summary, these findings indicate that there is an increase in the percentage of scientific conceptions regarding many concepts of light. These could result from the learning activities provided in the teaching unit. Chaichana increasingly developed a concern for the students' prior knowledge. He gave time to his students to discuss and share their ideas. During most of the activities, he used a meaningful context to help students to relate the concept to the real world. He also encouraged students by asking thoughtful and open-ended questions and when the students did not respond to his questions, he repeated, rearranged or added more questions. He gave the students a chance to construct their learning through interaction with their peers. Chaichana focused on the students' cooperative work. However, most of Chaichana's students were classified as having misconceptions about some concepts of light, especially the concept of image formation on a plane, curved mirror, lens, and optical instrument. This could result from the learning activities provided in these two lessons. For example, Chaichana had difficulty teaching the concepts of a curved mirror and he also skipped the concepts of optical instruments. The students were asked to do a group report about optical instruments instead of doing a group experiment.

Three Focused Students' Conceptions about Light before (pretest) and after (posttest) Implementation of the Light Learning Unit (LLU)

The three students' responses and explanations related to concepts of light were analyzed and divided into four categories: scientific conceptions (SC), partial scientific conceptions (PSC), misconceptions (MC), and No response (NR). The details of each student's conception of light are shown below.

Chadaporn's Conception of Light before (pretest) and after (posttest) the LLU Implementation

Table 6.26 shows Chadaporn's conception of light before (pretest) and after (posttest) implementing the LLU

Table 6.26 Chadaporn's conception of light before (pretest) and after (posttest) implementing the LLU

Concepts of Light	Sub Concepts	The Pre-Instruction Conceptions	The Post-Instruction Conceptions
Nature of light	Travel of light	Light can continue to travel until it is blocked by something.(SC)	Light can continue to travel until it is blocked by something.(SC)
	Light source	Light from a luminous object travels only as far as it can illuminate the area surrounding the luminous object.(MC)	Each point on a luminous object emits light in one direction.(MC)
	Media of light	Light can totally pass through a transparent object, and light can partially pass through a translucent object, but light cannot pass through an opaque object.(SC)	Light can totally pass through a transparent object, and light can partially pass through a translucent object, but light cannot pass through an opaque object.(SC)

Table 6.26 (Continued)

Concepts of Light	Sub Concepts	The Pre-Instruction Conceptions	The Post-Instruction Conceptions
	The image lies behind the mirror	An object has its image behind the surface of the mirror in a position in front of the observer.(MC)	The image lies behind the mirror and it is just as far behind the mirror as the actual object is in front of the mirror.(SC)
	The image is a left-right reversal	The image is a left-right reversal.(SC)	The image of an object is exactly the same as the actual object. (MC)
	Curved mirror 1	The image exists between 2f to infinity and the image would appear bigger than the actual object. (SC)	The image exists between 2f to infinity and the image would appear bigger than the actual object. (SC)
Image formation	Curved mirror 2	The focal length is 0.03 meters and they identify the curved mirror as a convex mirror.(MC)	The focal length is 0.03 meters and they identify the curved mirror as a convex mirror.(MC)
	Image formation by a lens 1	The focal length is 0.09 meters and they can determine that the lens is a converging lens and the magnification of the lens is 1/3.(SC)	The focal length is 0.09 meters and they can determine that the lens is a converging lens and the magnification of the lens is 1/3.(SC)
	Image formation by a lens 2	The image distance is 0.1 meters and they can determine that the image is a real image and the magnification of the lens is 2.(MC)	The image distance is 0.05 meters and they can determine that the image is a real image and the magnification of the lens is 2.(MC)
The refraction of light	The refraction of light 1	The image of a fish appears shallower than it should be because the speed of light through the water is slower than the speed of light through the air.(SC)	The image of a fish appears shallower than it should be because the speed of light through the water is slower than the speed of light through the air.(SC)

Table 6.26 (Continued)

Concepts of Light	Sub Concepts	The Pre-Instruction Conceptions	The Post-Instruction Conceptions
The refraction of light	The refraction of light 2	The image of a fish appears shallower than it should be because the speed of light through the water is slower than the speed of light through the air. (SC)	The image of a fish appears deeper than it should be because the speed of light through the water is faster than the speed of light through the air. (MC)
	The refraction of a prism	Purple is most refracted color and red is the least refracted color and the spectrum of a rainbow made by a prism is continuous and each color has its own exact boundary. (PSC)	Purple is most refracted color and red is the least refracted color and the spectrum of a rainbow made by a prism is continuous and each color has its own exact boundary. (PSC)
	Refraction when the incident light rays travel perpendicular to two media	Refraction still occurs because light travels from one medium to another medium, or there is the transmission of light from one medium to another medium. (MC)	The refraction of light does not occur, but the light will reflect to the opposite side. (MC)
Color	Color in white light	The color of an object is determined by the colored light it absorbs. (MC)	When someone sees the color black, light from the object doesn't reflect to his/ her eyes, and when someone sees the color white, the light rays from the object reflect all of it to his/her eyes. (SC)
	Colored object in colored light	The students would see themselves wearing green and black striped T-shirts with green caps under a green spotlight. (SC)	The students would see themselves wearing green and black striped T-shirts with green caps under a green spotlight. (SC)

Table 6.26 (Continued)

Concepts of Light	Sub Concepts	The Pre-Instruction Conceptions	The Post-Instruction Conceptions
Color	Color using a filter	The color of an object is the color of the light that is reflected by that object. (SC)	The color of an object is a physical property of that object. (MC)
	Seeing color	The students would see a white wall because all of the cone cells in the fovea of the eye are responsive. (MC)	The students would see a white wall because all of the cone cells in the fovea of the eye are responsive. (MC)
Optical Instruments	Telescope	The objective lens of the telescope makes a bigger image. (MC)	The objective lens of a telescope makes a bigger image. (MC)
	Microscope	The image from the microscope is big and the position of the real image formed by the objective lens is more than two focal lengths of the eyepiece lens. (MC)	The image from the microscope is big and the position of the real image formed by the objective lens is more than two focal lengths of the eyepiece lens. (MC)
	A comparison between a camera and the human eye	The image from a camera is the real image and smaller than the actual object, but the image from the human eye is a virtual image and smaller than the actual object. (MC)	Both the images from a camera and the human eye are real images, and smaller than the actual object. (SC)
Seeing	Seeing the candle flame	The reflected light from the candle flame travels to the students' eyes. (MC)	The reflected light from the candle flame travels to the students' eyes. (MC)
	Seeing the candle stick	The light from the candle flame shines to the candle stick and then reflects to the students' eyes. (SC)	The light from the candle stick travels to the students' eyes. (MC)
	The eye problem	The given picture shows nearsightedness. When the students put a converging lens into the eyeglasses, this lens spreads the light out before it gets to the eye-lens, and when the eye-lens converges the light, the light converges on the back of the eye for proper focus. (MC)	The given picture shows nearsightedness. When the students put a converging lens into the eyeglasses, this lens spreads the light out before it gets to the eye-lens, and when the eye-lens converges the light, the light converges on the back of the eye for proper focus. (MC)

While Chadaporn showed evidence of holding misconceptions about several concepts of light in pre-instruction, including the nature of light (light source), image formation by a plane, by a curved mirror, and by a lens (the image formation by plane mirror lies behind the mirror, convex mirror, and image formation by lens 2), the refraction of light (refraction when the incident light ray travels perpendicular to two media), color (color in white light and seeing color), optical instruments (telescopes, microscopes, and a comparison between a camera and the human eye), and seeing (seeing the candle flame and the eye problem). After instruction, many of Chadaporn's pre-instruction misconceptions were no longer apparent. Chadaporn’s conceptions changed from misconceptions to scientific conceptions in these areas: the concept of the image formation by a plane, by a curved mirror, and by a lens (the image formation by plane mirror lies behind the mirror), color (color in white light), and seeing (the comparison between a camera and the human eye). This was supported by Chadaporn’s worksheet that showed her understanding about the image formation by a plane mirror. She wrote that “the image by a plane mirror is behind the mirror and the distances of object and image are the same.” However, as Table 6.26 shows, Chadaporn still had misconceptions about some sub concepts of light.

Chalerm’s Conceptions of Light before and after the Implementation

Table 6.27 shows Chalerm’s conceptions of light before and after implementing the LLU.

Table 6.27 Chalerm’s conceptions of light before and after implementing the LLU

Concepts of Light	Sub Concepts	The Pre-Instruction Conceptions	The Post-Instruction Conceptions
The nature of light	Travel of light	Light can continue to travel until it is blocked by something.(SC)	Light only travel as far as it is visible. (MC)
	Light source	Light from a luminous object travels only as far as it can illuminate the area surrounding the luminous object.(MC)	Light from a luminous object travels only as far as it can illuminate the area surrounding the luminous object.(MC)

Table 6.27 (Continued)

Concepts of Light	Sub Concepts	The Pre-Instruction Conceptions	The Post-Instruction Conceptions
The nature of light	Media of light	Light can totally pass through a transparent object, and light can partially pass through a translucent object, but light cannot pass through an opaque object.(SC)	Light can totally pass through a transparent object, and light can partially pass through a translucent object, but light cannot pass through an opaque object.(SC)
Image formation	Image lies behind the mirror	The image of an object is on the mirror's surface.(MC)	The image lies behind the mirror and it is just as far behind the mirror as the actual object is in front of the mirror.(SC)
	The image is a left-right reversal	The image is a left-right reversal.(SC)	The image is a left-right reversal.(SC)
	Curved mirror 1	The image existed between the focal point (f) and 2f and the image would be the same size as the actual object.(MC)	The image exists between 2f to infinity and the image would be bigger than the actual object. (SC)
	Curved mirror 2	The focal length is 0.03 meters and they know that the curved mirror is convex.(MC)	The focal length is 0.03 meters and they know that the curved mirror is convex(MC)
	Image formation by lens 1	The focal length is 0.09 meters and they know that the lens is a converging lens and the magnification of the lens is 1/3.(SC)	The focal length is 0.09 meters and they know that the lens is a converging lens and the magnificent of the lens is 1/3.(SC)
	Image formation by lens 2	The image distance is 0.1 meters and they know that the image is a real image and the magnification of the lens is 2.(MC)	The image distance is 0.05 meters and they know that the image is a real image and the magnification of the lens is 2.(MC)

Table 6.27 (Continued)

Concepts of Light	Sub Concepts	The Pre-Instruction Conceptions	The Post-Instruction Conceptions
The refraction of light	The refraction of light 1	The refracted ray that correctly expresses the refraction of light when light travels from oil into water is bending toward the normal line. (MC)	The image of a fish appears shallower than it should because the speed of light through the water is slower than the speed of light through the air.(SC)
	The refraction of light 2	The image of a fish appears deeper than it should because the speed of light through the water is faster than the speed of light through the air. (MC)	The image of a fish appears shallower than it should because the speed of light through the water is slower than the speed of light through the air. (SC)
	The refraction of prism	Purple is the least refracted color and red is the most refracted color. (MC)	Purple is the least refracted color and red is the most refracted color. (MC)
	Refraction when the incident light ray travels perpendicular to two media	The refraction of light does not occur, but the light will reflect in the opposite direction. (MC)	The refraction of light does not occur, but the light will reflect in the opposite direction. (MC)
Color	Color in white light	The color of an object is a physical property of that object. (MC)	Black is the least refracted color and white is the most reflected color. (MC)
	Colored object in colored light	The students would see themselves wearing green and black striped T-shirts and green caps under a green spotlight. (SC)	The students would see themselves wearing green and yellow striped T-shirts with green caps under a green spotlight. (MC)

Table 6.27 (Continued)

Concepts of Light	Sub Concepts	The Pre-Instruction Conceptions	The Post-Instruction Conceptions
Color	Color using a filter	The filter reflects the color red to the eyes. (MC)	The color of an object is the color of the light that is reflected by that object. (SC)
	Seeing color	The students would see a green wall because the brain would recognize the color they had looked at the first time. (MC)	The students would see a purple wall because the students saw a green object for a long time, and it made the green cone cells in the fovea of the eye not responsive while the red and blue cone cells responded. (SC)
Optical Instruments	Telescope	The objective lens of the telescope makes a bigger image. (MC)	The objective lens of the telescope makes a bigger image. (MC)
	Microscope	The image from the microscope is big and the position of the real image formed by the objective lens is more than two focal lengths of the eyepiece lens. (MC)	The image from the microscope is big and the position of the real image formed by the objective lens is more than two focal lengths of the eyepiece lens. (MC)
	A comparison between a camera and the human eye	The image from a camera is the real image and smaller than the actual object, but the image a human eye is a virtual image and smaller than the actual object. (MC)	The image from a camera is the real image and smaller than the actual object but the image from the human eye is a virtual image and smaller than the actual object. (MC)

Table 6.27 (Continued)

Concepts of Light	Sub Concepts	The Pre-Instruction Conceptions	The Post-Instruction Conceptions
	Seeing the candle flame	The light from the candle flame travels to students' eyes. (SC)	The reflected light from the candle flame travels to the students' eyes. (MC)
Seeing	Seeing the candle stick	The light from the candle stick travels to the students' eyes. (MC)	The light from the candle stick travels to the students' eyes. (MC)
	The eye problem	The given picture shows nearsightedness. When the students put a converging lens into the eyeglasses, it spreads the light out before it gets to the eye-lens, and when the eye-lens converges the light, the light will converge on the back of the eye for proper focus. (MC)	The given picture shows nearsightedness. When the students put a diverging lens into the eyeglasses, it spreads the light out before it gets to the eye-lens, and when the eye-lens converges the light, the light will converge on the back of the eye for proper focus. (SC)

Chalerm showed evidence of holding pre-instruction misconceptions about several concepts of light. For example, the nature of light (light source), image formation by plane mirror, by curved mirror, and by a lens (the image formation by plane mirror lies behind the mirror, concave mirror, convex mirror, image formation by lens 2), the refraction of light (the refraction of light 1, the refraction of light 2, the refraction caused by a prism, the refraction when the incident light ray travels perpendicular to two media), color (color in white light, color using a filter, seeing color), optical instruments (telescopes, microscopes, and comparison between a camera and the human eye), and seeing (seeing the candle stick, the eye problem). Throughout the implementation phase of the study, Chalerm's conceptions changed from misconception to scientific conceptions concerning the concepts of image formation by a plane mirror, by a curved mirror, and by a lens (the image formation by plane mirror lies behind the mirror, concave mirror, convex mirror), the refraction of light (the refraction of light 1 and 2), and color (color using a filter and seeing color). This was supported by Chalerm's worksheet that showed his understanding about the refraction of light. He wrote that "the refraction of light when light travels from oil into water bends away from the normal line because the speed of light in water is less than that in water."

Chai's Conception of Light before and after the Implementation

Table 6.28 shows Chai's conception of light before (pretest) and after (posttest) implementing the LLU.

Table 6.28 Chai's conception of light before (pretest) and after (posttest) implementing the LLU

Concepts of Light	Sub Concepts	The Pre-Instruction Conceptions	The Post-Instruction Conceptions
Nature of light	Travel of light	Light travels until it is out of energy. (MC)	Light travels until it is out of energy. (MC)
	Light source	Light from a luminous object travels only as far as it can illuminate the area surrounding the luminous object.(MC)	Light from a luminous object travels only as far as it can illuminate the area surrounding the luminous object.(MC)
	Media of light	Light can totally pass through a transparent object, light can partially pass through a translucent object, but light cannot pass through an opaque object.(SC)	Light can totally pass through a transparent object, light can partially pass through a translucent object, but light cannot pass through an opaque object.(SC)
The image formation	Image lies behind the mirror	The image of an object is on the mirror's surface.(MC)	The image of an object is on the mirror's surface.(MC)
	Image is a left-right reversal	The image is a left-right reversal.(SC)	The image is a left-right reversal.(SC)
	Curved mirror 1	The image existed between the focal point (f) and 2f and the image would be the same size as the actual object.(MC)	The image existed between the focal point (f) and 2f and the image would be the same size as the actual object.(MC)

Table 6.28 (Continued)

Concepts of Light	Sub Concepts	The Pre-Instruction Conceptions	The Post-Instruction Conceptions
The image formation	Curved mirror 2	The focal length is 0.03 meters and they can tell that the curved mirror is a convex mirror.(MC)	The focal length is 0.03 meters and they can tell that the curved mirror is a convex mirror.(MC)
	Image formation by lens 1	No Response (NR)	No Response (NR)
	Image formation by lens 2	The image distance is 0.1 meters and they can tell that the image is a real image and the magnification of the lens is 2.(MC)	The image distance is 0.05 meters and they can tell that the image is a real image and the magnification of the lens is 2.(MC)
The refraction of light	The refraction of light 1	The correct refracted ray that expresses the refraction of light when light travels from oil into water is bending toward the normal line. (MC)	The correct refracted ray that expresses the refraction of light when light travels from oil into water is bending toward the normal line. (MC)
	The refraction of light 2	The image of a fish appears deeper than it should because the speed of light through the water is faster than the speed of light through the air. (MC)	The image of a fish appears shallower than it should because the speed of light through the water is slower than the speed of light through the air. (SC)
	The refraction of prism	Purple is the least refracted color and red is the most refracted color. (MC)	Purple is the least refracted color and red is the most refracted color. (MC)
	Refraction when the incident light ray travels perpendicular to two media	The refraction of light does not occur, but the light will reflect in the opposite direction. (MC)	The refraction of light does not occur, but the light will reflect in the opposite direction. (MC)
Color	Color in white light	The color of an object is a physical property of that object. (MC)	Black is the least refracted color and white is the most reflected color. (MC)
	Color object in color light	The students would see themselves wearing green and yellow striped T-shirts and green caps under a green spotlight. (MC)	The students would see themselves wearing green and yellow striped T-shirts and green caps under a green spotlight. (MC)

Table 6.28 (Continued)

Concepts of Light	Sub Concepts	The Pre-Instruction Conceptions	The Post-Instruction Conceptions
Color	Color using a filter	The function of a filter is to change the color of the transmitted light. (MC)	The color of an object is the color of the light that is reflected by that object. (SC)
	Seeing color	The students would see a purple wall because they had seen a green object for a long time, which caused the green cone cells in the fovea of their eyes to not respond, while the red and blue cone cells responded. (SC)	The students would see a purple wall because they had seen a green object for a long time, which caused the green cone cells in the fovea of their eyes to not respond, while the red and blue cone cells responded. (SC)
Optical Instruments	Telescope	The objective lens of a telescope makes a bigger image. (MC)	The objective lens of a telescope makes a bigger image. (MC)
	Microscope	The image from a microscope is big and the position of the real image formed by the objective lens is more than two focal lengths of the eyepiece lens. (MC)	The image from a microscope is big and the position of the real image formed by the objective lens is more than two focal lengths of the eyepiece lens. (MC)
	The comparison between a camera and the human eye	The image from a camera is a real image and is smaller than the actual object, but the image from the human eye is a virtual image and is smaller than the actual object. (MC)	The image from a camera is a real image and is smaller than the actual object, but the image from the human eye is a virtual image and is smaller than the actual object. (MC)
Seeing	Seeing the candle flame	The light from the candle flame travels to the students’ eyes. (SC)	The reflected light from the candle flame travels to the students’ eyes. (MC)
	Seeing the candle stick	The light from the candle flame shines on the candle stick and then reflects to the students’ eyes. (SC)	The light from the candle flame shines on the candle stick and then reflects to the students’ eyes. (SC)

Table 6.28 (Continued)

Concepts of Light	Sub Concepts	The Pre-Instruction Conceptions	The Post-Instruction Conceptions
Seeing	The eye problem	The given picture shows nearsightedness. When the students put a converging lens into the eyeglasses, the lens spreads the light out before it gets to the eye-lens, and when the eye-lens converges the light, the light converges on the back of the eye for proper focus. (MC)	The given picture is nearsightedness. When the students put a diverging lens into the eyeglasses, this lens spreads the light out before it gets to the eye-lens, and when the eye-lens converges the light, the light converges on the back of the eye for proper focus. (SC)

Before teaching the concepts of light, Chai showed evidence of holding misconceptions regarding several concepts except the concept of the nature of light (media of light), image formation by a plane mirror, by a curved mirror (image is a left-right reversal and image formation by lens 1), color (seeing color), seeing (seeing the candle flame, seeing the color stick). Three pre-instructional misconceptions were no longer apparent and they became scientific conceptions. These three conceptions were the refraction of light 2 (the refraction of light 2), color (color using a filter), and seeing (the eye problem). This was supported by Chai's worksheet that showed his understanding about color. He wrote that "the color of an object is the color of the light that is reflected by that object." However, Chai still had many misconceptions.

In conclusion, students showed scientific conceptions about light in all six categories: the nature of light, image formation by a plane mirror and lens, curved mirrors, refraction of light, optical instruments, color, and seeing. These findings imply that the implementation the Light Learning Unit (LLU) enhances students' scientific understanding of the concepts of light.

Summary of Chaichana's Case

Chaichana implemented the Light Learning Unit (LLU) as suggested. He used a meaningful context to help students develop the concepts in the real world, gave the students an opportunity to construct their learning through interaction with their peers, focused on the students' cooperative work, and used various kinds of teaching strategies in his teaching practice. He increased his focus on his students' prior knowledge and encouraged students by asking thoughtful, open-ended questions. Consequently, some student's conceptions were improved. However, during his implementation, he skipped some lessons and activities. This might be the reason for his students' lack of knowledge on some topics, particularly optical instruments. It was very clear from the findings that the teaching was important in assisting students' learning. He skipped this lesson, because the activities in the lesson took too much time. Because of this, he asked the students to do a report on this concept. In this lesson, there were hands-on and minds-on activities that would have helped the students to understand concepts about optical instruments, including telescopes, microscopes, and cameras. Skipping this lesson probably affected the students' understanding of this topic. Moreover, he had difficulties with the content knowledge regarding the drawing of the ray diagram of a concave mirror, and the critical angle and total internal reflection. Chaichana and his students enjoyed teaching and learning about light using the LLU even though he did not agree to take the time to let his students design the experiment.

Cross Cases Study

This section focuses on a cross case study of three cases in this study including teachers' implementation of the Light Learning Unit (LLU), teachers' perceptions on teaching, students' perceptions on teacher's teaching, and students' conceptions of light are discussed to generate common findings. The details of cross case studies are discussed below.

Teachers' Implementation of the LLU

Different teachers implemented the LLU differently. Some teachers implemented the unit by following the teacher manual. Some of them adapted learning activities to be more appropriate for their students. Some of them skipped some activities or lessons. These differences existed because the teachers were individually different in terms of teaching styles, and their content knowledge. Therefore, they had different ways of implementing the LLU. For example, in this study, the three teachers, Sompong, Pranee, and Chaichana, had different teaching styles. Even though Sompong believed in constructivism, he usually taught science using teacher-centered learning. He thought that it was an important part of the teacher's role to offer all of his knowledge to his students. He also said that his students did not pay attention. Therefore, he often used a lecturing technique for teaching his students, instead of letting the students construct their own knowledge. Pranee usually taught her students by letting them do a report before they learned the concept. Then, she let her students do the experiment and asked them to think about the differences and similarities between the report they did and the results from the experiment. Chaichana usually taught the students by giving them some knowledge, and then he let his students do the experiment and a presentation.

When these three teachers implemented the LLU, it was obvious that Sompong and Chaichana seemed to follow the teacher manual. Their teaching practices were consistent with a social constructivist teaching approach. For example, they employed a variety of teaching strategies in their teaching practices, e.g. focusing on students' prior knowledge, using a meaningful context to help students develop the concept in the real world, encouraging students by asking thoughtful and open-ended questions, giving the students an opportunity to construct their learning through interaction with their peers, and focusing on the students' working cooperatively. They employed various kinds of assessment strategies. However, Pranee followed some activities in the LLU. She tended to be teacher-centered because she did not give the students a chance to discuss and she usually asked the students for an answer, and then she moved to other questions without talking or asking for the reasons behinds the students' answers. She usually asked simple yes or no questions. She hardly ever allowed students to present their reports, because there was not enough time in class and she usually made conclusions of the experiments by herself if the students could not make their own conclusions. When students in each group cooperatively did the experiment about the refraction of light, she rarely walked around from group to group to help her students and she never explained the procedure of the experiment to her students. She often told the students the conclusions of the experiment or activities more than asking them to figure them out on their own in their groups.

The three teachers had various reasons for what they did while they implemented the LLU. Sompong usually followed the instructional unit step by step. Many times, before he went to the classroom, he asked the researcher about the concepts or activities that he did not understand. In contrast, Pranee never asked the researcher about the concepts or activities that she did not understand. So, when she was teaching her students, she usually stopped teaching and read the manual to gain understanding. Moreover, she walked to the researcher and asked about particular concepts or activities that she did not understand. Chaichana sometimes asked the researcher before going to the classroom about the concepts or activities that he did not understand. Apparently, during implementation, Pranee and Chaichana had some trouble with some concepts or activities. Pranee did not understand the refraction of light. She told the students that the activity demonstrated refraction when light travels from air to water. Then, she asked students if the ray diagram of the refraction of light is different if light travels from water to air. She asked the students to observe a pen in a glass filled with water from the bottom of the glass. Moreover, Pranee was not aware of using misconceptions during her explanations of the reflection of light. For example, when discussing image formation from a plane mirror, she and her students used the word "shadow" to refer to "the image or reflection". For example, "have you ever looked at yourself in a plane mirror? Do you see your shadow on the mirror? And how do you describe what you see?" Chaichana did not understand how to draw the ray diagram of the concave mirror because he did not understand the property of a concave mirror: when light from the object travels to a concave mirror, the reflected ray is diverted from the mirror. Moreover, he was not clear about the total internal reflection because he incorrectly told the students that the critical angle is the angle that makes a total internal reflection instead of telling them that increasing the angle of incidence above the critical angle will result in total internal reflection.

However, classroom observations showed that Sompong and Chaichana's teaching practices were consistent with a social constructivist teaching approach because they took the roles of social constructivist teachers. They observed and intervened during in-class group work, asked open-ended questions during in-class group work, praised and gave encouragement during in-class group work, extended participation and involved group members, facilitated student responsibility and self-evaluation, promoted student learning of social skills, and encouraged the students to reach their potential. These roles were consistent with the goal of the National Education Act B.E.2542 (1999) and the National Science Content Standards (IPST, 2002) which require that Thai teachers should provide training in thinking processes, management, and how to face various situations. Teachers should teach students to apply knowledge for obviating and solving problems and organize activities for learners to draw from authentic experiences. Teachers should drill students on practical work for complete mastery, enable learners to think critically, acquire the reading habit, and develop a continuous thirst for knowledge.

In focusing on the students' prior knowledge, Sompong and Chaichana tried to ask thoughtful and open-ended questions. They also encouraged students to discuss and share their ideas. Moreover, she asked related questions to help them apply what they had learned in school to real situations. These probing questions promoted students' critical thinking skills. By contrast, Pranee asked the students yes or no questions, guided, and plain questions. She rarely allowed students to discuss and share ideas.

In using a meaningful context to help students to develop the concepts in the real world, Sompong and Chaichana helped the students to develop the concepts and encouraged the students to relate them to real life situations. An example of this was the case of Sompong. Sompong first let the students look at the plane mirror and discussed what the students saw in the mirror, what the reflection looked like, and where the reflection existed. Then, he asked the students to solve a real situation problem that was related to the reflection of light by a plane mirror. He helped the students to develop ideas about the reflection of light. By contrast, Pranee rarely allowed students to share and discuss. She just asked questions and waited for the students' answers. When the students answered, she asked the next question. She rarely helped the students to develop the concepts or encouraged the students to relate concepts to real life situations. When students did experiments working cooperatively in groups, Pranee rarely walked around from group to group to help her students.

Sompong and Chaichana gave the students an opportunity to construct their learning through interaction with their peers, and focused on the students' cooperative work. They also explained the procedure of the experiment to the students. While the students' worked in groups, Sompong and Chaichana extended their participation and were involved as group members. They walked from group to group to help the students. They encouraged students by asking thoughtful, open-ended questions. In contrast, even though Pranee gave the students an opportunity to construct their learning through interaction with their peers and focused on the students' cooperative work, she did not explain the procedure of the experiment to the students. Moreover, while the students worked in groups, she never extended her participation and got involved as a group member. She rarely walked from group to group to help the students.

During the implementation of the LLU, there were many days off which shortened the teaching time. For example, all students had to take the National Test for two days. Before taking the National Test, they prepared for the test for one week. The students had to attend the school sports competition day. The teacher was asked to attend a workshop for a week so his students did not learn science during that time. The teacher was sick for a week and his students did not learn science again. These days off were generally unanticipated. The teachers all faced time constraints. The schedule had become extremely tight. The teachers felt stressed. Some of them had to set up extra time to compensate for the time off, while some decided to skip the activities and employed lecturing to summarize the key ideas of the lessons.

Teachers' Perceptions on Teaching

All teachers from the three schools thought that the students enjoyed doing some activities in the LLU and the students paid more attention to the lesson which made teaching easier. Sompong said that he had changed his teaching strategy from transmitting the knowledge to his students to letting his students construct their own knowledge from the group experiments. However, Chaichana did not agree with the activities where the students designed the experiments. He thought that these activities took much time.

Students' Perceptions of Their Teacher's Teaching

Most of the students from the three schools paid more attention to the lesson when learning with the Light Learning Unit (LLU). Most of students understood and did the activities in the LLU. They understood the activities and could do them smoothly and enjoyably. The students felt the LLU could help them understand the concept of light. Most of the students were interested in doing activities. They thought that the LLU activities were helpful. The students also enjoyed working and discussing in groups. The activities gave them a clear understanding of abstract and difficult concepts.

Students' Conceptions of Light from the Implementation of the LLU

Students' conceptions of light were examined after the implementation of the LLU. The concepts of light included the nature of light, images, optical instruments, color, and seeing. Following are the details of the students' understanding of each concept of light.

Regarding the concept of the nature of light, the results showed that there was an increase in the percentage of scientific conceptions held by the students from the three schools concerning the sub concepts of light sources and media of light. In Sara school, the concepts where most students (more than 50 percent) held scientific conceptions were light sources, travel of light, and media of light, respectively. In Pattana School, the concepts where most students (more than 50 percent) held scientific conceptions were travel of light, and media of light, respectively. In Charoen School, the concept where most students (more than 50 percent) held a scientific conception was the travel of light. However, some students in all three schools still had misconceptions about the concept of the nature of light. Misconceptions were mostly found in Pattana School and Charoen School, especially on the topics of the nature of light (light source).

Regarding the concept of image formation, the results showed that there was an increase in the percentage of scientific conceptions held by the students of the three schools regarding some sub concepts about image formation (the image formation by a plane mirror lies behind the mirror and the image is a left-right reversal). In Sara School and Charoen School, most students (more than 60 percent) held scientific conceptions of image formation by a plane mirror (image is a left-right reversal). In Pattana School, most students (more than 40 percent) held scientific conceptions of image formation in a plane mirror (image is a left-right reversal). However, some students in all three schools still had misconceptions about the concept of image formation. Misconceptions were mostly found in all schools, especially regarding the concept of image formation by a curved mirror.

Regarding the concept of the refraction of light, the results found that there was an increase in the percentage of scientific conceptions held by the students of Sara School and Charoen School about some sub concepts concerning the refraction of light (refraction of light1 and 2). Some students in these two schools still held misconceptions about all sub concepts about the refraction of light. Misconceptions were mostly found in all schools, especially regarding the concept of an image formation by a curved mirror. In contrast, in Pattana School, there was an increase in the percentage of scientific conceptions held by the students about one sub concept, the refraction of light (the refraction of a prism), but most students held misconceptions about all sub concepts.

Concerning the concept of color, the results found that there was an increase in the percentage of scientific conceptions held by the students of Sara School in all the sub concepts of color. In this school, there was only one concept where most students held scientific conceptions about color (seeing color). In Pattana School, there was an increase in the percentage of scientific conceptions held by the students in two sub concepts of color. In this school, there was only one concept where most students held scientific conceptions about color (colored object in colored light). In contrast, in Charoen School, even though there was an increase in the percentage of scientific conceptions held by the students in all sub concepts about color, most of the students held misconceptions about all sub concepts.

Regarding the concept of optical instruments, the results from Sara School and Charoen School showed that there was an increase in the percentage of scientific conceptions held by the students. However, most students held misconceptions about many sub concepts. In Pattana School, there was an increase in the percentage of scientific conceptions held by the students in only one area, the sub concept about optical instruments (the comparison between a camera and the human eye).

Concerning the concept of seeing, even though there was an increase in the percentage of scientific conceptions held by the students in Sara School and Charoen School in all sub concept areas of seeing, most of the students held misconceptions in all sub concepts areas. In contrast, in Pattana School, there was an increase in the percentage of scientific conceptions held by the students in two sub concept categories, but most students held misconceptions in only one sub concept area.

Summary

The Light Learning Unit (LLU) is based on a social constructivist approach and was implemented by three participant teachers in three schools under the Bangkok Metropolis Administration (BMA). The teachers implemented the LLU differently based on their teaching styles. The implementation process provided the teachers with an opportunity to improve their content knowledge and teaching strategies. The findings from the implementation of the unit indicated that all of the teachers were happy with their teaching and felt that the LLU helped their students to enjoy doing some of the activities in the LLU, and that the students paid more attention to the lessons, making it easier for the teacher to teach. They also found that the LLU promoted students' understanding of the concepts of light. Most students were interested in doing the activities and enjoyed them. The findings from the concept test from the three classroom students also indicated that the students could understand some concepts of light.

In the next chapter, a review of the overall research, discussions, conclusions, implications, and recommendations will be discussed.

CHAPTER VII

CONCLUSIONS, DISCUSSIONS AND IMPLICATIONS

Introduction

This chapter focuses on the conclusions and a discussion of the research findings and the implications of the study. The research framework is reviewed in terms of the research purposes, questions, and methodology. Then, a discussion and the conclusions of the study are described in each phase. In the first phase, the findings from the teaching and learning about light and students' conceptions about light are discussed. In the second phase, the unit design and development is discussed. In the third phase, the three teachers' implementation of the Light Learning Unit (LLU), and students' conceptions of light after the implementation of the LLU in the 2007 academic year are also discussed. At the end of the chapter, the implications of the study are examined.

Review of the Research Framework

This study aimed to investigate the effects of the implementation of the Light Learning Unit (LLU) which is based on a social constructivist approach and was designed to enhance the instruction and learning of the concept of light. This study employed an interpretive methodology and a case study design that was divided into three phases: an exploratory phase, design and development of the unit, and implementation and evaluation of the unit. In the first phase, the teaching and learning about light and students' conceptions about light were investigated. The participants were thirty seven science teachers in schools under the Bangkok Metropolis Administration (BMA). Science teachers completed the questionnaire in November 2005 and three of thirty seven teachers were selected to be interviewed. The Light Diagnostic Test (LDT) was administered to114 students of the three selected teachers in November 2006 in schools under the Bangkok Metropolitan Administration (BMA) in the academic year 2005. The implications of the findings of the exploratory phase, the content guidelines from the National Science Curriculum Standards, successful teaching strategies from previous research, and the Thai educational context were used as guiding principles in designing and developing the unit in the second phase of the study which lasted from March to November 2007. In the final phase, the unit implementation and evaluation, the unit was implemented in three schools by three science teachers in December 2007, during the second semester of the academic year 2006. All three of the teachers had participated in the first phase of the study. In this phase, the implementation of the LLU by the teachers and the effects of the unit on students' understanding of light were investigated. A case study with multiple data gathering methods was employed for the third phase. The research framework is presented in Figure 7.1.

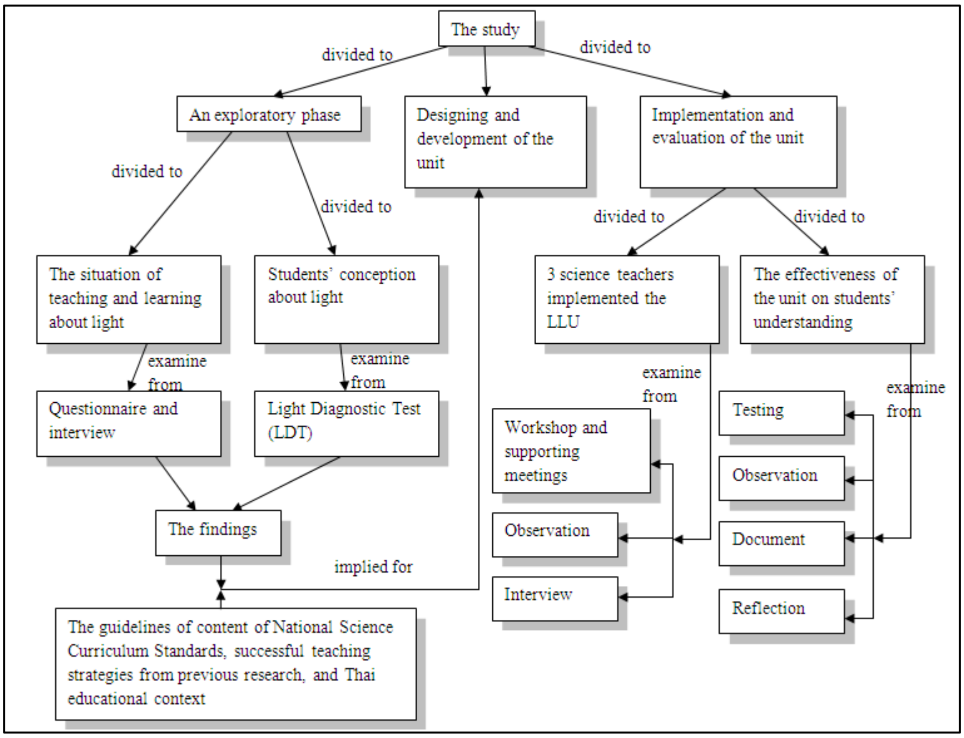


Figure 7.1 The research framework

Conclusions and Discussions of the Study

The conclusions and a discussion of this study regarding the research questions are organized into four sections. First, the current state of teaching and learning the concept of light is described. Second, the students' understanding of the concepts of light is illustrated. Third, the implementation of the Light Learning Unit (LLU) by the three teachers is described. Finally, the students' understanding of the concepts of light after implementing the LLU is also described.

First Phase: Exploratory Phase

The Current State of Teaching and Learning the Concept of Light

Findings from a teacher questionnaire and in-depth interviews about the current state of teaching and learning the concept of light indicate that teaching the concept of light in the academic year 2005 was not consistent with the National Education Act (ONEC, 1999) in many ways. In terms of curriculum and the use of textbooks, most of the teachers followed the curriculum and used textbooks from the Institute for the Promotion of Teaching Science and Technology (IPST.). Regarding teaching preparations, the result of this research is consistent with the research of Meinoratha (1997) which found that science teachers spent approximately 2-10 hours a week preparing to teach by studying the content in the textbook and in the teacher's manual. Preparation is important because it gives teachers more confidence when they teach. But this research is not consistent with the study of Rodlong (1986) which found that the majority of teachers, 57.1 percent, didn't spend time preparing because they had many other responsibilities and tasks.

To start the lessons, the results indicated that teachers reviewed the concepts from the previous period. The teachers didn't connect the students' prior knowledge to the new concepts. Consideration of prior knowledge, and hands on and minds on activities can help the students to gain a better understanding of concepts and results from experiments. This result is the same as the study of Tinsandee (2004), Pulputsa (2004) and Taraban et al. (2006).

The use of teaching methods was consistent with the research of Meinoratha (1997) and Rodlong (1986). The teachers used lectures, demonstrations, and experiments.

Considering measurement and evaluation, the results of this research are consistent with the research of Meinoratha (1997) and Chotisoot (2003) which found that science teachers used various kinds of assessments including pretests and posttests, students' homework or notebooks, lab reports, student presentations, assignments, reports, and student tasks. The use of various kinds of assessment is consistent with IPST (2002) which stated that science should assess both knowledge and process skills as well as students' attitudes towards science. Moreover, this study was consistent with Jonassen (1992) which said that measurement and evaluation should be part of the process of teaching. So, the use of a variety of assessments helps to increase learning (Black and Wiliam, 1998; White and Frederiksen, 1998).

Regarding the problems and needs of teachers, teachers needed equipment, materials, and learning resources. The results of this research were consistent with the research of Meinoratha (1997) and Rodlong (1986) which found that science teachers needed equipment, materials, and learning resources. Concerning the problems encountered when teaching the concepts of light and the needs of teachers, most teachers had a lack of content knowledge, new teaching strategies, equipment, materials, and learning resources. Moreover, the most difficult concept of light to teach was image formation from a mirror and lens. Most of teachers needed to know more about content knowledge and writing lesson plans. The concepts of light that they needed to know more about were image formation from a mirror and lens, the application of refraction of light, and the refraction of light. The teachers also needed to know more about new teaching strategies and they needed more equipment, material, and learning resources.

In summary, teaching and learning the concept of light was most likely based on memorization of the teachers' lectures. The teachers didn't use discussion and didn't give the students an opportunity to construct their own knowledge. The factors that impeded teachers' teaching the concept of light included a lack of content knowledge, teaching strategies, equipment, materials, and learning resources. The teaching strategies that the teachers had been using could not help their students to develop scientific conceptions of the concept of light.

The Students' Understanding of the Concept of Light

From the diagnostic test results, it was found that the majority of students had difficulties in understanding the concept of light. The students did not have a scientific understanding of the fundamental concepts. In the case of the concept of the nature of light, most of the students held misconceptions in all sub concepts. The students' misconceptions about the travel of light are consistent with the findings of Andersson and Karrqvist (1983) and Sangsupata (1995). These studies found that the students explained that light only travels as far as it is visible, light travels as far as possible, and light continues to travel until it is out of energy. For the concept of light source, the students' misconceptions were consistent with the findings of Sangsupata (1995) which stated that students thought that light is an entity which is located in space (the region around the light source), and light goes outward only in a radial direction. The students' misconceptions may have come from their experiences and explanations of their observations. Moreover, the concept regarding light rays is an abstract concept (Donovan and Bransford, 2005). So, imagination is required to understand this nature of light concept.

For the concept of the image formation by mirrors and lenses, it was found that students had the most misconceptions regarding plane mirrors, lenses, and curved mirrors respectively. The students' misconceptions about image formation by a plane mirror are consistent with the findings of Goldberg and McDermott (1986) and Sangsupata (1995). The students in these studies explained that the image formed by a plane mirror is on the mirror instead of behind it. They did not understand about left-right reversal. All of the misconceptions that students held may have come from their instruction, so the teacher should be careful when he/she explains a particular concept, or the students use their experiences to explain what they have seen. For the concept of image formation by a lens, the students' misconceptions coincided with the study of Goldberg and McDermott (1987).

For the concept of the refraction of light, it was found that most students had misconceptions about refraction from a prism, refraction when the incident light rays travel perpendicularly, and refraction, respectively. The students' had a misconception about the refraction of light: they did not understand that when light travels from one medium to another media, refraction occurs. Because refraction is a phenomenon that was close to students, they did not notice what was going on. For example, most of the students thought that when they observed a fish, the image of the fish was deeper than it should be.

Regarding the concept of color, it was found that most students had misconceptions about color in white light, the color by eye problem, color by a filter, and a colored object in colored light, respectively. The students' misconceptions about color are consistent with the findings of Salley (1996). The students thought that color is stimulated by a particular object to the observer's eyes or color comes from an object and also from light. The students held misconceptions because they used their experiences to explain what they had seen and they did not understand the fundamental concept. The students did not understand the reflection of light and the connection between the reflection of light and color. Reflected light rays may be an abstract concept.

Concerning the concept of Optical Instruments, it was found that most students had misconceptions regarding a comparison between a camera and the human eye, microscopes, and telescopes, respectively. The students held misconceptions because they used their experiences to explain what they had seen and they did not understand the fundamental concepts. For example, the students did not understand the concept of image formation by a mirror and lens and the connection between image formation by a mirror and lens and an optical instrument.

For the concept of seeing, it was found that most students had misconceptions about the eye problem, candle sticks, and seeing the candle flame respectively. The students held misconceptions because they did not understand the fundamental concepts. For example, if students do not understand the reflection of light, the students may not understand the concept of seeing. The students' misconception about seeing is consistent with the findings of Andersson and Karrqvist (1983), Ramadas and Driver, (1989) and Osborne, Smith, and Meadows (1993). The students in these studies thought that there was light from the eyes to the object instead of reflected light from that object bouncing into the observer's eyes.

In summary, the majority of students had misconceptions regarding the concept of color, the refraction of light, and image formation by mirrors and lenses. Many concepts about light are connected to each other. For example, the concept of optical instruments is connected with the concept of an image formation by mirrors and lenses. The concept of seeing is connected with the reflection of light. The students should understand the fundamental concept first, and then they will understand the advanced or more complicated concepts.

Second Phase: Unit Design and Development Phase

In the second phase, the Light Learning Unit (LLU) was designed and developed. The LLU is the unit for the teaching of light in Grade 8 science. The purpose of this learning unit is to enhance the scientific understanding of light. The design and development of the unit was guided by the teaching and learning of light and students' conceptions about light from the first phase of the study, the content guidelines from the National Science Curriculum Standards, teaching strategies from previous research, and the Thai educational context.

The content of light was divided into eight lessons on the topic of light: the nature of light, the reflection of light, curved mirrors, the refraction of light, image formations by lenses, optical instruments, color, seeing, and light intensity. The LLU takes twenty hours to complete. Each lesson plan contains information about the main concept, learning outcomes, instructional procedures, instructional materials, worksheets, and suggestions on formative assessment. In each lesson of the LLU, the students engage in a variety of hands on activities which ask them to be actively involved in the activities. The activities in all lessons used social interaction between the teacher and students and students and students. Group work, and group and whole class discussion are the main strategies of the unit.

Third Phase: Intervention Implementation and Evaluation Phase

The Implementation of the Light Learning Unit (LLU)

Each of the three teachers implemented the LLU differently. Two of them followed the teaching manual, but one did not. At the beginning of the implementation, one teacher felt worried and he seemed to have some stress when he taught the lesson because the LLU was quite different from his teaching style in previous years. However, in later weeks, he felt more comfortable and free teaching with the LLU and was able to adapt his teaching style to the LLU. In contrast, the other two teachers were not concerned about implementing the LLU.

While the three teachers were implementing the LLU, two teachers usually assessed students' prior knowledge by asking them questions. Their teaching strategies focused on cooperative group work. They also prepared hands-on and minds-on activities that allowed students to think about and discuss concepts with their peers in small groups. The classroom observations confirmed that students' understanding was enhanced by working in groups. The students were given time to discuss their findings and make conclusions within their groups and within the whole class. This helped students to understand the concepts they studied. Surprisingly, this study found that one teacher who was not familiar with social constructivism had a very strong impact on the implementation. For example, Sompong used lectures as his main teaching strategy before implementing the LLU. While Sompong was implementing the LLU, he was nervous about teaching the lessons, but he followed the instructional units step by step. He also used all of the instructional media and materials and often used all of the questions to determine the students' prior knowledge.

Chaichana also followed the activities in the teaching manual. He developed a better understanding among students by focusing on their prior knowledge. Although he skipped asking the suggested questions to assess students' prior knowledge in the first week of implementation, he followed the teaching manual more carefully in the following weeks. He used all of the suggested questions to determine the students' prior knowledge.

In contrast, Pranee did not follow the LLU, but focused on giving her students her conclusions. Pranee rarely allowed students to share and discuss their ideas. She just asked and waited for the students' answers. When the students answered, she asked the next question. Moreover, she emphasized written reports and rarely allowed students to present their reports to the class because there was not enough time. Therefore, she skipped some activities in the LLU.

Some teachers aligned their teaching with the LLU by focusing on a social constructivist approach. Many times, before the teachers entered the classroom, they asked the researcher about the concepts or activities that they did not understand. This means that they prepared themselves before teaching. For example, Sompong became more capable of formulating his own questions. On the other hand, Pranee did not employ a social constructivist approach in her class because she believed that there was not enough time for preparation and doing activities. (See in Pranee's case).

This study revealed that all teachers needed to finish the lessons. They said that some activities and the process of class discussions took a long time, so they skipped them. Some of them had to set up extra time to compensate, while some teachers decided to skip the activities and employed lecturing to summarize the key ideas of the lessons. Some of the teachers asked their students do reports.

The teachers had a chance to attend a workshop before implementing the LLU. The first workshop was set up to discuss light concepts and teaching strategies mentioned in the Light Learning Unit (LLU), and to discuss how each teacher implemented it. The feedback and comments from the teachers on the LLU were used for improvement of the LLU. The second and third workshops were set up to help teachers reflect upon their own thinking and teaching. These workshops provided opportunities for the teachers to develop both their content knowledge and teaching strategies. Moreover, about 15-30 minutes before starting the lesson, some of the teachers asked the researcher about concepts or activities that they did not understand. So, they implemented the LLU with confidence and they had no problems with the content knowledge or with understanding the activities. These findings were confirmed by Harlen (1999) who suggested that teachers benefit from discussing their teaching with experts or other teachers to develop their understanding of science and teaching science.

The Effect of the Implementation of the Light Learning Unit (LLU) on Students' Understanding of the Concept of Light

The occurrence of misconceptions before implementing the LLU is not surprising because there are many research studies with similar findings. There was evidence of students holding misconceptions about light in the pre-instructional activities. For example, students believed that a plane mirror image is located on the mirror surface, the object has its image behind the surface of the mirror in a position in front of the observer, and the image of an object is exactly the same as the actual object. There was consistency in the misconceptions including: light travels until it is out of energy, each point on a luminous object emits light in one direction, light from a luminous object travels only as far as it can illuminate the area surrounding the luminous object, and the color of an object is a property of that object.

The implementation of the LLU was successful in changing the students' understanding of the concept of light. Much of this success may be attributed to social constructivist approaches. Such approaches, which involve addressing the prior knowledge of the students, may have been an important factor in changing the students' understanding of light. The findings indicated that Sompong was the most successful in implementing the LLU to enhance students' conceptions about light, followed by Chaichana, and Pranee. Their success in implementing the LLU was also influenced by their own ability to understand the social constructivist approach, their personal habits, the level of their content knowledge, their perceptions of students' abilities, and their comfort levels in implementing the LLU.

When comparing the teachers, two main points were observed. First, their ability to understand the social constructivist approach, their personal habits, and their comfort level in implementing the LLU influenced their implementation of the LLU. In Sompong's case, even though he believed in constructivism, he usually taught science using a teacher-centered approach to learning. He also said that his students did not pay attention, so he often used a lecturing technique to teach his students. He believed that lectures promoted students' understanding of the subject matter, and that lectures were more suitable for his students. Sompong made an attempt to prepare LLU lessons. He loved to try new approaches. So, when he implemented the LLU, he employed a variety of teaching strategies. For example, he focused on students' prior knowledge, used a meaningful context to help students develop the concepts in the real world, encouraged students by asking thoughtful and open-ended questions, gave the students an opportunity to construct their learning through interaction with their peers, and focused on the students' cooperative work, and he employed various kinds of assessment strategies.

Second, teacher content knowledge also influenced their implementation. Sompong, who had more content knowledge than the others, did not have a problem with the content because he always prepared his lessons before teaching his students. If he had a problem, he asked the researcher before teaching his students. In contrast, Pranee and Chaichana had some trouble with some of the concepts. Pranee did not understand the refraction of light and was not aware of using misconceptions when she explained reflection of light concepts. Chaichana did not understand how to draw a ray diagram of a concave mirror because he did not understand the properties of a concave mirror. Moreover, he was not clear about the concept of total internal reflection and taught the students the wrong concept. This is consistent with the findings of McDiarmid, Ball, and Anderson (1989) which found that teachers who had strong content knowledge had the capability formulate their own questions and evaluate their students' understanding.

In contrast to the success experienced when changing the students' understanding of light through the implementation of the LLU, there were some difficulties and some of the students' misconceptions were not changed. These concepts related to the nature of light, refraction, the color of objects, and image formation in plane mirrors and convex lenses.

Chadaporn, Chalerm, and Chai, all focused students in Charoen School, still held misconceptions about the sub concepts of light sources. A possible factor in the existence of the misconception regarding a light source is that light is emitted in only one direction from each point on the luminous source. The students were not taught that a luminous object is an aggregate of point sources rather than an integrated whole. The solution is to help students realize that each point on the light source is emitting light in the same manner as individual point sources do so.

Regarding the misconceptions about image formation, in Sara and Charoen schools, most students (more than 60 percent) had scientific conceptions of an image formation in a plane mirror. In Pattana School, most students (more than 40 percent) had scientific conceptions of an image formation in a plane mirror. However, some students in all three schools still had misconceptions about the concept of image formation. Misconceptions were found in all schools, especially concerning the concept of image formation in a curved mirror and lens. A possible factor in the existence of the misconceptions about image formation in a curved mirror and lens was the teachers' lack of content knowledge.

The problem associated with refraction rays was the students' failure to correctly explain the path that light follows in passing from one medium to another medium when the incident light ray travels perpendicular to two media. The students tended to use the same rule for the predicted light path. All three focused students from Sara and Charoen schools still held misconceptions. Two of the three focused students from Pattana School also held misconceptions. They still thought that refraction occurs because light travels from one medium to the other medium.

Concerning the concept of color, two of three focused students from Pattana School and all three focused students from Charoen School continued to hold misconceptions. The misconception that color is an intrinsic property of an object may have come from their understanding of seeing, the complexities of using color theory to explain the perceived color of objects in colored light, and past experiences in mixing paint in art classes. Moreover, the concept of seeing light by the human eye is quite complex. Regarding the concept of seeing an object in white light, the misconception relating to color may be difficult for students to correct if they are unaware of the concept that light is a mixture of different colored lights. From this perspective, the importance of possessing the prior understanding that light from luminous objects, such as light bulbs, is composed of different colored light, make this a key concept to be understood before addressing the concept of color.

Regarding the concepts of optical instruments, two of three focused students from Pattana School and one focused student from Charoen School still held misconceptions. The teachers skipped some lessons and activities. This might be the reason her students lacked knowledge on some topics, particularly concerning optical instruments. It was very clear from the findings that teaching was important in assisting students' learning. The teachers had skipped this lesson because the activities in the lesson took too much time. Because of this, they asked the students to do a report on this concept. In this lesson, there were hands-on and minds-on activities that would have helped the students to understand optical instruments. For example, how telescopes, microscopes, and cameras work. Skipping this lesson probably affected the students' understanding of this topic.

Concerning misconceptions about seeing, even though there was an increase in the percentage of scientific conceptions held by the students in all sub concepts of seeing, most students had misconceptions in all of the sub concepts. The students thought that there light travels from the eyes to the object instead of reflected light from that object bouncing into the observer's eyes. This is related to the teaching of one teacher who gave her students the wrong explanation about the refraction of light. For example, she did not understand the ray diagram when light travels from one medium to the other media. For more details see Pranee's case.

Implications of the Study

The findings presented in this thesis have several implications. These implications are discussed below.

Implications for Teaching and Learning the Concepts of Light

Teachers should be aware of students' prior knowledge and alternative conceptions surrounding the fundamental concepts of light. In addition, teachers should build on students' prior knowledge by facilitating student interaction between the teacher and students and between students and students in the classroom. This study suggests that within a social group, it is important to focus on students' prior knowledge, use a meaningful context to help students to develop conceptual understandings in a real world context, encourage students by asking thoughtful and open-ended questions, provide students with opportunities to construct their learning through interaction with peers, and focus on the students' cooperative work. Teachers and curriculum developers should consider the above factors when planning and teaching the concepts of light.

Implications for Methodology

In this study, all teachers were from Bangkok and were selected using purposeful sampling. Therefore, this study does not try to generalize and may not succeed when used in other contexts. The implementation of the LLU seemed to be successful in these three classrooms. However, the LLU may not be suited to all teachers or subjects in other contexts. The reader should consider and learn more about the context of this study. Reflection on the findings may help them within their own teaching and learning contexts.

Implications for Professional Development

This study aimed to investigate the effectiveness of implementing a Light Learning Unit (LLU) based on social constructivist epistemology with the goal of enhancing students' understanding of the concepts of light. The key person with respect to implementation of the LLU was the teacher. The results from the teachers who implemented the LLU in this study indicated that implementing the LLU may help teachers to develop their teaching strategies. They may use the unit to develop teaching strategies consistent with the requirements of the National Education Act B.E.2542 (1999). Moreover, the three teachers from this study attended a workshop and teacher support meetings, which were essential to their learning. The teachers had an opportunity to reflect on their teaching and their students' responses. They shared ideas to further develop their teaching effectiveness and worked collaboratively on their teaching and professional development. For example, by planning lessons together, they helped one another to solve teaching problems. Accordingly, an implication with respect to professional development is the importance of providing opportunities for teachers to support peers' efforts to implement new curricula and instructional approaches.

Implications for Future Research

- Future research could be done to investigate the effect of the implementation of the LLU on the growth of the pedagogical content knowledge of teachers. It was evident in this study that the implementation of the Light Learning Unit provided a professional development opportunity for teachers. While many teachers gained a better conceptual understanding of light, and expanded their repertoire of strategies during the implementation, further studies need to be conducted to examine the growth of PCK among teachers before, during, and after implementation of the LLU.

- This study used a social constructivist approach to focus on students' understanding about light resulting within the context of peer interactions. However, the teachers discourse was not examined specifically and future studies might explore possible ways for teachers to communicate, with explicit attention paid to the nature of their discourse with respect to light.

- Future research might be conducted to see what happens when teachers have more ownership in creating their lessons about light, particularly in relation to their understanding of social constructivist epistemology.

REFERENCES

American Association for the Advancement of Science. 1993. **Benchmarks for science literacy: Project 2061**. New York: Oxford University Press.

Amos, S. 2002. "Teachers' Questions in the Science Classroom." In S. Amos and R. Boohan. (eds.). **Aspects of Teaching Secondary Science**. London: Routledge Falmer, 5-15.

Amsel, A. 1989. **Behaviorism, neobehaviorism, and cognitivism in learning theory: Historical and contemporary perspectives.** New Jersey: Erlbaum.

Anderson, B. and C. Karrqvist. 1983. "How Swedish pupils, aged 12-15 years, understand light and its properties" **European Journal of Science Education** 5(4): 387-402.

Anderson, C.W. and E. L. Smith. 1983. **Children's conceptions of light and color: understanding the concept of unseen rays**. Paper presented at the annual meeting of the American Educational Research Association.

Anderson, G. and N. Arsenault. 1998. **Fundamentals of educational research.** 2nd ed. London: The Farmer Press.

Atwater, M. M. 1996. "Social constructivism: Infusion into the multicultural science education research agenda." **Journal of Research in Science Teaching** 33 (8): 821-837.

Bell, A., M. Swan, B. Onslow, K. Pratt, and D. Purdy. 1985. **Diagnostic Teaching for Long Term Learning.** Report of ESRC Project HR8491/1: Shell Centre for Mathematical Education, University of Nottingham.

Berger, K. S. 1978. **The developing person**. New York: Worth Publishers.

Black, P. and D. Wiliam. 1998. "Assessment and Classroom Learning." **Assessment in Education** 5 (1): 7-71.

Bliss, J. 1995. "Piaget and After: The Case of Learning Science." **Studies in Science Education**. 25: 139-172.

Boonchoob, K. 2000. **A study of lower secondary science teacher competencies in The General Education Department School in The Educational Region 6.** Master of Science Thesis in Science Education, King Mongkut's Institute of Technology Ladkrabang.

Bradley, J. 1993. "Methodological issues and practices in qualitative research" **Library Quarterly** 63(4): 431-449.

Brooks, M. 1998. **The Case for Constructivist Classrooms** (Online). www.funderstanding.com/constructivism.cfm, March 12, 2006.

Brooks, J. G. and M. G. Brooks. 1993. **In search of understanding: the case for constructivist classrooms**. Virginia: Association for Supervision and Curriculum Development.

Brown, S. 1999. "Institutional strategies for assessment." In S. Brown and A. Glasner. (eds.). **Assessment Matters in Higher Education.** Buckingham: SRHE and Open University Press, 3-13.

______ and P. Knight. 1994. **Assessing Learners in Higher Education**. London: Kogan Page.

Bruning. R, G. Schraw., and R. Ronning. 1995. **Cognitive psychology and instruction.** 2nd ed. New Jersey: Prentice-Hall.

Bryman, A. 2001. **Social Research Methods**. 2nd ed. New York: Oxford University Press.

Burgess, H. 1985. **Case study and curriculum research: Some issues for teacher researchers**. Lewes: Falmer Press.

Capel, S., M. Leask, and T. Turner. 2001. **Learning to teach in the secondary school : a companion to school experience.** 3th ed. London: Routledge.

Chotisoot, P. 2003. **The study of status, problems and needs on instructional design of secondary school teacher in cooperative schools under Baromrachonanee I Bangkok Metropolis.** Master of Education Thesis in Educational Technology, Kasetsart University.

Cobb, P. 1994. "An Exchange: Constructivism in math and science education." **Educational Researcher** 23 (7): 13-20.

Cohen, D. K. 1996. **Standards-based school reform: Policy, practice, and performance** (Online). www.personal.umich.edu/~dkcohen/CohenStandardsBasedReform.pdf, March 12, 2006.

Cohen, L., L. Manion, and K. Morrison. 2000. **Research Methods in Education.** 5th ed. London: Routledge Falmer.

Crowther, D. T. 1997. **Constructivist Zone** (Online). www.unr.edu/homepage/jcannon/ejse/ejsev2n2ed.html, March 12, 2006.

Denzin, N. K. and Y. S. Lincoln. 1998. **Social sciences; Qualitative reasoning; Research; Methodology**. 2nd ed. California: Sage.

Department of Curriculum and Instruction Development. 2001. **Basic Education Curriculum BE. 2544 (A.D. 2001), Ministry of Education of Thailand. The Express Transportation Organization of Thailand (ETO)**. Bangkok: Nai Nath Pawin-Wiwat.

______. 2002. **Basic Education Curriculum B.E. 2544 (A.D. 2001)**. Bangkok, Thailand: The Express Transportation Organization of Thailand.

Derry, S. J. 1999. "A fish called peer learning: Searching for common themes." In A.M. O'Donnell and A. King. (eds.). **Cognitive perspectives on peer learning.** New Jersey: Lawrence Erlbaum, 197–211.

Dewey, J. 1916. **Democracy and Education. An introduction to the philosophy of education**. New York: Free Press.

Donovan, M. S., and J. Bransford. 2005. **How students learn: History, mathematics, and science in the classroom**. Washington, D.C.: National Academies Press.

Driver, R., A. Squires, P. Rushworth, and V. Wood-Robinson. 1994. **Making sense of secondary science: Research into children's ideas.** New York: Routledge.

Duit, R. and J. Confrey. 1996. "Reorganising the curriculum and teaching to improvelearning in science and mathematics." In D. F. Treagust, R. Duit, and B. J. Fraser. (eds.) **Improving teaching and learning in science and mathematics.** New York: Teachers College Press, 79-93.

Eggen, P. and D. Kauchak. 1997. **Educational Psychology: Windows on Classrooms**. New Jersey: Merrill.

Erickson, F. 1986. "Qualitative methods in research on teaching." In M. Wittrock. (ed.). **Handbook of Research on Teaching**. New York: Macmillan.

Ernest, P. 1999. **Social constructivism as a philosophy of mathematics: radical constructivism**. Albany: Sunny Press.

Feagin, J., A. Orum., and G. Sjoberg. 1991. **A case for case study**. Chapel Hill, North Carolina: University of North Carolina Press.

Feher, E. and K. M. Rice. 1992. "Children's conceptions of color." **Journal of Research in Science Teaching** 29 (5): 505-520.

Fethestonhaugh, T. and D. F. Treagust. 1992. "Students understanding of light and its properties: teaching to engender conceptual change." **Science Education** 76 (6): 653-672.

Forgione, Jr. and D. Pascal. 2001. **Commissioner of Education Statistics. International Test Scores** (Online). www.4brevard.com/choice/international-test-scores.htm, March 12, 2006.

Fosnot, C. T. 1996. "Constructivism: A psychological theory of learning." In C. T. Fosnot. (ed.). **Constructivism: Theory, perspectives, and practice.** New York: Teachers College Press, 8-33.

Frankfort - Nachmias, C. and D. Nachmias. 1992. **Research Methods in the Social Science**. London: Edward Arenold.

Frazee, B. M. and A. Rudnitski. 1995. **Integrated teaching methods: theory, classroom applications, and field-based connections.** New Jersey: Delmar.

Galili, I. 1996. "Students' conceptual change in geometrical optics." **International Journal of Science Education** 18 (7): 847- 868.

Gall, M. D. 1985. "Discussion Methods of Teaching." In T. Husen and T. N. Postlethwaite. (eds.). **International Encyclopedia of Education**). Oxford: Pergamon Press, 1423-1427.

Glenn, R. E. 2001. What Teachers Need To Be. **The Education Digest** 67 (1): 19-21.

Goldberg, F. and L. C. McDermott. 1986. "Student difficulties in understanding image formation by a plane mirror." **The Physics Teacher** 24: 472-480.

______. 1987. "An investigation of the student understanding of the real image formed by a converging lens or concave mirror." **American Journal of Physics** 55 (2): 108-119.

Guba, E. G. and Y. S. Lincoln. 1985. **Naturalistic Inquiry**. California: Sage Publications.

______. 1989. **Fourth Generation Evaluation.** California: SAGE Publications.

Guesne, E. 1978. "Light and vision of objects." In G. Delacote. (ed.). **Physics teaching in schools**. Toronto: University of Toronto Press, 265–273.

______. 1985. "Light." In R. Driver, E. Guesne and A. Tiberghien. (eds.). **Children's ideas in science**. Milton Keynes: Open University Press, 10-32.

Hammersley, M. 1986. **Case Studies in Classroom Research**. Milton Keynes: Open University Press.

Hand, B., D.F. Treagust., and K.Vance. 1997. "Student perception of the social sonstructivist classroom." **Science Education** 81: 561-575.

Harlen, W. 1999. **Effective teaching of science, a review of research**. Using Research Series. 21. Edinburg.Scottish Council for Research in Education : ERIC Reproductive Service ED.

Hipkins, R., R. Bolstad, R. Baker, A. Jones, M. Barker, B. Bell, R.Coll, B. Cooper, M. Forret, B. France, M. Haigh, A. Harlow, and I. Taylor. 2002. **Curriculum, Learning and Effective Pedagogy: A Literature Review in Science Education.** Wellington: Ministry of Education.

Hoepfl, M. 1997. "Choosing Qualitative Research: A Primer for Technology Education Researchers." **Journal of Technology Education** 9 (1): 47-63.

Institute for the Promoting of Teaching Science and Technology (IPST). 2002a. **National Science Content Standards.** Bangkok: Karusapa Press.

______. 2002b. **Science and Technology Teacher Standard**. Bangkok: Institute for the Promotion of Teaching Science and Technology (IPST), Ministry of Education.

Jaworski, B. 1993. **Constructivism and Teaching - The socio-cultural context** (Online). www.grout.demon.co.uk/Barbara/chreods.htm, March 12, 2006.

Johnson, D.W., and R. T. Johnson. 1987. **Learning together and alone: Cooperative, competitive, and individualistic.** New Jersey: Prentice Hall.

John-Steiner, V. and H. Mahn. 1996. "Sociocultural Approaches to Learning and Development: A Vygotskian framework." **Educational Psychologist** 31: 191- 206.

Jonassen, D. 1992. "Evaluating constructivistic learning." In T. M. Duffy and D. H. Jonassen. (eds.). **Constructivism and the technology of instruction: A conversation**. New Jersey: Lawrence Erlbaum Associates, 137-148.

Jonassen, D. 1994. "Thinking Technology: Towards a Constructivist Design Model." **Educational Technology** 34 (3): 34-37.

Jones, F. 1997. "The constructivist leader." In J. Rhoton and P. Bowers. (eds.). **Issues in Science Education**. U.S.A.: The National Teacher Science Association, 150-154.

Joppe, M. 2000. **The Research Process** (Online). www.ryerson.ca/mjoppe/rp.htm, September 13, 2007.

Jung, W. 1981. **Conceptual frameworks in elementary optics.** Proceedings of the International Workshop on Problems Concerning Students, Ludwigsburg, Germany.

Kuhn, T. S. 1970. **The Structure of Scientific Revolutions**. 2nd ed. Chicago: University of Chicago Press.

Larson, B. E. 1999. "Influences on Social Studies Teachers' Use of Classroom Discussion." The Social Studies 99 (3): 125–132.

Leengjaroonrat, S. 2000. **Effects of Constructivism Learning Process and Portfolilo on teaching Energy and Life, and Home Electrical Appliances in Mathayomsuksa 3 Kasetsart University Laboratory School.** Doctoral of Education Thesis in Curriculum and Instruction, Kasetsart University.

Linn, M. and N. B. Songer. 1991. "Teaching Thermodynamics to Middle School Student :What Are Appropriate Cognitive Demands." **Journal of Research in Science Teaching** 28: 885-915.

MacGregor, J. 1990. "Collaborative learning: Shared inquiry as a process of reform." In M. D. Svinicki. (ed.). **The changing face of college teaching, New Directions for Teaching and Learning**. San Francisco: Jossey-Bass, 19-30.

McMahon, M. 1997. **Social Constructivism and the World Wide Web - A Paradigm for Learning.** Paper presented at the ASCILITE Conference, Perth, Australia.

Maddux, C. D., D. Johnson., and J. Willis. 1997. **Behavioural Theories: A special type of behaviour instruction - integrated learning systems** (Online). www. coe.uh.edu/~ichen/edbook/ET-IT/integr.htm, March 12, 2006.

Martin, D. J. 2001. **Constructing early childhood science**. Australia: Delmar.

Matthews, M. R. 2000. "Constructivism in Science and Mathematics Education." In D.C. Phillips. (ed.). **National Society for the Study of Education, 99th Yearbook**. Chicago: University of Chicago Press, 161-192.

Maykut, P. and R. Morehouse. 1994. **Beginning Qualitative Research a Philosophic and practical Guide**. Routledge Falmer: Great Britain.

McDiarmid, G. W., D. L. Ball, and C. W. Anderson. 1989. "Why staying one chapter ahead doesn't really work: subject-specific pedagogy." In M. C. Reynolds. (ed.). **Knowledge Base for the Beginning Teacher**. New York: Pergamon Press, 193-205.

McRobbie, C. and K. Tobin 1997. "A social constructivist perspective on learning environments." **International Journal of Science Education** 19(2): 193-208.

Meinoratha, J. 1997. **Science instructional organization in schools under the Project for Extension of Educational Opportunity at the lower secondary level of the Bangkok Metropolis Administration.** Master of Arts in Teaching Thesis in Teaching Science, Kasetsart University.

Nastasi, B. K., and D. H. Clements. 1991. "Research on cooperative learning: Implications for practice." **School Psychology Review** 20: 110-131.

National Research Council. 1995. **National Science Education Standards**. Washington, D.C.: National Academy Press.

Nopakoon, P. 2002. **The Development of a Model of Learning and Teaching Science Process Using Constructivism Approach in the Fifth Grade of Kasetsart University Laboratory School.** Doctoral of Education Thesis in Curriculum and Instruction, Kasetsart University.

Office of Education Council. 2004. **Education in Thailand 2004**. Bangkok: Amarin Printing and Publishing.

Office of the National Education Commission. 1999. **National Education Act of B.E. 2542**. Bangkok: International Relations and Cooperation Center for Educational Reform (IRCE).

______. 2001. **Education in Thailand 2001/2002**. Bangkok: Kurusapa Lardprao Press.

______. 2002. **National Education Act B.E. 2542 (1999) and Amendments**. Office of the Prime Minister.

______. 2003. **Education in Thailand 2002/2003**. Bangkok: Amarin Printing and Publishing.

Oldfather, P., J. West., J. White., and J. Willmarth. 1999. **Learning through children's eyes: Social constructivism and the desire to learn. [Psychology in the Classroom Series]**. Washington, D.C.: American Psychological Association.

Ormrod, J. E. 2000. **Educational Psychology: Developing Learners.** 3rd ed. New Jersey: Pretice-Hall.

Osborne, J. F. 1996. "Beyond Constructivism." **Science Education**. 80 (1): 53-82.

Osborne, J. F., P. J. Black, , J. Meadows, and M. Smith. 1993. "Young children's (7-11) ideas about light and their development." **International Journal for Science Education** 15 (1): 83-93.

Patton, M.Q. 1990. **Qualitative evaluation and research methods**. Newbury Park, California: SAGE Publications.

Pravalpruk, S. 1999. "Learning and Assessment in the Science Classroom in Thailand." **Assessment in Education** 6 (1): 75-82.

Pea, R. D. 1993. "Learning scientific concepts through material and social activities: Conversational analysis meets conceptual change." **Educational psychologist** 28 (3): 265-277.

Piaget, J. 1974. **Understanding Causality**. New York: W. W Norton.

Puacharearn, P. and D. Fisher. 2004. **The Effectiveness of Cooperative Learning Integrated with Constructivist Teaching on Improving Learning Environments in Thai Secondary School Science Classrooms** (Online). www.iasce.net/Conference2004/22June/Panomporn/conference_full_%20paper_singapore .doc, March 12, 2006.

Punputsan, Y. 2004. **The comparison the concepts: about the velocity of light, the reflection of light, the refraction of light, and seeing in tenth grade students when used Wittrock and IPST models**. Master of Education Thesis in Scienec Education, Mahasarakam University.

Qin, Z., D. W. Johnson, and R. T. Johnson. 1995. “Cooperative vs. competitive efforts and problem solving.” **Review of Educational Research** 65: 129-143.

Radziszewska, B. and B. Rogoff. 1988. “Influence of adult and peer collaborators on children's planning skills.” **Developmental Psychology** 24 (6): 840-848.

Ramadas, J. and R. Driver. 1989. **Aspects of Secondary Students' Ideas about Light. Centre for Studies in Science and Maths Education**. England: University of Leeds.

Rice, M. L. and E. K. Wilson. 1999. “How technology aids constructivism in the social studies classroom.” **Social Studies** 90 (1): 28-33.

Rodlong, C. 1986. **A study of competencies, problems and needs of lower secondary school science teachers at tambol level in Educational Region 6.** Master of Arts in Teaching Thesis in Teaching Science, Kasetsart University.

Rust, C., B. O’Donova., and M. Price. 2005. “A social constructivist assessment process model: how the research literature shows us this could be best practice.” **Assessment and Evaluation in Higher Education** 30 (3): 233-241.

Sangsupata, S. 1995. **An analysis of Physics misconceptions about optics of high school science students in Bangkok, area 5 by consideration only the provided answer and both provided answers and reasons**. Report to Kasetsart University Research and Development Institute. Bangkok: Kasetsart University Research and Development Institute.

Salley, N. J. 1996a. **“**Toward a phenomenography of light and vision.” **International Journal of Science Education** 18 (7): 837- 846.

______. 1996b. “Children’s ideas on light and vision.” **International Journal of Science Education** 18 (6): 713- 723.

Schunk, D. H. 2000. **Learning theories: An educational perspective.** New Jersey: Upper Saddle River.

Scott, P. 1987. **A Constructivist view of learning and teaching in science**. **Children’s Learning in Science Project**. Centre for Studies in Science and Mathematics Education: University of Leeds, England.

Shapiro, B. L. 1994. **What Children Bring to Light**. New York: Teachers College Press.

She, H. and D. Fisher. 2002. “Teacher Communication Behaviour And Its Association With Students’ Cognitive And Attitudinal Outcomes In Science In Taiwan” **Journal of Research in Science Teaching** 39 (3): 63-78.

Shepardson, D. P. 1996. “Social interactions and the mediation of science learning in two small groups of first-graders.” **Journal of Research in Science Teaching** 33 (2): 159-178.

______ and S. J. Britsch. 2001. “The role of children's journals in elementary school science activities.” **Journal of Research in Science Teaching** 38 (1): 43-69.

Slavin, R. E. 1990. **Cooperative learning: Theory, research, and practice.** New Jersey: Prentice Hall.

Smith, B. L. and J. T. MacGregor. 1992. "What is collaborative learning?" In A. S. Goodsell, M. R. Maher, and V. Tinto. (eds.). **Collaborative Learning: A Sourcebook for Higher Education.** National Center on Postsecondary Teaching, Learning, and Assessment, Syracuse University.

Southerland, S.A. *et al*. 2000. "What Do You Mean By That: Using Structured Interviews to Assess Science Understanding." In J. J. Mintzes, J. H. Wandersee, and J. D. Novak. **Assessing Science Understanding.** San Diego: Academic Press.

Stake, R. 1995. **The art of case study research**. Thousand Oaks: SAGE Publications.

Taraban, B., P. Myers., and Bowen. 2006. "Effects of active-learning experience on achievement, attitudes and behaviors in high school biology." **Journal of Research in Science Teaching** 44: 960 – 979.

Tinsandee, P. 2004. **Teaching for change the misconceptions about the velocity of reflection light in eleventh grade students by using teaching strategy of Hesse**. Master of Education Thesis in Scienec Education, Mahasarakam University.

Tobin, K., and D. Tippins. 1993. "Constructivism as a referent for teaching and learning." In K. Tobin. (ed.). **The practice of constructivism in science education.** New Jersey: Lawrence Erlbaum Associates, 3-21.

Valanides, N. 2002. "Aspects of Costructivism." **Journal of Baltic Science Education** 2: 50-58.

Von Glasersfeld, E. 1989. "Constructivism in Education." In T. Husen, and T. N. Postlethwaite. (eds.). **The International Encyclopedia of Education. Research and Studies.** Oxford: Pergamon Press, 162-163.

Von Glasersfeld, E. 1995. **Radical constructivism: A way of knowing and learning.** London : The Falmer Press.

Von Glasersfeld, E. 1997. "Amplification of a constructivism perspective." **Issues in Education** 3 (2): 8-13.

Vygotsky, L. 1978. **Mind in Society**. Cambridge: Harvard University Press.

______. 1987. "Thinking and speech." In R. W. Riber and A. S. Carton. (eds.). **The collected works of S.L. Vygotsky, Volume 1: Problems of general psychology**. New York: Plenum.

Wadsworth, B. J. 1996. **Piaget's Theory of Cognitive and Affective Development: Foundations of Constructivism**. 5th edition. USA: Logman Publisher.

Watts, M. 1985. "Student conception of light: a case study." **Physics Education** 20 (4): 183-187.

______ and P. Maureen. 1989. "Thinking about thinking, learning about learning: constructivism in physics education." **Physics Education** 24: 236-330.

Wheatley, G. H. 1991. "Constructivist perspectives on science and mathematics learning." **Science Education** 75 (1): 9-21.

White, B. and J. Frederiksen. 1998. "Inquiry, modeling, and metacognition: Making science accessible to all students." **Cognition and Instruction** 16 (1): 3-118.

Windschitl, M. and T. Andre. 1998. "Using Computer Simulations to Enhance Conceptual Change: The Roles of Constructivist Instruction and Student Epistemological Beliefs." **Journal of Research in Science Teaching** 35: 145-160.

Wood, T., P. Cobb, and E. Yackel. 1995. "Reflections on learning and teaching mathematics in elementary school." In L. P. Steffe and J. Gale. (eds.). **Constructivism in education.** New Jersey: Lawrence Erlbaum, 401-422

Worrapan, W. 2003. **Teaching for change the misconceptions about the refraction of light and seeing in eleventh grade students by using teaching strategy of Hesse**. Master of Education Thesis in Scienec Education, Mahasarakam University.

Yin, R. 1994. **Case Study Research: Design And Methods.** 2nd ed. Beverly Hills, CA: Sage Publishing.

APPENDICES

Appendix A

The Current State of Teaching and Leaning Concept of Light Questionnaire (CSTLL)

The Questionnaire about Teaching Situation about the Topic of Light in Schools under the Project for Extension of Educational Opportunity at Lower Secondary Levels of the Bangkok Metropolis Administration

…………………..……………..

Explanation: this questionnaire is divided into three parts

Part 1 – Demographic data

Part 2 – Teaching in the classroom

Part 3 – Problems or suggestions

Part I: Demographic data

1. Sex

( ) Male
( ) Female

2. What is your age?

( ) 20 – 25 years old
( ) 26 – 30 years old
( ) 21 – 35 years old
( ) 36 – 40 years old
( ) more than 40 years old

3. What is your highest degree completed?

( ) Less than bachelor's degree
( ) Bachelor's degree
( ) Master's degree
( ) Doctoral degree
( ) Other (Specify) ....

4. What is your major field?

( ) Biology
( ) Chemistry
( ) Physics
( ) General Science
( ) Other (Specify) ....

5. What is your minor field?

( ) Biology
( ) Chemistry
( ) Physics
( ) General Science
( ) Other (Specify) ....

6. How many have you been years teaching science (the topic of light)?

( ) Less than 6 years
( ) 6 – 10 years
( ) 11 – 15 years
( ) 16 – 20 years
( ) More than 20 years

7. How many periods do you teach science per week?

   ( ) 1 – 5 periods a week
   ( ) 6 – 10 periods a week
   ( ) 11 – 15 periods a week
   ( ) 16 – 20 periods a week
   ( ) more than 20 periods a week

8. Do you teach subjects other than science?

   ( ) no
   ( ) yes (specify)..

9. Have you ever had teacher training on the following several topics?

   ( ) Light — How much? ....
   ( ) Motion and Force — How much? ....
   ( ) Matter — How much? ....

Part II: Teaching in the classroom

This part is a questionnaire about teaching in the classroom. There are both checklist and open-ended questions.

1. What are the books you will use for teaching and learning science?

   ( ) IPST science books
   ( ) IPST science books and the exercises that you prepare
   ( ) IPST science books and other books from private companies
   ( ) Only books from private companies
   ( ) Other (Specify) ....

2. How much time do you spend preparing for teaching each lesson of the topic of Light?

   ( ) 1 hour or less than
   ( ) 2 - 10 hours
   ( ) 11 - 15 hours
   ( ) more than 15 hours

3. Please describe how you plan a lesson before teaching it.

....
....
....
....

4. What teaching methods do you use to introduce the students to a new lesson in the topic of Light?
....
....
....
....
....
....
....

5. In each topic of light, what are the teaching strategies you use?

Topics	**Class time**	**Percent of Teaching strategies**			
		% Lecture	**% Demonstration**	**% Experiments**	**% Other**
1. Reflection					
2. Refraction					
3. Image formation from mirror and lens					
4. Application of refraction					
5. Sight					
6. Light intensity					

6. What do you do when the students are doing an experiment?

( ) Watch them from the front of the classroom
( ) Prepare for teaching /examining students' work
( ) Give advice when students have a problems
( ) Observe students' behavior
( ) Other (Specify) ....

7. After finishing an experiment, how do you help your students understand their results?

( ) Lead a discussion
( ) Have students lead a discussion
( ) Both teacher and students discuss together
( ) The teacher lets students present the results of their experiment

( ) Other (Specify) ....

8. How do you help students summarize their experimental results?

( ) The results are summarized by the teacher
( ) The results are summarized by the whole class of students
( ) The results are summarized by each student
( ) The teacher guides the students to summarize the results
( ) Other (Specify) ....

9. How do you decide what material or resources to use for the topic of Light?
....
....
....
....

10. How do you determine the activities for the topic of Light?
....
....
....
....

11. What are the topics that you feel are hard to teach? Please numbers the topics below in orders of difficulty to teach (with "1" being the most difficult and "6" being the least difficult)

1) .... Reflection
2) .... Refraction
3) .... Image formation from mirror and lens
4) .... The application of refraction
5) .... Sight
6) .... Light intensity

12. What are the topics that you feel that most students feel hard to understand? Please numbers the topics below in orders of student's difficult to understand (with "1" being the most student's difficult to understand and "6" being the least student's difficult to understand)

1) .... Reflection
2) .... Refraction
3) .... Image formation from mirror and lens
4) .... The application of refraction
5) .... Sight
6) .... Light intensity

Part III: Problems or suggestions

1. Do you have problems doing lesson plans?

   ( ) Yes
   ( ) No

   If you chose "yes", what kinds of problems do you have?

   ( ) no expert to advise
   ( ) no time to prepare
   ( ) no skills for make a lesson plan
   ( ) Others (Specify) ……………………………………………...………

   Suggestion for solution …………………………………………………...

2. Do you have problems teaching the topic of light?

   ( ) Yes
   ( ) No

   If you chose "yes", what kinds of problems do you have?

   ( ) Lack of content
   ( ) Lack of teaching strategies
   ( ) Lack of material, resources
   ( ) Others (Specify) ………………………………………………………

   Suggestion for solution …………………………………………………..

3. Check any areas below where you feel you need more content knowledge

   1) ……………. Reflection
   2) ……………. Refraction
   3) ……………. Image formation from mirror and lens
   4) ……………. The application of refraction
   5) ……………. Sight
   6) ……………. Light intensity

4. Other problems

………………………………………………………………………………………………………
………………………………………………………………………………………………………
………………………………………………………………………………………………………
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Appendix B

Interview questions to explore current state of teaching and leaning concept of light

Interview Questions to Explore Current

State of Teaching and Leaning Concept of Light

1. What curriculum do you currently use?

2. What do you think about this curriculum?

3. What science textbook do you use?

4. What do you think about this textbook?

5. Do you use any other textbook besides that of IPST? Why?

6. What teaching strategies do you use to teach the concept of light?

7. How do you assess student understanding of light?

10. What is the most difficult topic of light to students? Why?

11. What are your difficulties in teaching light?

12. What you do think you need to improve teaching light?

Appendix C

Light Diagnostic Test (LDT)

Light Diagnostic Test

Explanation:

Diagnostic test about light is consisted of 27 items with 60 minutes

There are three types in this test

2.1 Choose the right answer and reason

2.2 Choose the answer and write the reason to support your answer

2.2 Choose the answer and draw the picture to support your answer

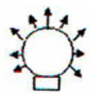
Name…………………..Surname…………………………student no………………

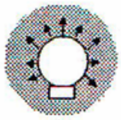
1. How far does light go?
    a. Light only travel as far as it is visible.
    b. Light travels as far as it is possible.
    c. Light travels as far as it is out of energy.
    d. Light can go further as far as until it is blocked by something.

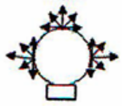
    Reasons:

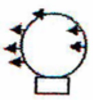
    1. Light is energy. When light travels, energy spread out to medium.
    2. Human sees light because the optic nerve was stimulated.
    3. Light is electromagnetic wave. When light travels, energy does not spread out to medium.
    4. Light cannot travel through the blocked object.

2. Which picture show the scientific concept of light from light source?

    a. 

    b. 

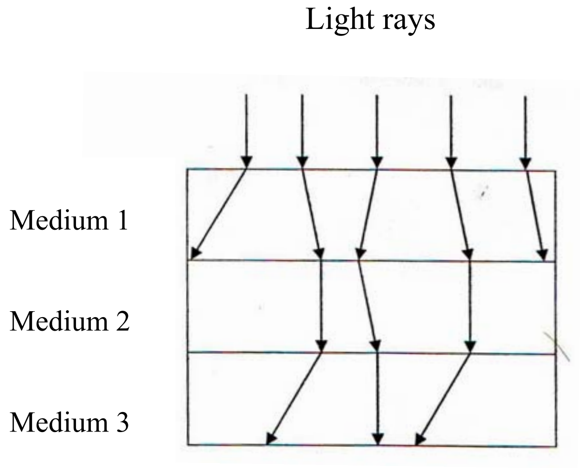
    c. 

    d. 

    Reasons:

    1. Light is an entity which is located in space (region around the light source)
    2. Light fades away with distance from the source
    3. Light goes out only in radial direction or each point on a luminous object emits light in one direction.
    4. Light emanates leaving each point of the light source and propagates, diverging in all spatial directions.

3. Light travels to three media as picture below. What is medium 1, 2 and 3 respectively?

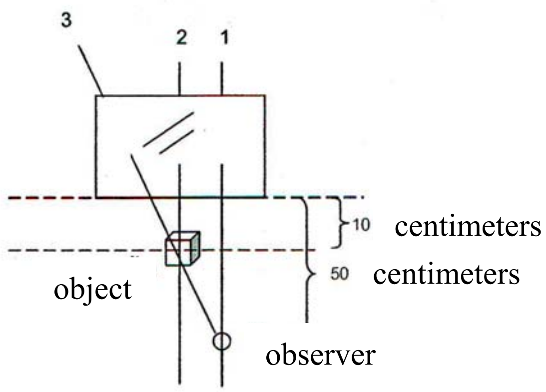


   a. Transparent, translucent, opaque
   b. Translucent, transparent, opaque
   c. Transparent, transparent, opaque
   d. Translucent, translucent, opaque

   Reasons:

....
....
....
....
....

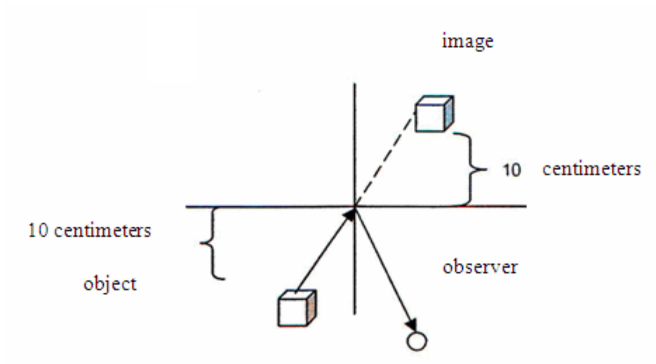
4. The picture shows the 20x30 centimeter plane mirror. The object is placed in front of the mirror at 10 centimeter. If the observer sits in front of the mirror at 50 centimeter and sits at right direction from the object, what the position the observer sees the object?



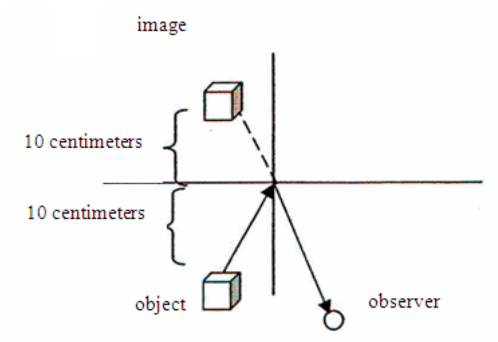
a. The image will exist at 10 centimeter as line 1.
b. The image will exist at 10 centimeter as line 2.
c. The image will exist on the mirror as line 2.
d. The image will exist at 10 centimeter as line 3.

This situation can show in which ray diagram?

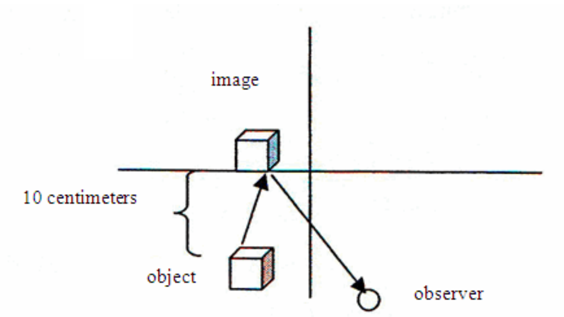
1.



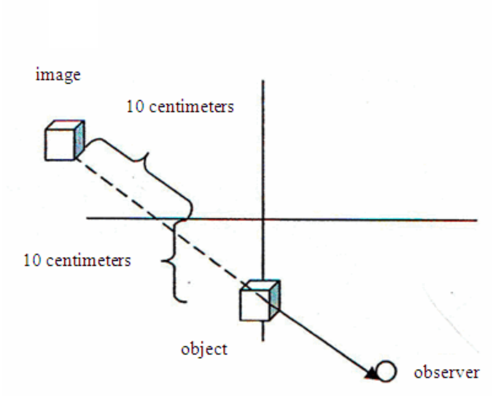
2.



3.



4.



5. If the object  is in front of the plane mirror, what is its image look like?

a. 

b. 

c. 

d. 

Reasons:

1. The image is virtual, upside down image and left and right reversal.
2. The image is virtual, upside image and left and right reversal.
3. The image is real, upside image and left and right reversal.
4. The image of object was exactly same with actual object.

6. What is the mirror the dentist use to check the patient teeth and the mirror at the intersection on the road respectively?

a. Concave, convex
b. Concave, concave

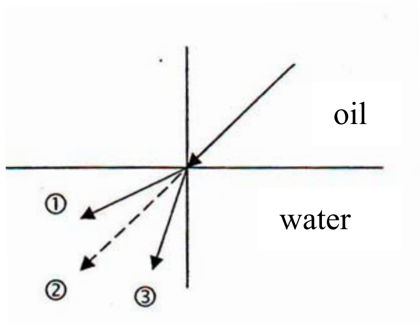
c. Convex, concave

d. Convex, convex

Reasons:

………………………………………………………………………………………………………
………………………………………………………………………………………………………
………………………………………………………………………………………………………

7. What is the possible refracted ray that can express the refraction of light when light travel from oil into water?



a. 1

b. 2

c. 3

d. None

Reasons:

1. Due to the oil's density is less than in water and when light travels from the less density medium to more density medium, light will bend away from the normal line.
2. Because the speed of light in the oil is more than in water, refraction occurs.
3. Due to the oil's density is less than in water and when light travels from the less density medium to more density medium, light will bend toward the normal line.
4. The light is still travels in the same line because the speed of light in oil and water is not much difference.

8. When the observer sees on the bank, the location of image of fish would be?

   a. The image of fish is deeper than it should be.
   b. The image of fish is shallower than it should be.
   c. The image of fish is the same it should be.
   d. None

   Reasons:

   1. The refraction occurs and light will bend away from the normal line.
   2. The refraction occurs because the speed of light in water is more than in water.
   3. The refraction occurs and light will bend toward the normal line.
   4. Both 1 and 2

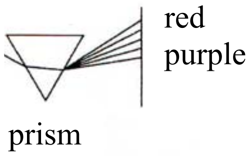
9. What happens when light passing from one medium into another if it hits the second medium at right angles to its surface?

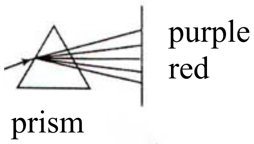
   a. Light will not change direction when passing from one transparent material into another if it hits the second material at right angles to its surface.
   b. The refraction of light does not occur but the light will reflect to the opposite.
   c. The refraction occurs in the same direction with incident direction. This seems no refraction occurs.
   d. The refraction occurs because light travels into two media.

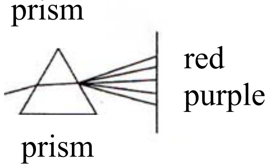
   Reasons:

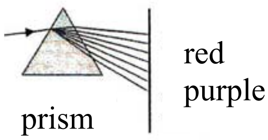
   1. Light does not change the direction.
   2. Because front waves of the incident light travels to the medium at the same time, the refraction of light does not occur.
   3. When light travels at right angles to its surface, there is no refraction because the speed of light in oil and water is not much difference.
   4. The refraction still occurs because light travels from one medium to another medium

10. What is picture that can express the refraction of light when light travel into prism?

a. 

b. 

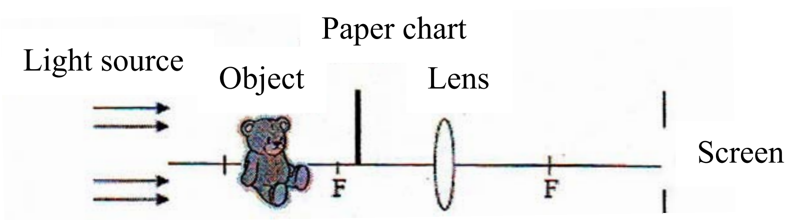
c. 

d. 

Reasons:

1. When the white light travels through the prism, the angle of refraction is different for different color of light. The purple is most refracted and the red is the less refracted.
2. When the white light travels through the prism, the angle of refraction is different for different color of light. The purple ray is the least refracted and the red ray is the most refracted.
3. The spectrum of rainbow made by prism is continued and each color has its own exact boundary.
4. Both 1 and 3

11. What happens if half of the lens were covered?



a. The image and its intensity are still the same with the whole lens.

b. The image is still the same with the whole lens but the intensity decreases.
c. The half image exists and the same intensity with the whole lens.
d. The half image exists and the intensity decreases.

Reasons:

1. Light is converted by converging lens. The image is sharp.
2. Converging lens makes upside down image.
3. No lens, no image.
4. Half lens makes half image.

12. Why human see object in black color and white color?
    a. There is white or black color into eyes.
    b. Seeing black or white because light reflects color of the object (black or white).
    c. When light hits object and then there is no refracted light into eye, black color exist. When light hits object and then there is refracted light into eye, white color exist.
    d. When light hits object and then there is no reflected light into eye, black color exist. When light hits object and then there is reflected light into eye, white color exist.

    Reasons:

    1. Seeing light color because a particular light travels to eyes
    2. The color of an object is determined by colored light it absorbs such as black object absorbs all color lights but white object reflects all color lights
    3. The color of an object is a physical property of that object.
    4. White color is more reflected than black color

13. The object is put in front of the lens at 0.18 meter. Then, the image exists in front of that lens at 0.06 meter. Is this lens converging or diverging lens? What are the focal length and the magnificent of the lens?

    a. Converging lens with 0.09 meter focal length and its magnificent is 1/3
    b. Diverging lens with 0.09 meter focal length and its magnificent is 1/3

c. Converging lens with 0.045 meter focal length and its magnificent is 1/3
d. Diverging lens with 0.045 meter focal length and its magnificent is 1/3

Reasons:

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14. What happened when the students look at the green object for a long time and then look at the white wall and why?

a. Green
b. Magenta
c. White
d. Black

Reasons:

1. The students saw the green object for a long time, it made the green cone cell in fovea of the eye not is responded and the red and blue cone cells worked.
2. The brain would recognize the color they look at the first time.
3. Seeing light is caused from the working of all cone cells in fovea of the eye.
4. Seeing light is caused from the non-working of all cone cells in fovea of the eye.

15. Why the white light travels to red filter is red color light?

a. The color of an object is the color of the light that is reflected by that object.
b. The function of a filter is to change the color of the transmitted light.
c. Light travels through red filter is still white but something from filter excite the red color to be most reflected to eye.
d. Red light is the reflected light from the filter.

Reasons:

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16. The object is put in front of the converging lens at 0.1 meter and this lens has the focal length as 0.05 meter. What is the type of image, the image distance, and the magnificent of the lens?

    a. The image is real. The image is two times bigger than object at 0.05 meter from lens.
    b. The image is real. The image is two times bigger than object at 0.1 meter from lens.
    c. The image is real. The image is the same size with object at 0.1 meter from lens.
    d. The image is virtual. The image is bigger than object at 0.1 meter from lens.

    Reasons:

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17. How Dang sees the candle flame in the dark room?

    a. Dang has eyes.
    b. The reflected light from candle flame travels to Dang's eyes.
    c. Light from the candle flame travels to Dang's retina.
    d. Light from the candle flame travels to Dang's eyes

    Draw the picture to represent it

18. How Dang sees the candle stick in the dark room?
    a. Dang has eyes.
    b. Light from the candle flame travels to Dang's eyes.
    c. The light from candle stick travels to Dang's eyes.
    d. Light from the candle flame travels to candle stick then light reflected to Dang's eye.

    Draw the picture to represent it

19. The object is put in front of the curve mirror at 0.05 meter. Then, the virtual image exists behind that mirror at 0.1 meter. Is this curve mirror the concave or convex mirror? What is the focal length of this curve mirror?

    a. Convex mirror with 0.03 meter focal length
    b. Concave mirror with 0.03 meter focal length
    c. Convex mirror with 0.1 meter focal length
    d. Concave mirror with 0.1 meter focal length

    Reasons:

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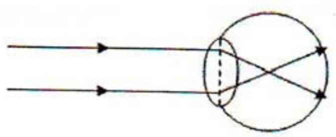
20. What the eye problem is with the following picture and its correction?



    a. Nearsightedness, diverging eyeglass lens
    b. Farsightedness, converging eyeglass lens
    c. Nearsightedness, converging eyeglass lens

d. Farsightedness, diverging eyeglass lens

Reasons:

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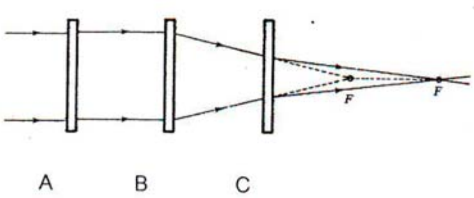
21. What sentence is right about telescope?
    a. objective lens makes upside down image and eyepiece lens makes bigger image
    b. objective lens makes bigger image
    c. image from telescope should be real, upside down
    d. the focal length in eyepiece lens is more than it in objective lens

Draw the picture to represent it

22. From the picture what is A, B, and C



a. Transparent mirror, diverging lens, and diverging lens
b. Converging lens, transparent mirror, and diverging lens
c. Transparent mirror, diverging lens, and converging lens
d. Diverging lens, diverging lens, and converging lens

Reasons:

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23. Is the image from camera and retina different?
    a. Yes
    b. No
    Reasons:
    1. The image is real, upside down image and smaller than object both in camera and retina.
    2. The image from camera is real, upside down image and smaller than object but the image from retina is virtual, upside image and smaller than object.
    3. The image from camera is virtual, upside image and smaller than object but the image from retina is virtual, upside image and the same size with object.
    4. The image is real, upside image and smaller than object both in camera and retina.

24. The object is put in front of the diverging lens at 0.15 meter and this lens has the focal length as 0.06 meter. What are the type of image and the image distance?

    a. The image is real and exists at 0.1 meter from lens.
    b. The image is virtual and exists at 0.1 meter from lens.
    c. The image is real and exists at 0.043 meter from lens.
    d. The image is virtual and exists at 0.043 meter from lens.
    Draw the ray diagram.

25. Where the image exists, the size of image of the concave mirror when the object is put between the focal point (f) and 2f by the concave mirror?

    a. The image is real, upside down image and bigger than object at more than C.

b. The image is virtual, upside down image and bigger than object at more than C.
c. The image is real image, upside down and the same size with object between F and C.
d. The image is virtual, upside down image and smaller than object at more than C.

Draw the ray diagram.

26. What happened when the students wear striped T-shirt with white and red and green cap in the green spotlight?

a. Striped T-shirt with green and black and green cap in the green spotlight
b. Green T-shirt with and green cap in the green spotlight
c. Striped T-shirt with green and yellow and green cap in the green spotlight
d. Striped T-shirt with green and white and white cap in the green spotlight

Reasons:

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27. Microscope is consisted with 2 diverging lens. The image from objective lens is far from eyepiece lens as?

a. As focal length of eyepiece
b. More than focal length of eyepiece a bit
c. More than 2 focal length of eyepiece a bit
d. Less than focal length of eyepiece

Draw the picture to represent it

BIOGRAPHICAL DATA

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BIRTH DATE	May 3, 1980
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EDUCATION	2007 Univ. of Georgia International Research Internship 2004 Mahidol Univ. Grad. Dip. (Teaching Science Profession) 2003 Mahidol Univ. B.Sc. (Physics)
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SCHOLARSHIPS	2003-2009 Scholarships for studying in B.Sc., Grad. Dip. and Ph.D. from the Institute for Promotion of Teaching Science and Technology (IPST), Thailand