8-1-2012

Middle School Teachers' Familiarity with, Interest in, Performance on, and Conceptual and Pedagogical Knowledge of Light

Simeon Mbewe
Southern Illinois University Carbondale, smbewe2004@yahoo.co.uk

MIDDLE SCHOOL TEACHERS' FAMILIARITY WITH, INTEREST IN, PERFORMANCE ON, AND CONCEPTUAL AND PEDAGOGICAL KNOWLEDGE OF LIGHT

by

Simeon Mbewe

B.Sc. Ed., University of Zambia, 1988
M.S., University of the Witwatersrand, 2001

A Dissertation
Submitted in Partial Fulfillment of the Requirements for the
Doctor of Philosophy Degree

Department of Curriculum and Instruction
in the Graduate School
Southern Illinois University Carbondale
August 2012

DISSERTATION APPROVAL

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Approved by:

Dr. Frackson Mumba, Co-Chair

Dr. Kevin C. Wise, Co-Chair

Dr. Vivien M. Chabalengula

Dr. Terri Wilson

Dr. Aldo D. Migone

Graduate School
Southern Illinois University Carbondale
April 25, 2012

AN ABSTRACT OF THE DISSERTATION OF

SIMEON MBEWE, for the Doctor of Philosophy degree in CURRICULUM & INSTRUCTION, presented on April 25, 2012, at Southern Illinois University Carbondale.

TITLE: MIDDLE SCHOOL TEACHERS' FAMILIARITY WITH, INTEREST IN, PERFORMANCE ON, AND CONCEPTUAL AND PEDAGOGICAL KNOWLEDGE OF LIGHT

MAJOR PROFESSORS: DR. FRACKSON K. MUMBA and DR. KEVIN C. WISE

The purpose of this study was threefold: Examine middle school teachers' familiarity with, interest in, conceptual knowledge of and performance on light; Examine their ability to identify misconceptions on light and their suggested pedagogical ideas to address the identified misconceptions; and Establish the relationship between the middle school teachers' interest, familiarity, conceptual understanding, performance, misconception identification, and pedagogical ideas for light.

Sixty six (66) middle school science teachers enrolled in three math and science teacher professional development projects at Southern Illinois University Carbondale participated in this study. This study used mixed-methods approach to collect and analyze data. The participants responded in writing to four different instruments: Familiarity and Interest Questionnaire, Conceptual Knowledge Test, Two-tier Performance Test, and Misconceptions Identification Questionnaire.

Data was analyzed quantitatively by conducting non-parametric (Wilcoxon, Mann-Whitney U, and Kruskal-Wallis) and parametric (paired samples, independent samples, and One-Way ANOVA) tests. Qualitative data was analyzed using thematic analysis and open coding to identify emerging themes and categories.

The results showed that the teachers reported high levels of familiarity with and interest in learning more about light concepts. However, they had low conceptual knowledge and performance on light concepts. As such, middle school teachers' perceived knowledge of light concepts was not consistent with their actual knowledge of light. To some extent, the teachers identified students' misconceptions expressed in some scenarios on light and also suggested pedagogical ideas for addressing such misconceptions in middle school science classrooms. However, most teachers did not provide details on their pedagogical ideas for light. Correlations among the four constructs (familiarity, interest, conceptual understanding, and performance) were only significant between performance and conceptual understanding, r (64) = .50, p = .000. There was no significant relationship between conceptual understanding and familiarity, and between performance and familiarity. In view of these findings, it is evident that some teachers did not have sound conceptual understanding and pedagogical ideas to effectively help their students develop the understanding of light concepts accentuated in the US national science education standards. These findings have implications on teacher education and science teaching and learning.

DEDICATION

I dedicate this work to my wife, Catherine Tembo Mbewe and my children Greemara Mbewe, Kapyela Mbewe, Malisela Mbewe, and Yolonimo Mbewe. I also dedicate this work to my late father, Mr. Stephen Kapyela Mbewe and my late mother, Mrs. Greemara Njobvu-Mbewe.

ACKNOWLEDGEMENTS

First and foremost, my sincere thanks go to the Principal Investigators, Dr. Mary Wright, Mr. Harvey Henson, Dr. Frackson Mumba, and Dr. Lingguo Bu, of Science, Mathematics and Action Research for Teachers (SMART) graduate program for graciously granting me a research assistantship to pursue my doctoral studies. If I were not granted this assistantship this work would not have been a reality that it has become. I would also like to thank the University of Zambia management and council for granting me a study leave.

I would like to express my sincere gratitude and appreciation to the members of my dissertation committee: Dr. Frackson Mumba, Dr. Kevin. C. Wise, Dr. Vivien M. Chabalengula, Dr. Terri Wilson, and Dr. Aldo D. Migone. Their contributions and insight have shaped the outcome of this dissertation. My heartfelt appreciation goes to Dr. Frackson Mumba for his quick, constructive and scholarly feedback and criticisms throughout the preparation of this this work.

I would like to record my gratitude to the teachers in SIPAMS, PIASCS and SMART projects during the spring 2012 semester for the cooperation they rendered me during data collection for this dissertation.

I also wish to express my deepest sense of gratitude to my wife Catherine Tembo Mbewe and my children Greemara Mbewe, Kapyela Mbewe, Malisela Mbewe and Yolonimo Mbewe for their patience, and perseverance throughout the period of this study.

Finally, my sincere thanks go to the members of Carbondale Church of Christ at 1805 West Sycamore Street for their spiritual support throughout this study.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

Introduction

Concerns about the quality of science teaching in elementary and middle schools have been the focus of educational research, worldwide, in the past decades. Similarly, the need for quality science teachers in elementary and middle schools has been a national priority in the United States since the implementation of No Child Left behind (NCLB) Act in 2002. Although there is no agreed-upon definition of teacher quality, Darling-Hammond and Prince (2007) identified five characteristics of general teacher quality: strong general intelligence and verbal ability that help teachers organize and explain ideas, as well as to observe and think diagnostically; strong content knowledge which should be up to a threshold level that relates to what is to be taught; knowledge of how to teach others in that area (pedagogy), in particular how to use hands-on learning techniques (e.g. laboratory work in science) and how to develop higher-order thinking skills; an understanding of learners and their learning and development – including how to assess and scaffold learning, how to support students who have learning differences or difficulties, and how to support the learning of medium of instruction for those who are not already proficient; and adaptive expertise that allow teachers to make judgments about what is likely to work in a given context in response to students' needs. In general, these characteristics of teacher quality focus on what teachers should know and do in their classrooms as opposed to what teachers possess by way of academic qualifications.

Low teacher quality has a negative impact on science instruction and student achievement. For example, Darling-Hammond (2000) found that teacher quality was a significant factor in predicting student achievement. Sanders and Rivers (1996) also reported that students taught by ineffective teachers had lower achievement than those taught by effective teachers. Similarly, Porter and Smithson (2000) reported that “the best predictors of student achievement gains are the properties of instruction as it occurs in schools, what content is taught, how effectively, to which students, and to what levels of achievement” (p. 2). Thus, these research findings underscore the importance of preparing teachers with a clear content-focus as it leads to increased content knowledge and the ability to translate this content into pedagogy among teachers and improved student achievement. Similarly, science educators argue for teacher professional development programs focused on subject-matter knowledge, connected to specific standards for student performance, and embedded in a systemic context (Supovitz & Turner, 2000).

In view of the research findings stated above, it is significant to prepare elementary and middle school science teachers who can effectively teach physical science topics, especially the ones that research identified as difficult to teach such as light, sound, electricity, energy, forces and motion, magnetism, and electromagnetic induction (Bahar & Polat, 2007). In addition to having sound science knowledge, science teachers should be aware of the difficulties certain topics present to students. In order to start addressing this educational problem, this study examined middle school science teachers' familiarity with, interest in, conceptual knowledge of and performance on *light* and their pedagogical ideas for *light* in middle school classrooms. In this study, *familiarity* refers to personal sense of acquaintance with something encountered before (Mandler, 1980). *Interest* refers to a resulting curiosity in something by an individual due to the interaction of the person with the context and situation, and it is also actualized individual interest or situational interest (Hidi & Harackiewicz, 2000; Mitchell, 1993). *Conceptual understanding* refers to a reasonable level of articulation of the knowledge distributed and represented in key sectors of specific domain, and the scientific principles that describe the relationships among concepts in a specific domain (Alao & Guthrie, 1999). *Performance* refers to the accomplishment of an understanding of concepts measured against preset known standards of accuracy and completeness (Yip, Tsang & Cheung, 2003). *Pedagogy* refers to specialized knowledge of strategies and student conceptions of content that a teacher should possess (Smith, 2000).

Statement of the Problem

Science education research shows that both teachers and students have misconceptions on several science topics such as light, force and motion, and electricity (Cochran & Jones, 1998; Heywood, 2005; Küçüközer & Kocakülah, 2007). In particular, light is one of the most difficult topics for teachers and students in physical science (Langley, Ronen, & Elyon, 1997). As such, science educators have raised doubt on whether middle school science teachers can effectively teach light and its related concepts (McDermott, 2006). Most middle school science teachers do not have adequate training in science because middle school teacher education programs are broad and have less emphasis on science content knowledge (McDermott, Heron, Shaffer, Stetzer, 2006). However, in their role as science course designers and instructors, middle school science teachers must make instructional decisions that can promote effective science teaching and learning in such settings. Therefore, the success of providing quality instruction on light in middle school classrooms will largely depend on middle school teachers' instructional practice, conceptual knowledge about light, and their ability to identify students' misconceptions on light. Similarly, Talbot, Briggs and Otero (2009) argued that teachers should have sound ideas of how they would present the concepts on specific science topics to their students. Smith (2000) also reported that teachers need to demonstrate specialized knowledge of content and antecedent factors for effective instruction such as students' conceptions of the content.

Although several studies have been conducted on the topic of light, most of them mainly focused on identifying misconceptions among teachers (Bendall, Goldberg & Galili, 1993; Feher & Rice, 1987; Galili, Bendall & Goldberg, 1993; Heywood, 2005; McDermott et al., 2006). For example, Krall, Christopher, and Atwood (2009) compared in-service elementary and middle school teachers' understanding of selected light and force and motion concepts. Krall, *et al*. found that both groups of teachers lacked a conceptual understanding of light and demonstrated poor performance on the given tasks.

Other studies have mainly focused on assessing the development of teachers' pedagogical content knowledge [PCK] of light (Gess-Newsome, 2002; Neale, Smith & Johnston, 1990; Smith, 2000; Van Driel, Jong & Verloop, 2002; Van Driel, Verloop, & De Vos, 1998; Van Zee, Hammer, Bell, Roy & Peter, 2005). For example, Van Zee, Hammer, Bell, Roy and Peter (2005), used an ethnographic case study to document an example of inquiry learning and teaching of light during a summer institute for elementary and middle school teachers. Van Zee *et al.* reported that the participants improved their pedagogical content knowledge of light.

So far, no study has examined teachers' *familiarity* with and *interest* in the topic of light. As such, there is a dearth of research on middle school science teachers' familiarity with and interest in learning more about light and its related concepts. Both teachers' familiarity with and interest in learning more about certain difficult science topics have influence on their instructional practice (Ebenezer & Zoller, 1993), and subsequently on student achievement (Shernoff & Hoogstra, 2001). For example, teachers who are not familiar with concepts of light and not interested in learning more about light are unlikely to teach the topic well in their classrooms, and subsequently affect student achievement on light. Similarly, Van Driel, *et al* (1998) acknowledged that familiarity with a specific topic in combination with teaching experience positively contributes to teachers' sound pedagogical content knowledge. Furthermore, familiarity plays an integral role in conceptual understanding of key concepts in science (Ngo, Brown, Sargent & Dopkins 2010). Various forms of conceptual processing such as rating the pleasantness of the meaning of words and solving anagrams enhance familiarity-based recognition more than do various forms of perceptual processing such as rating the difficulty of generating rhymes to words and reading words (Jacoby, 1991; Toth, 1996; Verfaellie & Treadwell, 1993; Wagner, Gabrieli, & Verfaellie, 1997). This entails that familiarity-based recognition of stimuli without pre-existing conceptual representations is more profoundly enhanced by conceptual than perceptual processing at encoding information (Ngo *et al*., 2010). For these reasons, it is appropriate to investigate in-service middle school science teachers' levels of familiarity with light concepts.

Similarly, *interest* is central in determining how humans select and persist in processing certain types of information in preference to others (Hidi, 1990). Hidi discusses the many factors that contribute to text-based interest and suggests that interest elicits spontaneous, rather than conscious selective allocation of attention. Hidi further contends that the psychological and physiological processes associated with interesting information have unique aspects not present in processing information without such interest. While interest is an outcome of motivated behavior as it develops and deepens with engagement, it also mediates engagement from a developmental point of view (Hidi & Renninger, 2006). Hidi and Renninger also state that when learners have a well-developed individual interest, they maximize learning because they need to have positive feelings about the learning material. That is, both interest in and positive feelings towards the learning material are essential for paying attention to content, set of goals, and learning. For example, Smith (2000) reported that pre-service elementary school teachers who acknowledged having "experienced the shame and embarrassment of feeling unable to understand science", developed an interest in teaching science and consequently committed themselves to learning more about how to teach science effectively in science methods classes. For these above mentioned reasons, it is appropriate to investigate the extent to which in-service middle school science teachers are interested in learning about the concepts of light.

Furthermore, science education literature shows that no study has examined middle school science teachers' ability to identify students' misconceptions on light and how they would address such misconceptions in their classrooms.

Therefore, this study examined middle school teachers' familiarity with, interest in, conceptual knowledge of, performance on and pedagogical ideas about light in middle school classrooms. The results of this study were used to state what the middle school science teachers in the study know about light, their interest in learning more about light, familiarity with concepts of light, their ability to identify students' misconceptions on light, and how they would address such misconceptions in their classrooms.

This study focused on light because it is one of the main topics that teachers teach in middle school science and emphasized in the US national science education standards [NSES] (NRC, 1996). The concepts of light assessed in this study are: *vision (how an eye is able to see), light travelling at a greater speed than an airplane, the reflection of light, the refraction of light, the formation of shadows, the electromagnetic spectrum, why opaque objects appear the color they do in white light, why opaque objects appear the color they do in colored lights, color* *filters, light as a form of energy, luminous objects, non-luminous objects, light as transverse waves, wavelength of waves, amplitude of waves, crest of waves, and trough of waves.*

Purpose of the Study

The purpose of this study was threefold: Examine middle school teachers' familiarity with, interest in, conceptual knowledge of and performance on light; Examine their ability to identify misconceptions on light and their suggested pedagogical ideas to address the identified misconceptions; and Establish the relationship between the middle school teachers' interest, familiarity, conceptual understanding, performance, misconception identification, and pedagogical ideas for light.

Research Questions

1. To what extent are middle school in-service teachers familiar with the concepts of light emphasized in school science curriculum?
2. To what extent are middle school in-service teachers interested in learning more about the concepts of light?
3. To what extent do middle school in-service teachers conceptually understand the concepts of light emphasized in school science curriculum?
4. What is the performance level of middle school in-service teachers on the concepts of light emphasized in school science curriculum?
5. To what extent are middle school in-service teachers able to identify students' misconceptions on light?
6. How do middle school in-service teachers envision addressing the identified misconceptions about light in middle school classrooms?

7. To what extent are middle school in-service teachers' familiarity, interest, conceptual understanding, performance, and pedagogical ideas for light related?

Rationale for this Study

Science education literature shows that most previous studies have mainly focused on assessing teachers' knowledge about light. No study was located that has examined science teachers' familiarity with, and interest in learning more about light. Furthermore, studies on conceptual knowledge and performance on light and its related concepts have mostly focused on elementary education pre-service (Atwood, Christopher, & McNall, 2005; Bendall, Goldberg & Galili, 1993) and in-service (Atwood & Christopher, 2004; Greenwood & Scribner-MacLean, 1997) teachers. Although research shows that pre-service and in-service elementary school teachers have low conceptual understanding of and low performance levels on light, most previous studies used either multiple choice questions or interviews as sources of data. The present study used multiple sources of data such as a questionnaire (see appendix E on page 228) to assess teachers', familiarity with and interest in light and its related concepts, a conceptual knowledge test (see Appendix F on page 231) and a performance test (see Appendix G on page 232) to determine teachers' conceptual understanding of and knowledge about light concepts. Furthermore, literature shows that researchers have not examined middle school science teachers' ability to identify students' misconceptions on light and their pedagogical ideas on how to address the identified misconceptions in middle school classrooms. Yet, these aspects have influence on effective science teaching and learning in schools. Therefore, the present study goes beyond previous studies on light by examining middle school science teachers' familiarity with and interest in learning more about light, content knowledge about light, ability to identify students' misconceptions on light and how they would address such misconceptions in their classrooms.

Significance of the Study

In the past decade, the importance of preparing effective teachers has been at the center of reforms in science education (National Research Council, [NRC], 1996). Among the characteristics associated with effective science teaching are a desire for scientific knowledge including how to cultivate it among students, a specialized knowledge of appropriate ways to present science to children, an awareness of children's informal ideas, prior knowledge and experiences related to challenging science concepts, and an ability to create various learning environments through various teaching approaches (Zembal-Saul, Starr & Krajcik, 1999). This study embraces the above mentioned characteristics as it is situated in the area of pedagogical content knowledge in the domain of specific science subject matter knowledge. Therefore, this study is noteworthy because it sought to contribute to existing literature on content and pedagogical knowledge about light by documenting middle school teachers' familiarity with, interest in learning more about, conceptual knowledge about and performance on light concepts and their abilities to identify students' misconceptions about light concepts and how they would address such misconceptions in middle school classrooms. The findings of this study may have implications for science teaching and learning in middle school classrooms and teacher education. Furthermore, the results of this study might be of significance to science teachers, school administrators, science teacher educators, science curriculum designers and science education researchers. For example, science teachers would become aware of the expectations of the curriculum in the teaching of light and what needs to be improved on with regard to teaching of light and its related concepts in middle schools. Similarly, school administrators would become aware of how they would support their science teachers to effectively teach the topic of light. Teacher educators may use the findings in developing science methods courses and professional development programs for pre-service and in-service teachers, respectively. Science curriculum designers would use the results as guides to develop effective lessons and units on the topic of light for middle school students. Science education researchers may use the findings of this study as the starting points for further research on the topic of light and other science topics that are difficult for teachers to teach and for students to learn in schools.

Theoretical Framework of the Study

This section will first highlight the principles of constructivism as they apply to this study. Then, the section describes the relationship of the elements of this study (familiarity, interest, conceptual understanding, knowledge and pedagogy) to the tenets of constructivism.

Constructivism states that knowledge can't be transferred into the mind of a learner, instead a learner constructs his or her own knowledge by relating new ideas to existing ideas (Mandernach, 2006). As such, the constructivist approach to teaching and learning emphasize the pivotal role of prior knowledge in the learning process (Scott, Asoko, & Driver, 1992; Scott, Dyson, & Gater, 1987). According to constructivism, learning is the result of individual mental construction, whereby the learner learns by matching prior ideas with new information and establishing meaningful connections, rather than by internalising imagined facts to be regurgitated later (Kroll, 2004). In a constructivist approach, the context and beliefs and attitudes of the learner affect the learning of an individual (Cobb, 1996). Ideally, in the constructivist approach learners have more latitude in becoming effective problem-solvers, identifying and evaluating problems, as well as deciphering ways in which to transfer their learning to these problems.

Dewey (1916, 1938), asserted that knowledge emerges only from situations in which learners have meaningful experiences. Further, such situations have to be embedded in a social context, such as a classroom or community, where learners can take part in manipulating materials and, thus forming a community of learners who construct their knowledge together. Learners cannot achieve meaningful learning by means of rote memorisation; they can only learn by “directed living,” whereby concrete activities are combined with theory. The obvious implication of Dewey’s theory is that learners must be engaged in meaningful activities that induce them to apply the concepts they are trying to learn.

However, based on the psychological development of children, Piaget (1973) contrasted Dewey’s theory of constructivism by not limiting the construction of knowledge to meaningful experiences. Within Piaget’s theory of constructivism, the basis of learning is discovery: “To understand is to discover, or reconstruct by rediscovery and such conditions must be complied with if in the future individuals are to be formed who are capable of production and creativity and not simply repetition” (Piaget, 1973, p. 20). According to Piaget, children go through developmental stages (*sensory-motor, pre-operational, operational and concrete*) gaining knowledge through active experiences with the world physically or mentally while making sense of it. In the process, they accept ideas they may later discard.

Similar to Dewey’s view, Bruner (1973) viewed learning as a social process, whereby students construct new concepts based on current knowledge in contrast to Piaget’s view. A major theme in Bruner’s constructivist epistemology is that learning is an active process in which learners construct new ideas or concepts based upon their current and past knowledge (Bruning, Schraw, Norby & Ronning, 2004**)**. The learner selects and transforms information, constructs hypotheses, and makes decisions, relying on a cognitive structure to do so. Cognitive structure (i.e., schema, mental models) provides meaning and organization to experiences and allows the individual to go “beyond basic requirements" (Schunk, 2008, p 237). Furthermore, the extent to which learners engage in a task largely depends on how familiar they are with the presented information (Hatano & Wertsch, 2001) and also how much interested the learner is in learning more about the given information (Renninger, 2000).

Bruner (1960) recognized that *interest* in the material to be learned is the “best stimulus to learning, rather than such external goals as grades or later competitive advantage” (p. 14) as it leads to intuitive and analytical thinking among learners. Dewey (1944) had a similar view as Bruner’s. For example, his advocacy of experiential learning as the basis of the curriculum leads to a set of readiness requirements for those experiences. Some of the most salient elements for experiential learning are curiosity and interest in the task at hand (Dewey, 1998). A learner is therefore ready to learn when he or she has the necessary prerequisite experiences that allow him or her to be curious or interested in learning.

In summary, constructivism asserts that knowledge constructed by individuals because the only tools an individual uses to know are the senses-seeing, hearing, touching, smelling, and tasting (Lorsbach & Tobin, 1992). In this regard, most of the scholars interpret learning as the construction (instead of acquiring) and assimilation (instead of adoption) of knowledge using the tools available to an individual learner (Galili and Hazan, 2000).

The elements of the present study are teachers’ familiarity with, interest in, performance on, conceptual understanding of, ability to identify students’ misconceptions, and pedagogical ideas for concepts of light. This study examined familiarity and interest levels as elements that influence the construction of knowledge among teachers. On the other hand, performance, conceptual understanding, identification of students’ misconceptions, and pedagogical ideas were examined as the constructed knowledge among teachers. For the middle school teachers in this study, it is assumed that their constructed knowledge about light is as a result of their experiences in science courses as students themselves (elementary schools, high schools, college, and university), as classroom science teachers, and other experiences in society.

Familiarity and interest elements are so interrelated in literature, that it is not clear as to which of the two comes first. Recent attempts to describe the process of interest development espouse that the early development of interest seems to be influenced by an individual's affection toward the subject, but further interest development involves the interaction of knowledge with affection (Ainley, Corrigan, & Richardson, 2005). However, familiarity with concepts affects construction of knowledge by giving the learner a base on which to start building his or her new schemas (Tanner & Allen, 2005). Similarly, constructivism stresses the function of prior learning and extant concepts in the process of learning new material (Matthews, 2000). The central idea of constructivism is that learning is constructed by the learner building upon the foundations of previous knowledge. Thus, teachers' familiarity with and conceptual understanding of the concepts of light in this study is construed as the foundation on which new knowledge can be constructed and driven by their interest in wanting to learn more about the concepts of light.

Interest can be described in three general approaches: individual interest (disposition of the person), interestingness (characteristics of the context and situation), and the resulting psychological state of the individual due to the interaction of the person with the context and situation (Pintrich & Schunk, 2002). Likewise, this study will consider interest as a resulting psychological state of the individual due to the interaction of the person with the context and situation (tenets of constructivism) which is also known as actualized individual interest or situational interest (Hidi & Harackiewicz, 2000; Mitchell, 1993). Researchers posit that situational interest is tied to specific content that generate interest in students, and may last longer than simply arousal.

Individual or personal interest is considered to be a relatively stable, enduring disposition toward content or object (Pintrinch & Schunk, 2002). Individual interest can be defined in specific domains and academic subjects or it can be defined as a general orientation toward the desire to learn new information (Ainley, Hidi, & Berndorff, 2002; Schiefele, 1991). This general interest orientation is similar to mastery goal orientation (Pintrinch & Schunk, 2002) that represents the approach behavior to novel, uncertain, or puzzling phenomena with the goal of understanding (Ainley, Hidi, & Berndorff, 2002). Thus, it is also possible for learning to occur due to interest even without being familiar with the concepts under study.

A number of studies show that interest in learning is positively correlated with achievement (Krapp, 2002). Specifically for science, others have found that interest in science was also a contributor to performance by students (Shernoff & Hoogstra, 2001). However, performance is predicted by ability beliefs (Pintrich & Schunk, 2002).   Although, ability self-concepts are better predictors of performance in the subject (Eccles & Wigfield, 2002), Renninger (2000) posited that there is a stored-knowledge component that represented the individual's knowledge and understanding of subject content, and research has empirically confirmed its relationship to individual interest (Ainley, Hidi, & Berndorff, 2002). That is, there must be organized knowledge possessed by the person in order for individual interest to emerge. This knowledge not only leads the individual to seek challenges and answers to his or her piqued curiosity, but also "informs his or her developing sense of possible selves" (Renninger, 2000, p. 379). That is a deepening knowledge that is valued, and it shapes a person's identity. This deepening knowledge that is valued in an individual is a manifestation of learning in cognitive constructivism that is described as the inductive, non-linear cycle of appraising new schemas, and reflection (Ginsurg & Opper, 1987). This means an individual is being engaged in continuous learning process by comparing the past experience to the present experience. In this case, a science teacher with keen interest in learning more about the concepts of light would strive to develop pedagogical ideas that are helpful to his or her students. Such a teacher would also strive to identify students' misconceptions on science topics before instruction.

Therefore apart from the middle school teachers' constructed content knowledge this study also examined the middle school teachers' constructed knowledge about their understanding of how students learn. In this vein the suggested pedagogical ideas for the concepts of light were examined through the lens of inquiry instructional practice. The passion for science starts with inquiry (Matthews, 2000). For this reason teachers are encouraged to change or supplement the traditional teaching model in which a teacher typically writes on a blackboard and gives a one-way dialogue to a student audience (Cuba, 1993). While in inquiry-based learning teachers are offered more freedom in how they should educate their students, this poses a challenge, particularly in science classes where teachers might not have a science background (Roehrig & Luft, 2004). In addition, inquiry-based learning also takes more time than traditional textbook learning.

However, a teacher who is aware of a constructivist way of learning should embrace inquiry based-learning methods where a teacher gives a little bit more autonomy or responsibility to students for their own learning, using their curiosity and enthusiasm to promote the learning process (Crawford, 2007). Constructivism has alerted teachers to the function of prior learning and extant concepts in the process of learning new material, by stressing the importance of understanding as a goal of science instruction, by fostering pupil engagement in lessons, and other such progressive matters (Matthews, 2000). Therefore its paradigm requires implicitly that teachers have knowledge of how learners' ideas emerge and are influenced through teaching because of the focus on children's ideas which portrays teaching in terms of seeking ways to challenge thinking through scientific inquiry (Heywood, 2005).

Scientific inquiry centers on natural phenomena and it is an attempt to understand nature, to explain that understanding, to make accurate predictions from the knowledge acquired, and to apply the knowledge to societal needs (National Research Council, 1996). The vision of NSES is that students in K-12 science classrooms develop abilities to do scientific inquiry, gain understandings about scientific inquiry, and teachers facilitate students in acquiring deep understanding of science concepts through inquiry approaches (NRC, 1996). Middle school science teachers are required to teach science through inquiry-based instruction in order for their students to be engaged in meaningful learning of science (American Association for the Advancement of Science [AAAS], 1989, 1993; National Council for Teachers of Mathematics [NCTM], 1989; National Research Council, 1996, 2000). This is because in an inquiry-based science lesson, students formulate their own questions and answer questions through exploration.

Inquiry-based learning allows different students to solve problems in different ways, capitalizing on their individual strengths (Chiappeta and Koballa, 2006). Tafoya, Sunal & Knecht (1980) identify four levels of inquiry as confirmation/verification, structured, guided and open. Confirmation/verification inquiry level activities require students to verify concepts. At this level an end product (answer) is known and the procedure to be followed is given to the students by the teacher or instructor. At structured inquiry level activities, students are presented with a problem in which they do not know the results (answer/end product), but they are given a procedure to follow in order to complete the activity. Guided inquiry level activities provide the student only with a problem to investigate. Students are given a chance to determine the process to use and decide the data to collect. Open inquiry level activities allow students to formulate hypotheses or problems and the procedure for collecting data for interpretation and drawing conclusions.

As stated above, the core of constructivism is the belief that knowledge is not given but gained through real experiences that have a purpose and meaning to the learner, and the exchange of perspectives about the experience with others (Vygotsky, 1978). Likewise, the middle school teachers in this study have constructed knowledge about light, and developed pedagogical ideas about light through various experiences. Furthermore, teachers' familiarity with and interest in learning more about light concepts are individual aspects that can influence their constructed knowledge, conceptual understanding and pedagogical ideas about light concepts.

The tenets of constructivism described above on how learners learn makes constructivism the appropriate theoretical framework for this study which is aimed at examining middle school teachers' familiarity with, interest in learning more about light, and their conceptual knowledge and performance on light, teachers' ability to identify students' misconceptions on light and their pedagogical ideas on how to address the identified misconceptions in middle school classrooms; and establishing the relationship among middle school teachers' familiarity, interest, conceptual understanding, performance, misconceptions identification, and pedagogical ideas.

Delimitations of the Study

1. This study was limited to the investigation of the concepts of light as covered in the middle school science curriculum. Therefore, the results would not be generalized to concepts and phenomena beyond middle school grade level.
2. The participants in the study were middle school teachers who were participating in professional development programs at Southern Illinois University Carbondale.
3. The participants' responses were treated as their knowledge about light as a result of their teaching experiences and as students in science courses.

Limitations of the Study

1. Potential differences in experiences, as well as science content background knowledge among the participants could influence their familiarity with, interest in, performance on, conceptual and pedagogical knowledge that were examined in this study.
2. Participation by subjects was voluntary. As such, the possibility for subject mortality might pose a significant threat to the retention of subjects.
3. A sample of convenience was used. Therefore, the results of this study may not be generalized beyond this group of middle school teachers.
4. Participants were middle school teachers participating in math and science teacher professional development programs at Southern Illinois University Carbondale. It was not be possible for the researcher to randomly choose participants from this group.
5. Participants were predominantly white and female. Therefore, results may not be generalized beyond this demographic group of participants.

6. Although classroom observations would have added a practical dimension of how the participants teach the topic of light to their students, the researcher did not conduct lesson observations due to limited time teachers are available for this research project.
7. At the time of data collection some teachers had already taught the topic of light to their students.

Assumptions of the Study

1. The topic of light is one of the science topics the participants teach in schools.
2. The middle school teachers in the study had taught light in their classes before.
3. Participants had similar background knowledge and experiences in science.
4. Participants learned about light in their undergraduate and graduate science courses offered in the program study they enrolled.
5. Participants did their best in responding to data collection instruments.

Definitions of Key Terms

Content knowledge refers to knowledge of the substantive and syntactic structures of a discipline (Smith, 2000).

Curricular knowledge is defined as knowledge of the "programs designed for the teaching of particular subjects" (Shulman, 1986, p. 10) and knowledge of alternative curriculum materials cited in Abd-El-Khalick (2006, p. 3).

Encoding information is equated to learning and it refers to storing knowledge in memory in an organized, meaningful fashion (Schunk, 2008).

General pedagogical knowledge is a teacher's knowledge of broad principles and strategies for classroom organization and management (Shulman, 1987).

Light is the part of the electromagnetic spectrum which can be detected by a human eye and is responsible for the sense of sight. (Taffel, 1992, p. 710; Victor, Kellough & Tai, 2008, p. 487).

Light ray refers to an imaginary straight line of light that is part of a beam of light. A beam of light is imagined to be composed of an infinite number of straight lines of light bundled together. (Taffel, 1992, p. 321).

Middle school: In this study, middle school will be treated as equivalent to intermediate school or junior high school. This will be taken to include all classes that take science ranging from grade four through grade eight.

Opaque object refers to an object that stops or absorbs light rays (Lucas, 1991, p. 7).

Pedagogical knowledge is the specialized knowledge of strategies and student conceptions of content that a teacher is expected to possess (Smith, 2000).

Pedagogical Content Knowledge (PCK) – is defined as the "special amalgam . . . [or] the blending of content and pedagogy into an understanding of how particular topics, problems, or issues are organized, represented, and adapted to the diverse interests and abilities of learners, and presented for instruction" (Shulman, 1987, p. 8).

Substantive knowledge refers to knowledge of the global structures or principles of conceptual organization of a discipline. It includes knowledge of facts, concepts, and principles within a content area and knowledge of the relationships among these foundational ideas (Wilson, Shulman, & Richert, 1987).

Syntactic knowledge refers to knowledge of the principles of inquiry and values inherent to the field, and of the methods with which new ideas are added and deficient ones are replaced by those who produce knowledge in that field (Abd-El-Khalick, 2006, p. 3).

Teacher quality refers to teacher characteristics such as education, experience, and beliefs (Hinchey, 2010, p. 2).

Teacher performance refers to what a teacher does both inside and outside the classroom, and includes such elements as classroom interaction with students and collaborative activity with parents and other in the school community (Hinchey, 2010, p. 2)

Teacher effectiveness refers to teacher influence on student learning and includes elements as student test scores and student motivation (Hinchey, 2010, p. 3)

Transparent object refers to an object where light rays pass through easily; a real image can be observed through a transparent object (Lucas, 1991, p. 8).

Familiarity refers to personal sense of acquaintance with something encountered before (Mandler, 1980).

Interest refers to a resulting curiosity in something by an individual due to the interaction of the person with the context and situation which is also known as actualized individual interest or situational interest (Hidi & Harackiewicz, 2000; Mitchell, 1993).

Conceptual Understanding refers to a reasonable level of articulation of the knowledge distributed and represented in major sectors of specific domain, and the scientific principles that describe the relationships among concepts in the specific domain (Alao, S., & Guthrie, J. T., 1999).

Vision (how an eye is able to see): Without light there can be no vision. We see a body only when light coming from that body enters the eye. (Taffel, 1992, p. 317).

Speed of light refers to the distance covered by light in a unit time. For example the speed of light in a vacuum is approximately 300 million meters per sec (300 000 kilometers per sec). (Taffel, 1992, p. 318).

Reflection of light refers to the action of light striking a surface and bouncing off (Lucas, 1991, p.8).

Refraction of light refers to the bending of light rays as they pass through different mediums (Lucas, 1991, p. 8).

Formation of shadows: A shadow is formed when an opaque object cuts of the light rays coming from a source of light. A shadow is a dark space behind an object. (Taffel, 1992, p. 321).

The electromagnetic spectrum: This is a collection of electromagnetic waves: Gamma rays, X-rays, Ultraviolet rays, Visible light, Infrared rays, microwaves, Radio waves. Electromagnetic waves consist of mutually perpendicular vibrating electric and magnetic fields travelling at the speed of light along a propagation direction which is also perpendicular to the electric and magnetic fields. (Taffel, 1992, p. 334; Victor, Kellough & Tai, 2008, p. 487)

White light or white spectrum is a mixture of all colors of light: Red, orange, Yellow, Green, Blue, Indigo, and Violet. (Taffel, 1991, p. 320; Lucas, 1991, p. 8).

Why opaque objects appear in the color they do in white light: The color of an opaque object is the color of the light it reflects to the eye. (Taffel, 1991, p. 320).

Why opaque objects appear the color they do in colored lights: An opaque object absorbs all other colored lights thereby appearing black except its own color. (Taffel, 1991, p. 321).

Color filter is a transparent colored object that transmits its own color of light and absorbs all other colors. (Taffel, 1992, p. 320).

Light as a form of energy: That light is a form of energy is confirmed by the fact that sunlight is the ultimate source of energy on earth. Delicate experiments show that light exerts a tiny pressure capable of moving matter. In photoelectric cell or “electric eye,” light does the work needed to eject electrons from the light-sensitive surface on which it falls. In this process, light is converted into electrical energy. Light can also be converted into other forms of energy. The sun brought to a focus on a piece of paper with a magnifying glass is converted into enough heat to ignite the paper. In the green plant, light energy is converted into the chemical energy needed by the plant for growth. (Taffel, 1992, p. 317).

Luminous object refers to an object that is a source of light energy. (Lucas, 1991, p.7). A luminous object produces and emits its own light. (Taffel, 1991, p. 317).

Non-luminous object refers to an object that becomes visible only when it reflects light back to our eyes; it is not a direct source of light. (Lucas, 1991, p.7).

Light as transverse waves refers to light waves, in which the vibrations of the electric and magnetic fields are perpendicular to the direction of propagation of light (Lucas, 1991, p.7; Taffel, 1992, p. 714).

Wavelength of waves refers to the distance between corresponding parts of two waves moving in the same direction. For example, the distance from crest to crest or trough to trough. (Lucas, 1991, p.8; Victor, Kellough & Tai, 2008, p. 487).

Amplitude of waves refers to the height of a crest or depth of a trough of a transverse wave measured from a point of zero displacement. (Taffel, 1992, p. 704).

Crest of waves refers to a maximum displacement height of a vibrating particle or transverse wave (Lucas, 1991, p. 8; Taffel, 1992, p. 704).

Trough of waves refers to a maximum displacement depth of a vibrating particle or transverse wave (Lucas, 1991, p. 8; Taffel, 1992, p. 704).

Abbreviations

AAAS - American Association for the Advancement of Science

CPD – Continuing Professional Development

K-8- Kindergarten through Eighth grade

LEA- Local Education Agency

IBHE- Illinois Board of Higher Education

ISBE- Illinois State Board of Education

ISU- Illinois State University

NAEP - National Assessment of Educational Progress

NCLB- No Child Left Behind

NCTM - National Council for Teachers of Mathematics

NRC - National Research Council

NSES- National Science Education Standards PCK – Pedagogical Content Knowledge

PIASCS- Partnership for Improved Achievement in Science through Computational Science

SIPAMS- Southern Illinois Partnership for Achievement in Mathematics and Science

SIUC- Southern Illinois University Carbondale

SMART- Science, Mathematics and Action Research for Teachers

CHAPTER 2

LITERATURE REVIEW

Introduction

This chapter presents a review of literature on the concept of light. The chapter starts by outlining the light concepts in elementary and middle school curriculum followed by discussion on how familiarity and interest in science are related to achievement. The chapter goes on to review literature on misconceptions of light among students including the sources of the misconceptions such as textbooks and teachers. Then, the chapter presents reasons why teachers need to demonstrate a sound conceptual understanding of the concepts of light including research done on the conceptual understanding of light by teachers. A review of literature on Pedagogical Content Knowledge and professional development programs on light will be presented next. The chapter ends with a summary and implications of literature reviewed including directions from literature review.

Light Concepts in Elementary and Middle School Science Curriculum

Current US National Science Education Standards (NSES) (National Research Council [NRC], 1996) state that elementary students should ‘understand and apply the concept that light travels in a straight line until it strikes an object’. Students at this level should also understand that light can be reflected by a mirror, refracted by a lens, or absorbed by an object. Middle school students are expected to further this understanding of light phenomena by learning that the interaction between light and matter includes the ability to be transmitted, absorbed, reflected, and refracted. They should also understand that in order to see an object, light must be either emitted by an object or reflected by another object, and then, in both cases, the light must enter the eye (NRC, 1996).

Magnusson and Palinscar (2005) state that understanding light requires the organization of knowledge around core concepts which they identified as follows:

- All objects (experienced in our everyday lives) reflect and absorb light, and some objects also transmit light.
    - Dark or black objects mainly absorb light; light or white objects mainly reflect light.
    - There is an inverse relationship between light reflected from and absorbed by an object: more reflected light means less absorbed light.
- Light reflects from objects in a particular way: the angle of incoming light equals the angle of reflected light.
- What we see is light reflected from objects.
    - There must be a source of light for us to see an object.
    - Sources of illumination can produce light (e.g., the sun) or can reflect light (e.g., the moon).
- When an object blocks a source of light, a shadow is formed. Shadows are dark because there is no light reaching them to be reflected to our eyes. The distance of an object from a source of light it blocks determines the size of the objects' shadow. The shape of an objects' shadow depends on the angle of the object to the light, so the shadow of an object may have more than one shape.
- The color of an object is the color of light reflected from the object.
    - The colors of light come from white light, which can be separated into many colors.

    - The color of an object depends on the extent to which particular colors of light in white light are reflected and absorbed.
- Other concepts: The nature of light as both a wave and a particle are beyond what elementary students need to understand, but they are included in this study because teachers need to understand the concepts of transverse waves, wavelength, amplitude, trough and crest in order for them to help their students compare light to other forms of energy such as heat, sound, electrical and mechanical.

Familiarity and Achievement in Science

Familiarity refers to a personal sense of acquaintance with something encountered before (Mandler, 1980). In this case, the middle school teachers' personal acquaintance with the light concepts is as a result of their encounters in science courses as students themselves (elementary schools, high schools, college, and university), as classroom science teachers, and other experiences in society. Tanner and Allen (2005) referred to this as "knowing" – a familiarity with a broad range of ideas in science that get covered in a course or curriculum. In addition, this definition of familiarity embraces the view that some teachers have familiarity with or knowledge of a host of concepts, but with limited depth of understanding of the concepts and their connections to broader ideas and principles (National Center for Education Statistics, 2004). Therefore, familiarity with the concepts in this study will not be associated with deep understanding of the concepts but merely as knowledge which is associated with facts, memorization, and superficial knowledge (Wiggins & McTighe, 1998). This knowledge is however, very important in that it was considered as prior knowledge or constructed knowledge. Familiarity with light concepts were explored by the familiarity and interest questionnaire

(Appendix E) while conceptual understanding was explored by the conceptual knowledge test (Appendix F) and the multiple choice test on light (Appendix G).

Warren, Ballenger, Ogonowski, Rosebery, & Hudicourt-Barnes (2001) in the process of providing rich accounts of the centrality of language and culture to successful science teaching, expressed that when the students' familiarity with concepts is tapped, it can result into "robust understanding and achievement across a repertoire of performances and assessments of disciplinary knowledge and practice" (p. 548). For example Charity, Scarborough and Griffin (2004) found out that higher familiarity with School English was associated with better reading achievement, and these relationships were independent of memory ability. This was in a study that assessed 217 urban African American students using Wood-cock Reading Mastery Tests – Revised (WRMT-R) and sentence imitation assessment. Mullis, Martin, Beaton, Gonzalez, Kelly, & Smith (1997) found that students who were familiar with the concepts in the official curriculum guides in mathematics performed better than the students who were not. In a study of the relationship between students' exposure to technology and their achievement in science and math, Delen and Bulut (2011) found that students' familiarity with ICT and their exposure to technology helped to explain math and science achievement gaps between individuals and schools. Familiarity with technology is positively associated with performance (Attwell & Battle, 1999; Dumais, 2009). No study was found on familiarity with light concepts among teachers. In particular, no study was found among middle school teachers' familiarity with light concepts. Therefore, this study attempted to fill this gap in literature by examining middle school science teachers' familiarity with light and its related concepts.

Interest and Achievement in Science

Interest refers to a resulting curiosity in something by an individual due to the interaction of the person with the context and situation, and it is also known as actualized individual interest or situational interest (Hidi & Harackiewicz, 2000; Mitchell, 1993). Osborne, Simon, and Collins (2003) view it as a particular type of attitude towards some specific action to be performed towards an object (e.g. attitude towards doing school science). Crawley and Coe (1990) explored interest as a specific issue of students' attitude to school science, and their attitude to studying further courses in science in school with a view to gaining information of their effect on student subject choice. Therefore interest in this study was construed as a specific form of students' attitudes to light concepts, and their attitude to studying more about light concepts with a view to gaining information of their effect on student knowledge of light concepts.

In an analysis of science education from a sociocultural perspective, Lemke (2001) points out that student interest in, attitudes toward, and motivation toward science, and student willingness to entertain particular conceptual accounts of phenomena depend on community beliefs, acceptable identities, and the consequences for a student's life outside the classroom. While some may question the value of scientific knowledge (De Boer, 2000), lack of interest in science and technology remains a matter of concern for any society attempting to raise its standards of scientific literacy (Osborne, Simon, & Collins, 2003). This becomes especially so with the evidence that children's interest and attitude to science declines from the point of entry to secondary school (Breakwell & Beardsell, 1992).

Research studies have identified gender, personality, structural variables and curriculum variables as factors that influence students' attitudes towards science (Osborne et al., 2003). Most studies show that boys have more positive attitudes towards science than girls (Breakwell

& Beardsell, 1992; Jones, Howe, & Rua, 2000; Jovanovic & King, 1998; Weiburgh, 1995). Studies in structural variables indicate that socio-economic class of students has unclear effects on attitude towards science (Osborne et al., 2003), but parental support is positively related to attitude towards science (Simpson & Oliver, 1990). Involvement in science extracurricular activities produced mixed results: positive (Kingsland, 1991; Woolnough, 1994) and negative (Breakwell & Beardsell, 1992) while attitude of peers and friends remained a significant determinant of attitude towards science. Classroom and the quality of teaching are very strong factors that positively affect attitude towards science (Ebenezer & Zoller, 1993; Myers & Fouts, 1992; Osborne & Collins, 2000; Piburn, 1993). Curriculum variables have not been found to affect students' attitude (Simpson, Koballa, Oliver Crawley, 1994) but students' perceived difficulty of science has been determined to be a major factor with negative relationship to students' attitude towards science (Crawley & Black, 1992; Havard, 1996).

Some studies have shown a moderate relationship between attitude towards science and achievement (Beaton et al., 1996; Shrigley, 1990). Others have indicated that while there is only a moderate correlation between attitude towards science and achievement, they have also observed that this correlation is stronger for both high and low ability students (Jovan & King, 1998; Osborne & Collins, 2000; Simpson & Oliver, 1990; Weinburgh, 1995). Thus they linked 'doing well' in science to 'liking science' but other findings indicate that children can achieve highly in science without holding a positive attitude towards science (Osborne et al., 2003). However individual interest has a profound effect on cognitive functioning and performance because individuals interested in a task or activity pay more attention, are persistent for longer periods of time, and acquire more and qualitatively different knowledge than individuals without interest (Hidi, 1990).

Students' Misconceptions on Light

There is evidence that students have difficulties understanding light and its related concepts. For example, studies on knowledge about light, vision and optics phenomena have revealed that students possess alternative knowledge that is different from scientifically accepted knowledge (Andersson & Karrqvist, 1983; Bendall, Goldberg, & Galili, 1993; Chu, Treagust, & Chandrasegaran, 2009; Feher & Rice 1988; Fetherstonhaugh 1990; Goldberg & McDermott 1986, 1987; Guesne 1985; Jung 1987; Langley, Ronen & Eylon, 1997; LaRosa, Watts 1985; Osborne, Black, Meadows, & Smith, 1993; Ramadas & Driver, 1989; Saxena, 1991; Selley, 1996; Shapiro, 1994). For example, Langley et al. (1997) found out that students did not indicate direction in their representation of light. Fetherstonhaugh (1990) also found that a significant number of Western Australian students believed that the distance light travels depends on its energy. Goldberg & McDermott (1987) established that students believe that luminous objects that have a determined form send out parallel rays. Andersson and Bach (2005) found out that students think that shadows can be conceived as image, or as something belonging to an object. Bendall et al. (1993) found that most of the older students have the idea that the eye plays an active role while the object has a passive role in vision. More specifically, Palacios, Cazrla and Madrid (1989) documented that students think that the eyes send out something making it possible for human beings to see.

The students' alternative knowledge that is different from scientifically accepted knowledge is referred to as misconceptions (Tytler, 2002; Widodo, Duit, & Muller, 2002). These misconceptions are part of the students' preconceptions that they often come with to learning environments and affect the students learning of scientific concepts (Pfundt & Duit, 2006). The most negative effect that these misconceptions are responsible for is causing difficulties in learning among students (Hapkiewicz, 1992).

Other researchers initiated the concept of organizing the students' alternative knowledge about light into categories (e.g. Bouwens, 1987; Fetherstonhaugh & Treagust, 1992; Galili, Bendall & Goldberg, 1993; Jung, 1987; Rice & Feher, 1987; Ronen & Eylon, 1993; Selley, 1996). Some of the categories that emerged were the 'active' vision model (Guesne, 1985; Selley, 1996), holistic paradigm regarding images and shadows (Rice & Feher, 1987), image projection model (Galili et al., 1993), and heuristic (Feher & Rice, 1988) or hybrid (Galili et al., 1993) or synthetic (Vosniadou, 1994) models. In the 'active' vision model, an eye is perceived to play an active role in that it produces light in order for humans or animals to see objects (Selley, 1996). In a 'holistic' paradigm regarding images and shadows, students often conceptualize that the image is created at the object and travels through space (Rice and Feher, 1987). In the 'image projection' model, students explain the image formation in plane mirrors in terms of light rays carrying the image (Galili et al., 1993). In the 'heuristic' or 'hybrid' or 'synthetic' model, students often interpret light concepts using a mixture of pre-instruction and post-instruction understandings of the concepts (Feher & Rice 1988; Galili et al., 1993; Vosniadou, 1994). That is in this model there is often a clash between the spontaneous and formal interpretations (Galili & Hazan, 2000). For example, student diagrams and verbal comments would be in conflict, where a student would make a comment indicating that light rays carry an image while the diagram indicates the correct position of the image.

The difficulties in learning scientific concepts including light among learners have several sources. In learning about scientific concepts in general, Al-Rubayea (1996) listed the most frequent sources for incorrect ideas of Saudi Arabian students as guessing, physics textbooks, general information from everyday life, teacher, experience, TV or radio, newspaper or magazine, the phrasing of the questions, and parents. Ivowi (1984) stated that teachers and textbooks were the primary sources of Nigerian students' misconceptions. Heller and Finely (1992) identified teachers as a probable source of students' misconceptions. Beaty (1987) claimed that students learn misconceptions from physics textbooks since misconceptions are presented as facts in students' textbooks. Iona (1987) stated that if the textbooks had fewer errors, some misconceptions might not be widely distributed or gain acceptance.

Using document analysis, Kaltakci and Eryilmaz (2010) illustrated how students' experiences, textbooks, language used, and teachers are among several possible sources of students' misconceptions in light. For example, Kaltakci and Eryilmaz assert that personal experience is responsible for many students having the belief that moving back from a vertically held plane mirror allows them to see more of the image of their body; textbooks are responsible for the misconception that only the lens of the eye is accountable for the refraction of light without considering the cornea of the eye where 70 percent of refraction occurs due to a great change in the refractive index; language is responsible for the misconception that color is a property of objects rather than light due to daily language usage which states “the table is red” instead of “the table is reflecting red light”; and teachers could be responsible for the misconception about shadows by referring to findings by Bendall et al., (1993), and Feher & Rice (1987) where teachers had the conception that a shadow was a presence of something rather than as the absence of light.

Teachers' Conceptual Understanding of Light

Conceptual understanding refers to a reasonable level of articulation of the knowledge distributed and represented in major sectors of specific domain, and the scientific principles that describe the relationships among the concepts in the specific domain (Alao & Guthrie, 1999). The importance of conceptual development as well as the development of skills called for in the reformed science education (AAAS, 1994) cast into question the teachers' own conceptual understanding of the concepts to be developed in the students (Harlen & Hlroyd, 1997). As such, studies have addressed pre-service elementary teachers' conceptions of light phenomena (Atwood, Christopher, & McNall, 2005; Bendall et al., 1993), as well as the conceptions that in-service elementary teachers (Atwood & Christopher, 2004; Greenwood & Scribner-MacLean, 1997) and middle school science teachers (Trundle, Atwood, & Christopher, 2002) have about the topic of light. These studies collectively indicate that teachers over a broad range of ages and with diverse educational experiences have many conceptual difficulties with light concepts (Krall, Christopher, & Atwood, 2009). These findings suggest that teachers of K-8 students may hold non-scientific conceptions as well. Summers and Kruger (1992) found out that lack of conceptual understanding of various concepts contributed to the lack of the teachers' perceived competence to teach science and the teachers' retaining of many misconceptions found in school students. Therefore it is important for middle school teachers to possess sound conceptual knowledge about light concepts.

Several studies have been conducted on teachers' conceptions of light (Bendall et al., 1993; Feher & Rice, 1987; Heywood, 2005; McDermott, Heron, Shaffer, & Stetzer, 2006). For example, Bendall et al. (1993) reported that prospective teachers' ideas on light were in a stable state from adolescence to adulthood. The study was carried out in an activity-based science class where the teachers were enrolled. The design aimed at describing prospective elementary teachers' prior verbal and diagrammatic knowledge about various aspects of light, seeing, shadows, and mirror images. Data were collected through individual clinical interviews using simple apparatus (light bulb, objects, screen, and plane mirror). Four tasks were administered to each student: shadow task, bulb-screen task, bulb-eye task, and the bulb-eye-mirror task. The results show that the prospective teachers had prior knowledge that emerged from their interpretations of everyday experiences. Bendall et al. used these results to propose conceptual change instructional strategies for instructors of prospective teachers. The proposed instructional strategies involve helping prospective science teachers to make explicit connections between powerful explanatory ideas, their diagrammatic representations, and real world optical phenomena in order for them (prospective science teachers) to develop the desired conceptual understanding. However, no follow up investigation was done to document how the teachers implemented these strategies in their classrooms.

Although maturation among learners can change their early ideas about vision (Eylon, Ronen, & Ganiel, 1995; Eylon, Ronen, & Langley, 1993), Langley, Ronen, and Eylon (1997) point out that these ideas are not attributable to age, unless they are dealt with by the right type of instruction. This was in a study that formed one part of a 2-year project aimed at revising the instructional approach for geometrical optics in the 10^{th} grade. Data was collected through a questionnaire that was administered to 139 grade 10 Israeli students in five different high schools before formal instruction in optics. The schools were selected because of their suitability (with respect to availability of equipment and timetable considerations) and willingness of the participants to participate in the project. The instructional intervention was based on the extensive use of a diagrammatic representation as a descriptive, explanatory, and problem-solving tool in the domain of light. The study elicited conceptions and representations of light propagation, image formation, and sight typical to pre-instruction learners. However the researchers paid special attention to identifying precursors of problematic features of post-instruction students' knowledge. The premise for Langley et al.'s study was that the difficulties students have before, during, and after traditional instruction with respect to representing optical phenomena have their origins in the fragmented pre-scientific knowledge constructed on the basis of experience. They assert that these difficulties persist because the key factors leading to fragmentation are not usually addressed and remedied. The main findings of the study indicate that (a) pre-instruction students display some familiarity with optical systems, light propagation, and illumination patterns, (b) student-generated graphical representations describing and explaining optical phenomena display some features of formal ray tracing, (c) pre-instruction students have not developed a consistent descriptive and explanatory model for light propagation, and (d) the context of sight seems to have a confounding effect on the establishment of a unified prior model for optical phenomena.

In another study, Heywood (2005) showed that primary school trainee teachers experienced significant difficulties in articulating coherent explanations regarding basic ideas about light. This presents particular professional constraint within the current demands of the primary initial teacher training science curriculum. The study focused on primary school trainee teachers' conceptualization of the vision process and image formation in a plane mirror. Fifty-five non-specialists, undergraduate trainee primary teachers on a 4-year program of initial teacher training participated in this study. The process incorporated tracking trainees' ideas during university-taught sessions through collating and analyzing responses to the set tasks that included both the interpretation of annotated diagrams of the vision process and diagrammatic representation of image formation in a plane mirror. A selected sample of trainee teachers was also interviewed. Heywood (2005) argues that a more productive approach would be to focus on the professional issue of pedagogy through raising trainees' awareness of the conceptual difficulties in learning rather than the current curriculum focus that seems to privilege knowing over understanding. Heywood made no follow up study to find out how these teachers would teach the concepts in their classrooms.

Pedagogical Content Knowledge

In addition to conceptual understanding of the basic concepts of light, a teacher needs to develop sound pedagogical content knowledge (PCK). This is the specialized knowledge for teaching derived from the content knowledge that is specifically employed to facilitate learning as it is concerned with how to make particular subject matter comprehensible to particular students (Magnusson & Palincsar, 2005). For example when students erroneously claim that light is a gas, it is not sufficient for a teacher to simply know that light is energy, and not a state of matter. Instead, the teacher needs to further know what observations of light might convince students that it is not a gas, which in turn is informed by knowing how students think of gases, what their experiences of gas and light have likely been, and what is possible to observe within a classroom context. Studies in PCK have revealed the need for teachers to have a sound PCK in specific science content so as to teach their students effectively through the inquiry-based model of instruction (Smith, 2000; Van Driel, et al., 1998). This entails that teacher educators should make explicit the content and pedagogical knowledge in specific science content in the science methods courses for teachers. Van Driel et al. (1998) uphold "the importance of a thorough and coherent knowledge of subject matter" (p. 690). Research in PCK has added an informative dimension to the perception of science teaching by reintroducing the importance of content knowledge and promoting the renewed vigor in the subject-specific teaching areas at all levels of education (Gess-Newsome, 2002). As a result, PCK plays a critical role in the transformation process of science teachers' subject-matter knowledge into teachable content knowledge (Geddis, 1993).

Rowan, Schilling, Ball and Miller (2001) describe Shulman's view of PCK as a "form of *practical* knowledge that is used by teachers to guide their actions in highly contextualized classroom settings". They outline that:

> "this form of practical knowledge entails, among other things: (a) knowledge of how to structure and represent academic content for direct teaching to students, (b) knowledge of the common conceptions, misconceptions, and difficulties that students encounter when learning particular content, and (c) knowledge of the specific teaching strategies that can be used to address students' learning needs in particular classroom circumstances. … pedagogical content knowledge builds on other forms of professional knowledge, and is therefore a critical—and perhaps even the paramount—constitutive element in the knowledge base of teaching". (Rowan, Schilling, Ball, & Miller, 2001, pp. 2-3).

Studies have found that sound content and pedagogical knowledge possessed by a teacher leads to effective teaching and learning (Gess-Newsome, 2002; Van Driel, Jong & Verloop, 2002). One study examined the development of pre-service chemistry teachers' pedagogical content knowledge (Van Driel et al., 2002). Van Driel et al. (2002) discuss the concept of PCK within the context of science teaching. First, they define PCK within the tradition of research on teachers' craft knowledge and they identify possible purposes of research on PCK. Second, they indicate that investigations in PCK identify teaching experience as the major source of PCK, while adequate subject-matter knowledge appears to be a prerequisite. Finally, they present an empirical study which focuses on PCK with respect to chemical equilibrium. It was aimed at improving chemistry teachers' abilities to recognize specific preconceptions and conceptual difficulties related to chemical equilibrium, and promoting their use of interventions and strategies that promote conceptual change during classroom practice. A total of 12 teachers attended the workshop on voluntary basis with inspiration either by interest in the topic or by the wish to innovate their teaching practice. Therefore, the results of this research may not be taken as representative of all teachers. Data were appropriately generated by audio taping the workshop sessions, participants' written responses to assignments during the workshop, and evaluative questionnaires. In addition classroom lessons of two of the participants were audio taped during the implementation stage. After a stepwise analysis of the audio tapes they report the effects of participation in an in-service workshop supported by an experimental course in classroom practice on the teachers' PCK. The results showed that the chemistry teachers developed the valuable understanding of the relationship between micro and macro aspects of chemical equilibrium required of teachers in order to teach their students effectively (Van Driel et al., 2002).

With respect to the topic of light, Smith (2000) describes how she used PCK research findings as a road map for designing her senior science methods course and as a mirror within which to reflect on her work. In her report she describes the importance of knowing the ideas that students bring into the class room and the goodness of using these ideas to help the teachers understand the concepts and phenomena in science subject matter in order for the teachers to be effective science teachers. Smith (2000) reports how one teacher developed an understanding of how to teach a unit on shadows through PCK principles. This is part of a large two-year study of pre-service elementary teachers in a five year teacher preparation program where Smith studied students in their senior year course (TE 401) on “teaching subject matter to diverse learners” and students who took a special course in physics concurrently. Smith achieved this by interviewing students before and after the courses, and videotaped the class sessions.

Upon realizing that PCK is not a straightforward process to recognize or articulate, Loughran, Milroy, Berry, Gustone, and Mulhall (2001) used elements that give insight into the teachers’ PCK to examine experienced science teachers’ pedagogical content knowledge and ways in which that knowledge might be captured, articulated and portrayed to others. These elements are science teachers’ understanding of content (concepts), their particular views of teaching and learning within a context, and the subtleties of their practice in response to the learning demands of their students. Using interviews, group discussions, and observations of teaching, they obtained data that led them to propose Content Representation (CoRe) that is linked to Pedagogical and Professional experience Repertoires (PaP-eRs) as a way of documenting teachers’ PCK. Therefore from Loughran et al’s perspective, CoRe represents the particular content/topic of the science teaching while PaP-eRs help to illuminate specific aspects of the CoRe and therefore offer insights into pedagogical content knowledge itself. Loughran *et al*’s (2001) results offer new ways of conceptualizing what PCK is and how it might be captured, documented and disseminated. In order to portray PCK they used features such as classroom reality (the complexity of a real teaching situation including diversity of students’ responses), teachers’ thinking (about the content and responses from the students), students’ thinking (the links they are/not making and why), and the content itself (what is it about the content that shapes the teaching and learning and why).

For example, Loughram, Mulhall, & Berry (2004) used the particle theory concepts to illustrate how CoRe and PaP-eR interact when they reexamined the data collected earlier in

Loughran et al's study. This was in a longitudinal study which started by interviewing 50 high school teachers, then mixing interviewing with observation of classroom teaching and finally to working with small groups (three or four per group). Through this approach new understandings of PCK emerge that are of interest in terms of both academic (knowledge building about PCK) and teaching perspectives. The CoRe portrays the important science ideas/concepts including why it is important for students to know the particular ideas/concepts, what teachers did not expect their students to know at that time, difficulties/limitations concerned with teaching the ideas/concepts, the teachers' knowledge about their students' thinking which influenced their teaching of the ideas/concepts, teaching procedures (and particular reasons for using these procedures to engage with these ideas/concepts) and specific ways of ascertaining students' understanding or confusion around the idea of particle theory. The PaP-eR illustrated the importance of the teachers' understanding of the content in influencing how a teacher approaches the teaching of the particle model of matter.

In the present study, the elements that offer insight into teachers' PCK (CoRe and PaP-eR), will be revealed by the middle school teachers' responses to the conceptual knowledge questionnaire, their performance on light test and their pedagogical ideas about light concepts.

Professional Development Programs on Light

Research indicates that most of the middle school teachers require Continuing Professional Development (CPD) programs in order for them to offer meaningful teaching and learning to their students (Garet, Porter, Desimone, Birman & Yoon, 2001). The professional development activities advocated for are those that concentrate on teachers' knowledge of specific subject matter content and their understanding of how children learn the content because it has been observed that professional development activities centered on general pedagogies or teacher behaviors have not been able to adequately change teachers' knowledge, beliefs, or practices (Lee, Hart, Cuevas, & Enders, 2004).

Several professional development programs have been designed and implemented in order to enhance teachers' understanding of light and its related concepts (American Association of Physics Teachers, 2001; Hammer, 2000; Hestenes, 1997; Laws, 1991; McDermott, 1990, 1996 ; Polman & Pea, 2001; Van Zee, 2000). The evaluation of these PD shows improvement in teachers understanding of light concepts after the intervention. For example, Van Zee, Hammer, Bell, Roy, and Peter (2005), used a case study in the tradition of ethnography communication to document an example of inquiry learning and teaching of light during a summer institute for elementary and middle school teachers. In this study a small group of participants (three teachers, the lead instructor and the researcher) constructed an explanatory model for an optical phenomenon that they observed. The group made sense out of observing a straw that appeared to bend when placed at an angle in a cup of water and a dot that appeared to rise as water was poured into a cup on the side of which the dot had been drawn. Unlike many inquiry-based programs that focus on the subject matter, on the learning about science and the nature of science, Van Zee et al's study engaged the participants in the formation of beliefs that they needed to think for themselves that understanding physics involves accessing and incorporating their own knowledge and experiences. Van Zee et al emphasized that it is important to coordinate and reconcile alternative ways of thinking as students are engaged in observing an intriguing phenomenon. Data sources included video- and audio- tapes of instruction, copies of the participants' writings and drawings, field notes, interviews, and staff reflections. This was part of the project that involved the participants in developing case studies of their students' inquiries into physical science. The participants in Van Zee et al's study constructed an explanatory model for an intriguing optical phenomenon that they were observing on the refraction of light.

Neale, Smith, and Johnston (1990) studied eight lower elementary education (K-3) teachers' knowledge about light. These teachers participated in a 4-week summer institute that provided an intervention unit on light and shadows. The intervention was guided by conceptual change theoretical framework. Data sources were videotapes of lessons taught before and after the institute, interviews that measured students' understanding of light and shadows phenomena before and after the unit was taught and the teachers' written evaluations of the unit. They found out that the 8 teachers were successful in implementing the conceptual change unit on their own on light and shadows and in changing students' conceptions. The strategies focused on students' prior conceptions of light and shadows and sought to provide the conditions under which these preconceptions may be elicited and challenged so that students can construct more general, powerful, or correct conceptions. This kind of teaching calls for a thorough understanding of subject-matter knowledge, including knowledge of children's likely preconception and representations of subject matter that students can grasp and the teachers must know how to identify students' misconceptions and know how to challenge misconceptions by providing discrepant events.

Keys and Kennedy (1999) used a developmental approach research design to explore the daily interactions of one teacher as she strove to incorporate an inquiry orientation in the classroom while teaching science on the units of light and weather. The participants included a fourth grade teacher, a university assistant professor in science education and 26 fourth graders. Analysis was done via interpretive paradigm. Through negotiation of the meanings of inquiry in the implementation process, the teacher collaboratively developed an inquiry teaching that worked. Keys and Kennedy (1999) concluded that teacher educators should draw on themes that they likely espouse themselves. Therefore, they suggested more open-ended approaches to teacher education -where there is need to respond to teachers' individual knowledge bases, interests, and cognitive strengths in developing reform oriented practices.

Galili and Hazan (2000) explored a total of 166 ninth grade, tenth grade and teacher-training college students' knowledge of light, vision and related topics before and after commonly practiced instruction. This knowledge and the knowledge reported in studies of other populations were analyzed and interpreted with an intention to construct structures of alternative knowledge by learners of optics. They suggested a hierarchical structure as a representation of the collective conceptual knowledge of students in terms of facets and schemes of knowledge. Facets are aspects of views that 'reflect the conceptual, operational and representative ideas and beliefs of children' (Galili & Hazan, 2000, p. 60). Schemes of knowledge are 'elements in knowledge architecture conceived as representing a more inclusive unit of higher level of abstraction' of the concepts of light and they 'expose the common core explanatory pattern deployed by an individual for addressing different settings' (Galili & Hazan, 2000, p. 60). They subsequently assert that these schemes provide a basis for the design of more effective methods of instruction to challenge the fundamental patterns of alternative knowledge, instead of confronting students' misconceptions individually. On the basis of their study results, they made the following suggestions for the modifications in curricula to improve instruction in optics: the observers' role should be elaborated at the beginning of studying light, there is need for an intensive discussion on the instrumental nature of light rays, there is need to elaborate explicitly on the concept of the image, there is need to introduce the concept of light flux instead of exclusive reference to light rays, and there is need to include a minimal of qualitative treatment of certain topic which are presently only in advanced courses.

Summary and Implications

The reviewed literature indicates that both teachers and students have similar difficulties and misconceptions about light concepts. Many sources have been identified for the students' difficulties and misconceptions which include teachers. Yet, for teachers to teach their students effectively, they need to be aware of the sources and types of misconceptions among their students. Conceptual understanding of the concepts about light is very important for teachers and yet studies on the teachers' conceptions of light concepts show that teachers have conceptual difficulties and they also have non-scientific conceptions of light.

Literature also shows that elementary and middle school teachers have gone through education training programs that has not prepared them to have a deep conceptual understanding of science concepts. Yet, they are expected to teach their students to develop conceptual understanding of the science concepts. As a result, researchers have suggested professional development programs for elementary and middle school teachers in order to help them develop the desired conceptual and pedagogical understanding of many science concepts including light. Literature shows that a lot of research has been done in the areas of pedagogical content knowledge and subject matter knowledge in other science subjects among the elementary and middle school teachers. However, more of this research has been carried out among elementary school teachers than middle school teachers who actually need to develop the specialized subject pedagogical content knowledge.

Literature reviewed further shows that a number of studies have been done on elementary and middle school teachers' development of conceptual knowledge of the concepts of light through conceptual change strategies. Results from such studies have been used to develop teaching materials for use by teachers to teach the topic of light effectively to their students. While these efforts of developing teaching materials in light have been done in the hope of improving student achievement in elementary and middle schools, literature shows that students have continued to perform poorly on national and international tests. However, a common application of physics education research is to use appropriate methodologies to address student difficulties and misconceptions (Kaltakci & Eryilmaz, 2010). This entails that teachers have a great role in the process of identifying and eliminating the misconceptions on light and its related concepts. Therefore teachers need to demonstrate a sound conceptual understanding of the basic concepts in light before they can adequately teach or propose to teach their students effectively.

Literature also shows that no study has been carried out to determine the levels of familiarity and interest in the topic of light among elementary and middle school teachers. Most research studies have focused on teachers’ content knowledge and attitudes towards science.

Directions from Literature Review

From the literature reviewed it is evident that middle school teachers have difficulties in articulating the concepts of light. It is also evident in literature that teachers need professional development in order to understand light concepts and how to teach light concepts to their students. Likewise, this study was designed to find out middle school teachers’ performance on, conceptual understanding of and pedagogical ideas of light concepts. Previous studies have used either multiple choice questions or interviews to determine the teachers’ performance, conceptual understanding and pedagogical ideas of light. This study, in addition to multiple choice questions and semi-structured questionnaire, included questions that asked the teachers to write their ideas on the concepts on light to measure the teachers’ performance and conceptual understanding.

The study also included a unique way of determining the teachers' conceptual understanding and pedagogical ideas by using questions that asked the teachers to first identify students' misconceptions in given scenarios and then suggest ways of addressing the identified misconceptions. This study also attempted to fill the gap by examining middle school teachers' familiarity with and interest in learning more about light concepts.

Therefore, the purpose of this study was threefold. First the study examined middle school teachers' familiarity with, interest in learning more about light, and their conceptual knowledge and performance on light. Second this study examined the teachers' ability to identify misconceptions on light and their pedagogical ideas on how to address the identified misconceptions in middle school classrooms. Third the study also sought to establish how middle school teachers' interest, familiarity, conceptual understanding, performance, and pedagogical ideas for light are related.

CHAPTER 3

METHODOLOGY

Introduction

This chapter presents the purpose of the study, research questions, research design, context of the study, access and recruitment of participants, description of data collection instruments, reliability and validity of instruments, and data collection and analysis procedures. The chapter ends with a summary of data collection and analysis.

Purpose of the Study

The purpose of this study was threefold. First, the study examined middle school teachers' familiarity with, interest in learning more about light, and their conceptual knowledge and performance on light. Second, this study examined the teachers' ability to identify misconceptions on light and their pedagogical ideas on how to address the identified misconceptions in middle school classrooms. Third, the study sought to establish the relationship among the middle school teachers' interest, familiarity, conceptual understanding, performance, misconception identification, and pedagogical ideas for light.

Research Questions

1. To what extent are middle school in-service teachers familiar with the concepts of light emphasized in school science curriculum?
2. To what extent are middle school in-service teachers interested in learning more about the concepts of light?
3. To what extent do middle school in-service teachers conceptually understand the concepts of light emphasized in school science curriculum?

4. What is the performance level of middle school in-service teachers on the concepts of light emphasized in school science curriculum?
5. To what extent are middle school teachers able to identify students' misconceptions on light?
6. How do middle school in-service teachers envision addressing the identified misconceptions about light in middle school classrooms?
7. To what extent are middle school teachers' familiarity, interest, conceptual understanding, performance, and pedagogical ideas of light related?

Research Design

This is an explanatory educational research study (Fraenkel and Wallen, 2010). In particular, this study used mixed-methods approach where both quantitative and qualitative data collection, analysis, and integration procedures were conducted (Tashakkori & Teddlie, 2003). Mixed methods approach generally follows philosophical and methodological pragmatism with a very broad and inclusive ontological realism (Maxcy, 2003). Pragmatism (Johnson & Onwegbuzie, 2004) and inclusive ontology (Sanders, 1997) have played great roles in shaping the understanding of validity in mixed research approaches. This has led to labeling the criteria for assessing mixed research studies as legitimation, conceptualizing the legitimation in mixed studies in terms of inference quality and inference transferability, and identifying the types of legitimation for mixed research (Onwuegbuzie & Johnson, 2006). Greene, Caracelli and Graham (1989) derived five empirical general purposes of mixed-methodological research studies: Triangulation (i.e. seeking convergence and corroboration of findings from different methods that study the same phenomenon); Complementarity (i.e. seeking elaboration, illustration, enhancement, and clarification of the findings from one method with results from the other method); Development (i.e. using the findings from one method to help inform the other method); Initiation (i.e. discovering paradoxes and contradictions that lead to a re-framing of the research question); and Expansion (i.e. seeking to expand the breath and range of inquiry by using different methods for different inquiry components). Therefore, this study endeavored to observe these purposes before and during data collection, during data analysis, and interpretations of the results.

Creswell (2007) also identified four major types of mixed methods designs: *Triangulation design, Embedded design, Explanatory design, and Exploratory design*. Creswell stated that triangulation design also involves the concurrent collection and analysis of quantitative and qualitative data to enable a researcher to better understand a research problem (Creswell, 2005). In view of the rigor of the mixed-method design, this study used triangulation to gain an in-depth understanding of the middle school teachers' familiarity with, interest in learning more about, conceptual knowledge about, performance on and pedagogical ideas for light. In particular, this study used a *triangulation design* so as to be able to confirm, cross-validate, and corroborate the findings (Creswell, Plano Clark, Guttman & Hanson, 2003). The visual model of the procedures of the concurrent triangulation mixed-method design of this study is shown in Figure 3.1 on the next page. Quantitative data from the familiarity and interest questionnaire [Appendix E], conceptual knowledge test [Appendix F], multiple-choice performance test [Appendix G], and qualitative data from misconceptions identification questionnaire [Appendix H] were collected concurrently.

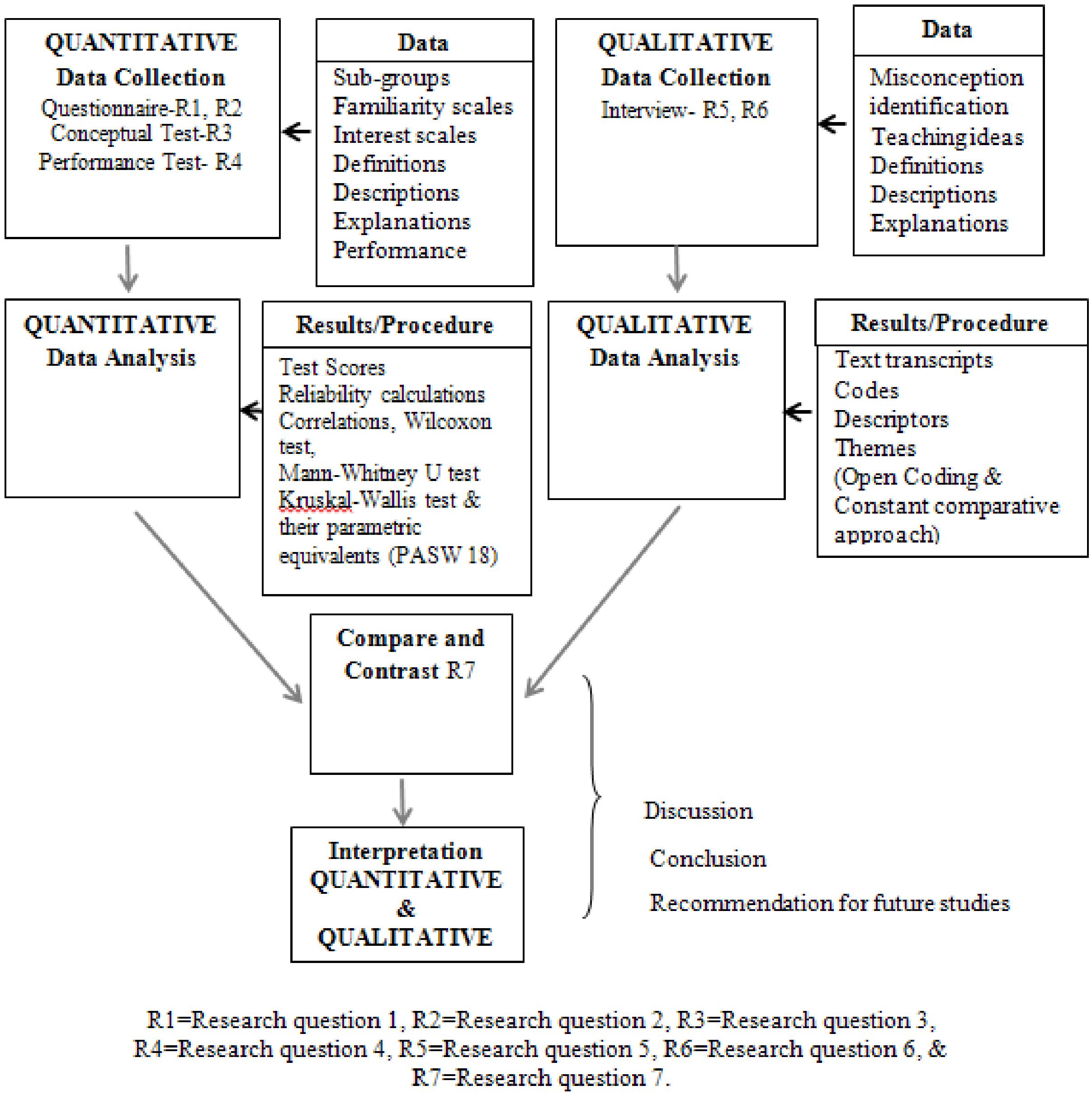

Figure 3.1: Visual model of the mixed triangulation design

The mixed-method triangulation design has its own strengths such as: both qualitative and quantitative types of data are collected during one phase of the research at the same time; each type of data can be collected and analyzed separately, using the techniques traditionally associated with each data type; if this research design is used by a team, the team can include individuals with both quantitative and qualitative expertise; and it gives researchers an opportunity to holistically analyze the research problem by looking at both types of data.

On the other hand, there are some challenges associated with the concurrent triangulation design. Below are some challenges and options for minimizing them:

1. Much effort and expertise are required, particularly because of the concurrent data collection and the fact that equal weight is usually given to each data type. In the present study, this weakness was addressed by constituting a dissertation committee that comprised faculty with qualitative and quantitative expertise. A researcher may face the question of what to do if the quantitative and qualitative results do not agree. These differences can be difficult to resolve and may require the collection of additional data. In the current study both qualitative and quantitative results agreed. Researchers need to consider the consequences of having different sample sizes when converging the two data sets. Different sample sizes are inherent in the design because quantitative and qualitative data are usually collected for different purposes (generalization versus in-depth description, respectively). Researchers can consider collecting large qualitative samples or weighing the cases.
2. The goal of mixed methods research is not to replace either quantitative or qualitative research. Instead, mixed research design utilizes the strengths of two or more approaches by combining them in one study, and attempts to minimize the weaknesses of the qualitative and quantitative approaches if employed separately (Creswell, 2003). For example in this study, the multiple choice performance tests' weakness was minimized by the conceptual knowledge test where participants were asked to write and explain their responses to demonstrate their understanding of the concepts in light.

As stated above, this study endeavored to maximize the strengths and minimize these challenges of mixed method approach before and during data collection, and during data analysis and during interpretations of the results.

Context of the Study

This study was conducted in three math and science teacher professional development projects at Southern Illinois University Carbondale (SIUC) namely: Science, Mathematics and Action Research for Teachers (SMART), Partnership for Improved Achievement in Science through Computational Science (PIASCS), and Southern Illinois Partnership for Achievement in Mathematics and Science (SIPAMS). The teachers in these projects were certified to teach middle school science. This means that although some of the teachers were not teaching middle school grades at the time of this study, they were actually certified to teach the content at middle school level.

SMART project

This was one of the Illinois Mathematics and Science Partnership graduate program projects funded by the US Department of Education through *Illinois State Board of Education* (ISBE) in the state of Illinois (Mumba, Wright & Henson, 2007). This resource of the Illinois Mathematics and Science Partnership program was funded by the No Child Left Behind (NCLB), Title II, Part B, funds. The project offers a Master of Science in Mathematics and Science Education (MSMSEd) Degree. The degree program framework includes innovative inquiry-based courses that provide content, pedagogical and research skills and technology integration skills. The courses are mainly offered online, with few face to face sessions. This is done to accommodate teachers' full time responsibilities in schools. The program has 36 credit hours of coursework in chemistry, physics, biology, geology, mathematics, pedagogy, and action research courses. The duration of the program is 18 months. Two courses (6 credit hours) are offered per semester. The main goals and objectives of this project are:

Goals:

- Increase elementary school teachers' mathematics and science content and pedagogical knowledge.
- Increase elementary school teachers' knowledge and skills for conducting and applying educational research in their classrooms.
- Develop long-term relationships between teachers and SIUC scientists and mathematicians.
- Enhance existing partnerships and create new ones among SIUC and LEAs in Southern Illinois.

Objectives:

- Develop an intensive graduate program for elementary school teachers to address mathematics and science content (biology, chemistry, geology and physics) and pedagogical knowledge, National and State Learning Standards, leadership, mentoring, and communication skills.
- Infuse inquiry-based approaches through assembling of inquiry-based integrated math and science courses for the graduate program.
- Promote reflective teaching practices among the teachers through Action research.
- Provide a continuous professional network support to teachers through face-to-face and online contact.

These goals and objectives are aligned with the Illinois Mathematics and Science Partnerships (IMSP) benchmarks of increasing expertise in specific science and mathematics content; and confidence and effectiveness in teaching science and mathematics content. The program carters for schools that have greater than average difficulty in hiring highly qualified teachers in science and mathematics and those that are deemed not to be meeting Adequate Yearly Progress (AYP)- in many cases their students are not passing Illinois State standardized tests.

Figure 3.2 below shows the partnership organizational structure of this program. As shown in figure 3.2 the program is inherently inter-disciplinary, drawing on the knowledge and expertise of faculty from the College of Science (COS) and the College of Education and Human Services (COEHS). The program also extends its collaboration to include the departments of Plant Biology and Physics so that a well-rounded balance of life and physical sciences are represented. The teachers who participate in this program are recruited from the Local Education Agencies (LEAs) in collaboration with school principals, school districts and regional superintendents. Prospective graduate students should have an undergraduate degree in Elementary Education, or closely related field, and should already be certified elementary or middle school teachers in Illinois. They should have also passed the Illinois Test of Basic Skills, the Elementary Education Content Test and the Elementary Assessment of Professional Teaching Test. However, consideration is given to applicants who have comparable qualifications from another state. Students are required to submit official transcripts from all U.S. schools attended during their last two years of undergraduate study, and also for all graduate work completed.

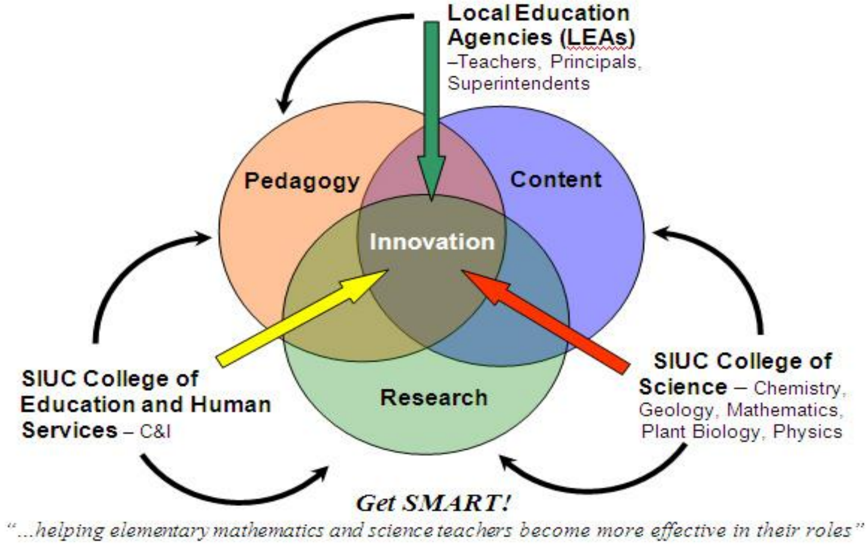

Figure 3. 2: SMART partnership organizational structure [Source: SMART website- http://www.smart.siu.edu/]

PIASCS project

This is one of the Illinois Mathematics and Science Partnership teacher professional development workshop projects funded by *Illinois State Board of Education* (ISBE) in the state of Illinois (Mumba, Zhu, Tsige & Ahmed, 2010). This partnership comprises SIUC (Departments of Computer Science, Electrical and Computer Engineering, Physics, Chemistry, Geology, *Aviation* Management and Flight, and Curriculum and Instruction), Southern Illinois Airport (SIA), Regional Office of Education 25 and its eleven school districts (Waltonville Community Consolidated School District 1, Webber Township High School District 204, Mount Vernon City Schools District 80, Mt. Vernon Township High School District 201, Woodlawn Community High School District 205, Grand Prairie Community Consolidated School District 6, Farrington Community Consolidated School District 99, Opdyke-Belle Rive Community Consolidated School District 5, Rome Grade Community Consolidated School District 2, Woodlawn Community Consolidated School District 4, Woodlawn Community High School

District 205) in southern Illinois. The partnership organizational structure reflects a multi-level, interactive model that incorporates external expertise, administrative and organizational oversight and leadership, and a coordinated interdisciplinary educational network to innovatively accomplish the project's objectives.

The project offers a professional development (PD) program that is aimed at developing middle and high school science Teacher-Leaders in computer simulations, animations and visualizations integration in science instruction, and subsequently increase student achievement in science. The main objectives of this project are:

1. Increase middle and high school teachers' science content and pedagogical knowledge, and subsequently increase student achievement in science.
2. Introduce middle and high school teachers to computer simulations, visualizations, and animations available on open sources to help them incorporate scientific inquiry, critical thinking, career awareness and application of such technologies into their classroom.
3. Increase teachers' use of, and comfort with, computer simulations and visualization tools in their science teaching.
4. Develop Teacher-Leaders in computer simulations, visualizations and animations integration in science curriculum.
5. Increase middle and high school teachers' knowledge and skills for conducting educational research through Action research; and applying research findings in their classrooms.
6. Develop long-term relationships between teachers and computer scientists, physicists, engineers, and chemists at SIUC campus and Aviation experts at Southern Illinois Airport.
7. Enhance existing partnerships and create new ones among SIUC and LEAs in southern Illinois.

These objectives are addressed through accomplishing the following activities:

- Designing and implementing an intensive and sustained PD program for teachers aimed at increasing their content and pedagogical knowledge and skills for integrating computer simulations, visualizations, and animations in middle and high school science curriculum.
- Introducing and exposing teachers to existing computer simulations and visualizations on open sources that are appropriate for middle and high school science instruction.
- Training teachers how to adapt and modify existing simulation programs from open sources to fit into middle and high school science courses as supplements to science instruction.
- Educating and training science teachers to develop their own computer simulations, animations and visualizations for their science lessons or topics that are not available on open source simulation and learning tools.
- Engaging teachers in designing or modifying existing lessons to specifically address the learning challenges of, and provide learning opportunities for students through the use of computer simulations and visualizations as supplements.
- Teachers implementing modified lessons in their classrooms and assessing their impact on student achievement.
- Teachers conducting Action research to promote reflective teaching practices.
- Providing a continuous professional support network for teachers through face-to-face and online interactions.

The PIASCS project was guided by a theory of change that states: “An intensive and sustained teacher professional development focused on infusing interactive computer simulations and visualizations in science curriculum accompanied by ongoing support and reinforcement increases teachers' content and pedagogical knowledge and yields improved instructional practice and student achievement" (Mumba *et al.*, 2010, p. 3).

The project follows the traditional PD model of offering a two-week summer workshop and four follow-up workshop sessions during the school year. The project also offers Action research course to participating teachers in fall and spring semesters. In the first week of the workshop, teachers learn about the descriptions of animations, simulations, visualizations and models. They also learn about how to adapt existing simulations into their science curriculum. Teachers also learn about how to make animations for their science lessons. In the second week of the workshop, teachers are engaged in lesson development in order for them to demonstrate their understanding and skills for integrating simulations and animations in science lessons. They present their lessons to peers and revise them after feedback.

SIPAMS project

This is a three-year (2010-2013) Illinois Board of Higher Education (IBHE) funded teacher professional development (PD) program at Southern Illinois University Carbondale (SIUC). SIPAMS is a collaborative partnership between two universities (SIUC and ISU) and eleven school districts in Southern Illinois namely: Cairo School District 1, Anna Community Consolidated School District 37, Carbondale Elementary School District 95, Dongola Unit School District 66, Carterville Community Unit School District 5, Herrin Community Unit School District 4, Murphysboro Community Unit School District 186, Sparta Community Unit School District 140, Vienna School District 55, Harrisburg Community Unit School District 3, Eldorado Community Unit School District 4, and Illinois State University (ISU). The program serves mathematics and science teachers of grades 4-8 in the eleven partner school districts in southern Illinois. The main aim of this project is to increase mathematics and science teachers' content knowledge and pedagogical skills and students' achievement in mathematics and science subject areas (Mumba, Henson, Hunter & Wright, 2010). A fundamental goal of this program is to improve mathematics and science teaching and learning in participating schools by providing a PD program that is focused on *Content and pedagogy, curriculum articulation, reading in content areas, assessment, and mentoring*.

The objectives of this project are:

1. Increase elementary and middle school teachers' mathematics and science content and pedagogical knowledge.
2. Increase elementary and middle school teachers' knowledge and skills for conducting educational research and applying research findings in their classrooms.
3. Increase elementary and middle school teachers' knowledge of how to teach mathematics and science to students with special needs.
4. Develop long-term relationships between teachers and SIUC and ISU scientists, mathematicians, and teacher educators.
5. Enhance existing partnerships and create new ones among SIUC, ISU and LEAs in Southern Illinois.

These objectives are addressed through accomplishing the following activities:

- Developing an intensive professional development program for elementary and middle school teachers to address mathematics and science content and pedagogical knowledge, National and State Learning Standards, leadership, and mentoring.
- Infusing inquiry-based approaches through assembling of inquiry-based integrated mathematics and science courses for grades 4-8, integrating content-related reading as a component of pedagogy.

- Designing or modifying lessons to help teachers specifically address the learning challenges of and provide learning opportunities for students with special needs.
- Promoting reflective teaching practices among the teachers through Action Research.
- Providing a continuous professional support network for teachers through face-to-face interactions and online instruction.

The main objective was framed in order to meet the needs for elementary and middle school science and mathematics teachers serving in the 11 partner school districts and other LEAs in Southern Illinois. The program provides a combination of Professional Development (PD) and graduate training to in-service elementary and middle school teachers in science and mathematics, including reading in content areas. In this partnership, mathematics and science teachers are brought closer to scientists, mathematicians, and teacher educators, who engage them in discussions of cognitive issues, support them to master significant mathematics and science content integrated with pedagogy, familiarize them with instructional technologies utilized in mathematics and science education, and provide additional high-quality, standards-based PD activities. This program's defining features emphasize teachers working together with experts in content, pedagogy, and technology while staying in control of developing pedagogical solutions to meet classroom needs. These PD experiences empower teachers to apply current theoretical frameworks for students' thinking and strategy development in mathematics and science and further to re-structure their classroom instruction based on their own deeper understanding of the content and how their students learn the content.

The intended outcomes are: *increased teachers' content knowledge and pedagogical skills (short-term outcome), improved instructional practice (mid-term outcome), and increased student achievement in mathematics and science (long-term outcome).* The participants include

Southern Illinois University Carbondale & Illinois State University professors in mathematics, sciences, mathematics and science education, content-related reading, curriculum specialists from the partner school districts, principals, and elementary and middle school teachers and their students. All these participants form an inquiry-oriented learning community. Scientists and mathematicians provide insight into the methods that are used in the fields to pursue a scientific process of discovery and problem-solving. Pedagogical specialists present models for integrating science, mathematics, and technology, including content-related reading strategies, and effective ways of teaching mathematics and science in diverse classrooms such as inclusive classrooms. The program also enhances faculty's understanding of the K-12 education system, and the challenges teachers face in science and mathematics teaching and how to provide professional support to help teachers meet such challenges. The program is conducted through PD activities in summer with four follow-up sessions during the school year, in each of the three years of the grant.

Participants

Participants for this study were drawn from the three math and science teacher professional development projects at Southern Illinois University Carbondale (SIUC) described in the context of the study section above (See pages 53- 62). A total of 66 middle school teachers participated in this study. There were 10 males and 56 females. Twenty-six (26) teachers were in enrolled in the Science, Mathematics and Action Research for Teachers (SMART) graduate program, twenty-two (22) teachers were in the Partnership for Improved Achievement in Science through Computational Science (PIASCS), and eighteen (18) teachers were in the Southern Illinois Partnership for Achievement in Mathematics and Science (SIPAMS) project. However, some participants were enrolled in more than one of the three projects. For example seven teachers were enrolled in both SIPAMS and PIASCS, one teacher was in both SMART and PIASCS, and seven teachers were in both SMART and SIPAMS. Data from such participants was collected only in one project where they appeared first. Additional profiles of the participants are provided in Table 3.1 on the next page. At the time of data collection, SMART project teachers were in their fourth semester of their six semesters for the masters' degree program. They had completed a total of eighteen graduate credit hours – that is 6 credit hours in mathematics [Mathematical Topics for Teachers and Advanced Topics in the Teaching of Mathematics] and 12 credit hours in science [Science for Elementary Teachers, Contemporary Biology for Teachers, Chemistry Topics for Teachers and Earth and Space Science for Teachers]. They were enrolled in 6 graduate credit hours in mathematics [Teaching Problem Solving in School Mathematics (Grades K-8)] and science [Special Physics Topics for Teachers]. At the time of data collection the participants in the SIPAMS project were attending follow-up Math and Science Teacher Workshop sessions. Similarly, PIASCS group of teachers were attending follow-up computer simulation and animation Workshop sessions.

Table 3.1

Number and Percentage of Teachers in each Sub-group

Sub-groups	Ranges	Number of participants	Percentage
Grade taught	K-5th	27	40.9
	6th-12th	39	59.1
Teaching experience	1-5 years	29	43.9
	6-10 years	17	25.8
	11+ years	20	30.3
Number of science courses taken in high school	1-3 courses	27	40.9
	4+ courses	39	59.1
Number of science courses taken in college/university	1-3 courses	19	28.8
	4-6 courses	28	42.4
	7+ courses	19	28.8

N=66

Table 3.1 shows the distribution of the participants' grades taught, teaching experience, number of science courses taken in high school and number of courses taken in college or university. 40.9 percent of the teachers reported teaching K-5th grades while 59.1 percent reported teaching 6th -12th grades. However, these teachers were all certified to teacher content at middle school level in Illinois.

Access and Recruitment of Participants

First, the researcher asked for permission from the Principal Investigators to use the teachers in the professional development projects as participants in this study. Second, the researcher applied to SIUC Human Subjects Committee to use human subjects in this study. The permission was granted in spring 2011 (see Appendix A on page 224). Third, the researcher asked the participants to volunteer to take part in the study. The recruitment of participants was done through face to face during the follow-up workshop days and through the projects coordinator. Participants were informed that participation or non-participation in the study had no effect on their course grade in their degree program or their participation in the projects. Participants were assured that all reasonable steps would be taken to protect their identity and that all records, transcripts and interview notes were kept in a secure location. This was achieved by describing the role of the participants as stated in the human subject's application and consent letters (see Appendix B on page 225). Participants were also given an invitation to participate in the study (see Appendix C on page 226). Participants were asked to complete the consent form (Appendix D on page 227) before completing any of the data collection instruments. Only those who agreed to participate in the data collection were given the data collection instruments to complete.

Data Collection Instruments

Participants in this study responded to four instruments: *familiarity and interest questionnaire* (Appendix E on page 229), *conceptual knowledge test* (Appendix F on page 232), Performance *test on light* (Appendix G on page 233), and *semi-structured interview* (Appendix H on page 251).

Familiarity and interest questionnaire

The familiarity and interest questionnaire (See Appendix E on page 229) was used to collect quantitative data on teachers' demographic information, familiarity with and interest in learning more about light concepts. The format for familiarity and interest questionnaire was adapted from the instrument used by Miles (2010) to investigate science process skills among teachers. The reliabilities for the familiarity and interest instruments in Miles's study were 0.953 and 0.957, respectively. In Miles's study, the questionnaire had three parts: the preface, and parts A and B. The preface asked the participants to provide demographic information. Part A asked the participants to mark each skill as "term not familiar to me," "term familiar to me but not understood," or "term familiar to me and I understand its meaning." Part B asked the participants to mark each skill as "not at all interested in learning more," "interested in learning more," or "very interested in learning". Likewise, for the present study, the *Familiarity and Interest* questionnaire had sections 1, 2, and 3. In section 1, participants were asked to provide the following demographic information: Gender, subject area of certification, teaching subjects, number of science courses taken in college/university, number of science courses taken in high school, the science courses previously taken in college/university and science courses currently taken in college/university. In sections 2 and 3, the participants were asked to respond to items on 3-Likert scale on their familiarity with and interest in the following 17 concepts of light: *vision (how an eye is able to see), light travelling at a greater speed than an airplane, reflection of light, refraction of light, formation of shadows, the electromagnetic spectrum, why opaque objects appear in the color they do in white light, why opaque objects appear the way they do in colored lights, color filters, light as a form of energy, luminous objects, non-luminous objects, light as transverse waves, wavelength of waves, amplitude of waves, crest of waves, and trough of waves.* In section 2, the participants were asked to mark each of the 17 concepts as "concept is not familiar to me," or "concept is familiar to me but not understood," or "concept is familiar to me and I understand its meaning." In section 3, the participants were asked to mark each of the 17 concepts or phenomena as "not at all interested in receiving more information," or "interested in receiving more information," or "very interested in receiving more information".

Conceptual knowledge test

The conceptual knowledge test (see Appendix G on page 233) was used to collect both quantitative and qualitative data. The format of the conceptual knowledge test was also adapted from a test used by Miles (2010) to investigate teachers' conceptual understanding of science process skills. The reliability of Miles' (2010) conceptual knowledge test was 0.743. In the present study, the participants were asked to define, describe or explain 17 concepts of light. These were the same concepts listed in the Familiarity and Interest questionnaire. As shown in Appendix G, the concept items on light in the conceptual knowledge test were worded slightly different from the way they were presented in the familiarity and interest questionnaire (Appendix F). For example, the item on "The refraction of light" in the familiarity and interest questionnaire was worded as a question "What does the term 'refraction of light' mean to you"?, in the conceptual knowledge test. The questions elicited the teachers' conceptual understanding of the concepts of light.

Performance test

A 24-item multiple choice performance test on light (see Appendix H on page 251) was used to collect quantitative data. The performance test was developed by Chu, Treagust and Chandrasegaran (2009). The test was used with authors' permission (see Appendix I). According to Chu et al. (2009) they developed this test using items utilized in previous studies that investigated misconceptions on light (Fetherstonaugh &Treagust 1992; Langley, Ronen, & Eylon 1997; La Rosa, Mayer & Vicentini-Missoni 1984). The instrument had a total of 24 two-tier multiple choice items of which 20 of them make ten pairs of items that investigated participants' understanding of particular concepts of light in different contexts. The contexts of the items and the common concepts associated with each pair are summarized in Table 3.2 below.

Table 3.2

Item pairs, contexts and light concepts

Pair Number	**Item Pairs and contexts**	**Light concepts involved/tested**
1	Item 1-Light propagation during the day Item 2-Light propagation at night	Light travels in straight lines in all directions until it strikes an object.
2	Item 4-Visibility of a non-luminous object Item 5-Visibility of a luminous object	Light travels in straight lines past an obstruction.
3	Item 6-Distribution of light by a covered source Item 7 Distribution of light by an open source	Light from a source is distributed in all directions.
4	Item 8-Visibility of a lighted lamp above an obstruction Item 9-Illumination by a lighted lamp above an obstruction	Light travels in straight lines past an obstruction.
5	Item 11-Vision of cats in the dark Item 12-Human vision in the dark	An object is visible because light is reflected from the object to the eyes.
6	Item 15-Seeing an image while in front of a mirror Item 16-Seeing an image while not in front of a mirror	An image is seen in a mirror because light from the flower is reflected by the mirror into our eyes and the image is the same size as the flower.
7	Item 18-Removing the lens between the lens and the screen Item 19-Covering the top half of the lens	A lens forms an image when light passes through it.
8	Item 20-Shining white light on red glass Item 23-Light from a flashlight falling on a red filter	Colored transparent objects absorb all colors of white light and only transmit the light of its color.
9	Item 21-Appearnce of a red rose in yellow light Item 22-Appearance of a blue book	An object absorbs all the other colors of light and only reflects its own color.
10	Item 3-A human being standing in the passage of light Item 24-Shinning light on a card and a filter	Shadow is formed when light is blocked by an object.

The remaining four test items were also two-tier items but each item investigated participants' understanding of a particular concept:-item 10 investigated the effect of the shape of an opaque lamp shade on the direction of light rays, item 13 the visibility of all colors in white light, item 14 the possibility of seeing more of oneself in a mirror, and item 17 the effect of refraction.

This instrument was further validated by science education experts at SIUC. In this study, the 24-item multiple choice test was used to determine the performance level of the middle school teachers on light concepts. Therefore, this test also measured the level of conceptual understanding of the nature of light among the middle school teachers. In each item, the participants were asked to choose the most correct answer and the most correct reason.

Misconceptions identification questionnaire

An open items questionnaire was used to collect qualitative data. The questions were designed following the format of the 'Open Response' questions in the Diagnostic Teacher Assessments in Mathematics and Science [DTAMS] used to measure teachers' pedagogical content knowledge in magnetism, electricity, force and motion (Bush, 2004). In the DTAMSs' open response section, each question has a scenario with two parts: (a) and (b). According to Bush, teachers were asked to write responses to parts (a) and (b) in the spaces provided by responding to the following directions:

> Directions for part (a):
>
> In each question, students expressed a misconception. Please describe the currently accepted scientific explanation of the phenomenon that the students are not understanding. Explain the science in as much depth as possible, even if that level of depth would be inappropriate to expect middle school students to know. Your explanation should demonstrate a thorough knowledge of the underlying science – simply stating the opposite of the students' misconception without further explanation is not sufficient.

Directions for part (b):

Explain how you would address this misconception using best instructional practices. Please describe the classroom instruction, including what the students and teacher are doing, in enough detail so that the reader can envision what is happening. For example, if you refer to a specific lesson, textbook, activity, piece of equipment, or media, assume the reader is not familiar with it and explain how it is used to support student learning. Assume you have access to any equipment that would be available in a reasonably well-funded K-12 school setting so that your proposed instruction is feasible to implement.

Likewise, in the present study, 40 participants from the SIPAMS and PIASCS projects were asked to respond to the questionnaire items (a) and (b) in writing. The questionnaire began by collecting data about the teachers' prior experiences in the learning of light, understanding of what light is and descriptions of some basic concepts of light that they expect their students to learn. Then, the questionnaire collected data on the teachers' ability to identify students' misconceptions in a given scenario and pedagogical ideas of how to address such misconceptions in middle school science course. The questionnaire had 9 scenarios involving light concepts. For example one of the scenarios was:

In reply to a question about how an eye is able to see an object, one of your students mentions that the eye emits light in order for people or animals to see an object. In addition, other students in class agree and provide evidence that we use phrases such as 'her eyes shine', 'his face radiates light', and ' she casts a glance'.

Part A:

Please describe the currently accepted scientific explanation of the phenomenon that the students are not understanding. Explain the science in as much depth as possible, even if that level of depth would be inappropriate to expect middle school students to know. Your explanation should demonstrate a thorough knowledge of the underlying science – simply stating the opposite of the students' misconception without further explanation is not sufficient.

Part B:

Explain how you would address this misconception using best instructional practices. Please describe the classroom instruction, including what the students and teacher are doing, in enough detail so that the reader can envision what is happening. For example, if you refer to a specific lesson, textbook, activity, piece of equipment, or media, assume the reader is not familiar with it and explain how it is used to support student learning. Assume you have access to any equipment that would be available in a reasonably well-funded K-12 school setting so that your proposed instruction is feasible to implement.

The questionnaire was designed as an error analysis questionnaire, which belongs to one of the four categories of items used to explore pedagogical content knowledge (Baxter & Lederman, 2002). Error analysis items require the teacher to identify the student's logical error and then propose a way of teaching. The other three categories are: communication with the learner items – these require the teacher to identify appropriate communication between teacher and student (e.g. when a student appears to be confused, what would be the "next step" activity or query to help the student understand the problem?), organization of instruction items- these focus on teachers' plans for instruction (e.g. a failed activity is described and a successful one is asked from the participant) and learner characteristics items- these assess teachers' knowledge of developmental norms within the discipline, or sequences of skill development (e.g. a teacher is having trouble teaching the refraction of light to third graders. Why?) (Baxter & Lederman, 2002).

Similarly, in this study, each logical error scenario had two parts - A and B. In part A, the participants were asked to identify and explain the logical error portrayed by the student(s) in a given scenario. The aim was to elicit the participants' understanding of the underlying concept or phenomena that the student(s) in the scenario were not understanding. In part B, the participants were asked to suggest how they would teach the concept or phenomenon in the given scenario so as to help the students realize the portrayed logical error. The aim was to elicit the participants' pedagogical ideas for the light concept in each given scenario.

Reliability and Validity

This section discusses the reliability and validity of the instruments that were used in this study. Quantitative data was collected using the familiarity and interest questionnaire, the conceptual knowledge test, and a 24-item multiple choice two tier light performance test. Qualitative data was collected using a questionnaire.

Reliability and validity of quantitative instruments

In quantitative research, reliability and validity of the instrument are very important for minimizing errors that might arise from measurement procedures. Reliability refers to the accuracy and precision of a measurement procedure (Thorndike, 1997). Reliability of the quantitative instruments (familiarity questionnaire, interest questionnaire, conceptual knowledge test, and performance test) were determined by computing Cronbach's alpha (α) values. The Chronbach's alpha (α) values for familiarity questionnaire was .94, for interest questionnaire was .98, for conceptual knowledge test was .83, and for performance test was .74. These values are acceptable measures of reliability because they are more than .70 the thresh hold value of acceptability as a measure of reliability.

Validity refers to the degree to which a study accurately reflects or assesses the specific concept or construct that the researcher is attempting to measure (Thorndike, 1997). Content validity of the quantitative instruments was established with the help of physics and science education experts at SIUC. For content validity physics experts checked for the extent to which the items in the instruments and the scores from the items were representative of all possible questions on light in middle school science curriculum. The construct validity was established with the help of science education experts at SIUC. This helped assess whether the quantitative instruments' questions were appropriate for the concepts they were aimed to measure, and if they were well constructed.

Reliability and validity of qualitative instruments

Qualitative researchers are more concerned with validity than reliability (Merriam, 1998). Instead, they seek believability, based on coherence, insight, and instrumental utility (Eisner, 1991) and trustworthiness (Lincoln & Guba, 1985) through a process of verification rather than through traditional reliability computations. This process is termed as credibility establishment.

In this study, credibility was established by way of evidence based on structural corroboration, consensus and referential or interpretive adequacy (Ary, Jacobs, & Sorensen, 2010). Structural corroboration was put to use by employing multiple sources of data in the study: familiarity and interest questionnaire and performance test. Consensus among science education experts was established during the development of the questionnaire and in the treatment of data that was collected. Science education experts at SIUC looked at the questions to establish their worthiness. Referential or interpretive adequacy was established by using evidence descriptors which in this study were direct quotations from the participants in the questionnaire responses.

Data Collection Procedures

As stated in the preceding sections above, four different instruments were used to collect data in SMART, SIPAMS and PIASCS PD projects at SIUC. Teachers in the SMART project met mid-December 2011; SIPAMS group met early-January 2012; and the PIASCS group met mid-January 2012 for workshops. The instruments were administered on four separate days during the follow-up workshop sessions. In each project group, the first instrument to be administered was the familiarity and interest questionnaire, followed by the conceptual knowledge test, multiple choice performance test, and the structured questionnaire. Forty (eighteen from SIPAMS and twenty-two from PIASCS) teachers responded to the structured questionnaire in writing.

Data Analysis Procedures

Familiarity and interest questionnaire

Participants' responses to items in the questionnaire were scored and assigned a score. For the familiarity part of the questionnaire, "concept or phenomenon is not familiar to me" was assigned a score of 1, "concept or phenomenon is familiar to me but not understood" was assigned a score of 2, and "concept or phenomenon is familiar to me and I understand its meaning" was assigned a score of 3. For the interest part of the questionnaire, "not at all interested in receiving more information" was assigned a score of 1, "interested in receiving more information" was assigned a score of 2, and "very interested in receiving more information" was assigned a score of 3. To determine the middle school teachers' familiarity with concepts or phenomena about light the percentages of teachers were computed for "concept or phenomenon is not familiar to me", "concept or phenomenon is familiar to me and I understand its meaning", and "concept or phenomenon is familiar to me but not understood" for each concept or phenomenon about light. Then, the overall teachers' familiarity with the concepts of light was determined by comparing the percentages of teachers under each response for each concept or phenomenon about light. The data was then analyzed for differences between teachers' familiarity with basic and advanced light concepts within the whole group of teachers and within teacher group variables of grade taught, number of science courses taken in high school, years of teaching experience, and number of science courses taken in college using Wilcoxon tests. A Wilcoxon test is a non-parametric equivalent of a paired sample t-test. The data was further analyzed to compare the teachers' ratings on familiarity with basic, advanced, and all light concepts between teachers' group variables of grade taught and number of science courses taken in high school using a Mann-Whitney U test. Mann-Whitney U test is a non-parametric equivalent of independent samples t-test. The data was also analyzed to compare the teachers' ratings on familiarity with basic, advanced, and all light concepts among group variables of teaching experience, number of science courses taken in college or university, and the teachers' project using a Kruskall-Wallis test. Kruskall-Wallis test is a non-parametric test equivalent to a One-Way Analysis of Variance (ANOVA) test. These non-parametric tests were used because the number of participants in each of the three projects and group variables was less than 30- a threshold number of participants for parametric tests. Also the scores were not normally distributed because they were ordinal. The same data analysis procedures described above were used to analyze data on teachers' interest in learning more about the concepts of light.

Conceptual knowledge test

The middle school teachers' conceptual knowledge were examined using the conceptual knowledge test, in which participants were asked to define, explain or describe 17 concepts of light. The responses were scored by matching participants' responses with the standard definitions, explanations, and descriptions of the concepts provided in Chapter 1 on pages 17-21. These definitions, explanations, and descriptions of the 17 concepts of light were taken from research articles (Andersson & Karrqvist, 1983; Bendall, Goldberg & Galili, 1993; Bouwens, 1987; De Vries, 1986; Galili & Hazan, 2000; Langley, Ronen & Elyon, 1997), physics textbook (Taffel, 1992) and K-8 science teachers textbook (Victor, Kellough, & Tai, 2008), and other teaching materials about the nature of light (Lucas, 1991). A correct response included all key terms found in the definition, explanation, or description, with a verbatim not being required; a partially correct response included at least one of the key terms or ideas, but not all found in the definition or derivatives of such ideas and providing an incomplete understanding of the term; and incorrect response did not include key terms or ideas or was unrelated or irrelevant to the concept or phenomenon about the nature of light. A correct response received a score of 2, a partially correct response received a score of 1, and an incorrect response received a score of 0. The percentages of participants were calculated for correct, partially correct, and incorrect responses for each item in the test. Then, the overall teachers' conceptual understanding of the light concepts was determined by comparing the percentages of teachers under each response for each item in the test.

The data was then analyzed for differences between teachers' conceptual understanding of basic and advanced light concepts within the whole group of teachers and within teacher group variables of grade taught, number of science courses taken in high school, years of teaching experience, and number of science courses taken in college using paired samples t-tests. The data was further analyzed to compare the teachers' scores on conceptual understanding of basic, advanced, and all light concepts between teachers' group variables of grade taught and number of science courses taken in high school using independent samples t-tests. The data was also analyzed to compare the teachers' scores on conceptual understanding of basic, advanced, and all light concepts among group variables of teaching experience, number of science courses taken in college or university, and the teachers' project using One-way ANOVA tests. These parametric tests were used despite the number of participants in each of the three projects and group variables being less than 30- a threshold number of participants for parametric tests. This was because the scores were of scale category and therefore normally distributed.

Performance test

The 24-item multiple choice performance test measured the performance level of the middle school teachers on light concepts. Each item had two-tiers: the multiple choice question and the reason for the answer. A response for each item was considered correct when a participant answered both tiers of the item correctly. A response was considered to be incorrect for the item if either the multiple choice answer or the reason or both were wrong. A correctly answered item was scored '1' while an incorrectly answered item was scored '0'. Therefore, the total score ranged from 0 to 24. The percentages of participants were calculated for correct and incorrect responses for each item in the test. Then, the overall teachers' performance on the two tier light test was determined by comparing the percentages of teachers under each response for each item in the test.

The data was analyzed to compare the teachers' performance scores on the two tier light test between teachers' group variables of grade taught and number of science courses taken in high school using independent samples t-tests. The data was further analyzed to compare the teachers' scores on the two tier light test among group variables of teaching experience, number of science courses taken in college or university, and the teachers' project using One-way ANOVA tests. These parametric tests were used despite the number of participants in each of the three projects and group variables being less than 30- a threshold number of participants for parametric tests. This was because the scores were of scale category and therefore normally distributed.

The data was also analyzed qualitatively in detail to identify the pattern of teachers' responses and their reasons for such responses. The 24 items in the two tier multiple choice light test were grouped to form nine strands: The way light travels; The visibility of non-luminous and luminous objects; The distribution of light from a light source; Vision; Mirror images; Refraction images; Filters; Color appearance of objects; and Shadow formation. For example, the strand "The way light travels" was formed by items 1, 2, 8, and 9 in the two tier test. The teachers' responses were coded as Correct Answer and Correct Reason (CACR), Correct Answer and Incorrect Reason (CAIR), Incorrect Answer and Correct Reason (IACR), and Incorrect Answer and Incorrect Reason (IAIR). The percentages of participants were calculated for CACR, CAIR, IACR, and IAIR for each item in each strand. The findings in each strand were discussed qualitatively.

Misconceptions identification questionnaire

Text transcripts were created from the written responses given by the teachers for each question on the open ended questionnaire. Analysis of the text transcripts followed an open coding procedure guided by the principles of this study. The open coding procedure involved reading the transcripts line-by- line and identifying and coding the concepts found in the data

(Strauss & Corbin, 1990). During the analysis concepts were identified and developed in terms of their properties and dimensions (Charmaz, 2006). This was achieved by following basic analytic procedures such as asking of questions about the data; and making of comparisons for similarities and differences between each incident, event and other instances of phenomena (Silverman, 2003). Therefore the text transcripts were analyzed qualitatively following five steps: (1) preliminary exploration of the data by reading through the written responses, (2) coding the data by segmenting and labeling the text, (3) using codes to develop themes by aggregating similar codes together, (4) connecting and interrelating themes, and (5) constructing a narrative (Creswell, 2002).

The analysis of the text transcripts involved developing descriptions of the middle school teachers' previous experiences with light concepts, descriptions of light, explanations of light concepts, identification and explanations of student misconceptions in the given scenarios, and suggested pedagogical ideas to address the identified misconceptions. The principles of this study were used, when particular attention was paid to whether the middle school teachers in this study were able to identify the students' misconceptions or not as this had a bearing on their conceptual understanding of the light concepts. This was also linked to their suggested pedagogical ideas. The goal was to consolidate, reduce, and interpret what the middle school teachers wrote so as to make meaning of the data (Merriam, 2009).

Relationship between familiarity, interest, conceptual knowledge, performance and pedagogical ideas

Pearson correlation coefficients were computed to determine the extent to which teachers' familiarity with, interest in, conceptual knowledge of, and performance on light were related. The computed correlation coefficients were discussed in relation to the pedagogical ideas suggested by the teachers.

Summary of Data Collection and Analysis

As stated in the context of the study section in this chapter, data was collected in the SMART, SIPAMS and PIASCS projects using the familiarity and interest questionnaire, conceptual knowledge test, performance test, and semi-structured questionnaire. The instruments were administered on four separate days of the follow-up workshops for each program. All participants responded in writing to the familiarity and interest questionnaire, the conceptual knowledge test, and the performance test. SIPAMS and PIASCS projects participants responded to the semi-structured questionnaire while the SMART program participants did not have an opportunity to respond to the semi-structured questionnaire due to limited time they were available for this study.

Frequencies and Percentages of teachers for individual concepts were computed for the three given responses: “concept or phenomenon is not familiar to me”, “concept or phenomenon is familiar to me but not understood”, and “concept or phenomenon is familiar to me and I understand its meaning” from the frequencies obtained by assigning scores of “1”, “2”, and “3”, respectively. Data was first analyzed for differences between teachers’ familiarity with basic and advanced light concepts within the whole group of teachers and within teacher group variables using Wilcoxon tests. Then, the differences between and among participants’ group variables were analyzed using Mann-Whitney U and Kruskal-Wallis tests, respectively. The same procedure was used to analyze data on teachers’ interest in learning more about the concepts of light.

Data in the conceptual understanding test was analyzed quantitatively to obtain frequencies and percentages of participants scoring correct, partially correct and incorrect by code scores of 2, 1, and 0 respectively. Data was first analyzed for differences between teachers' conceptual understanding of basic and advanced light concepts within the whole group of teachers and within teacher group variables using paired samples t-tests. Then data was analyzed statistically for differences between and among group variables using independent samples and One-Way ANOVA tests.

The 24-item multiple choice light performance test was scored to obtain frequencies and percentages of participants scoring correct and incorrect by code scores of 1 and 0 respectively. The data was analyzed for differences within, between and among teachers' group variables using paired samples, independent samples, and One-Way ANOVA tests, as described in the conceptual understanding data analysis section above.

The semi-structured questionnaire was analyzed for thematic narratives of the teachers' experiences with the topic of light, descriptions of basic light concepts expected of their students, ability to identify students' misconceptions and pedagogical ideas. A Pearson's correlation coefficient was computed to determine the relationship among the teachers' familiarity with, interest in, conceptual knowledge of, and performance on light. Finally the correlation coefficients were discussed in relation to the pedagogical ideas for light suggested by the teachers. Table 3.3 below provides a timeline for instrument development, data collection and analyses.

Table 3.3

Timeline for Study Data Collection and Analysis

Date	Activity
May 2011	Identifying and constructing data collection instruments
June 2011	Human subjects application & and approval
Mid-December 2011	Administering familiarity and interest questionnaire, conceptual knowledge test, and multiple choice performance test to SMART project participants.
Early-January 2012	Administering familiarity and interest questionnaire, conceptual knowledge test, multiple choice performance test, and semi-structured interview questionnaire to SIPAMS project participants
Mid-January 2012	Administering familiarity and interest questionnaire, conceptual knowledge test, multiple choice performance test, and semi-structured interview questionnaire to PIASCS project participants
Late-January 2012	Data Analysis of familiarity and interest questionnaire, and conceptual knowledge test.
February 2012	Data Analysis of performance test and semi-structured interview questionnaire.

CHAPTER 4

TEACHERS' FAMILIARITY WITH LIGHT CONCEPTS

Introduction

This chapter presents results to answer research question # 1: *To what extent are middle school in-service teachers familiar with the concepts of light emphasized in school science curriculum?* First, the chapter presents results of whole group's familiarity with light concepts. Second, the chapter presents results of between groups comparisons of familiarity with light concepts. Third, the chapter presents results for within groups comparisons of familiarity with light concepts. The chapter ends with a summary of the results on teachers' familiarity with the light concepts assessed in this study.

Teachers' Familiarity with Light Concepts

As shown in table 4.1, most teachers indicated they were familiar with the light concepts assessed in this study but did not understand their meanings. Specifically, an average of 49.28% of teachers said they were familiar with the light concepts but did not understand their meanings, 38.67% of teachers said they were familiar with the light concepts and understood their meanings, and 12.04% of teachers said they were not familiar with the light concepts.

Table 4.1

Percentages of Teachers' Familiarity with Light Concepts (N=66)

Concept	Type of concept	Concept is not familiar to me	Concept is familiar to me but not understood	Concept is familiar to me and I understand its meaning
		%	%	%
The reflection of light	Basic	1.5	40.9	57.6
The formation of shadows	Basic	3.0	39.4	57.6
Light travels at a greater speed than an airplane	Basic	3.0	42.4	54.5
Vision (how an eye is able to see objects)	Basic	0.0	47.0	53.0
The refraction of light	Basic	1.5	54.5	43.9
Appearance of opaque colored objects in white light.	Basic	18.2	51.5	30.3
Appearance of colored opaque objects in colored lights.	Basic	16.7	56.1	27.3
Average on basic concepts		6.27	47.4	46.31
Crest of waves	Advanced	12.1	42.4	45.5
Light as a form of energy	Advanced	6.1	50.0	43.9
Trough of waves	Advanced	15.2	42.4	42.4
Wavelength of waves	Advanced	10.6	48.5	40.9
Amplitude of waves	Advanced	18.2	48.5	33.3
The electromagnetic spectrum	Advanced	15.2	53.0	31.8
Color filters	Advanced	13.6	60.6	25.8
Luminous objects	Advanced	19.7	56.1	24.2
Non-luminous objects	Advanced	24.2	51.5	24.2
Light as transverse waves	Advanced	25.8	53.0	21.2
Average on advanced concepts		16.07	50.6	33.32
Average on all concepts		12.04	49.28	38.67

Table 4.1 also shows that more teachers were familiar with the basic than advanced light concepts. An average of 46.31 % of the teachers indicated that they were familiar with the basic light concepts and understood their meanings while 33.32 % indicated that they were familiar with the advanced light concepts and understood their meanings. The average percentage of teachers who indicated that they were not familiar with basic light concepts (6.27 %) was less than the percentage of teachers who indicated that they were not familiar with advanced light concepts (16.04 %). However, 47.4 % of the teachers indicated that they were familiar with basic

light concepts but did not understand their meanings while 50.6 % of the teachers indicated that they were familiar with advanced light concepts but did not understand their meanings.

These results suggest that most teachers were familiar with most light concepts but did not understand their meanings. In particular, teachers were more familiar with the basic than advanced light concepts.

Difference between Teachers' Familiarity with Basic and Advanced Light Concepts

A Wilcoxon test was performed to find out if there was a significant difference between teachers' familiarity with the basic and advanced light concepts. The results in Table 4.2 below show that teachers' rating on familiarity with the basic light concepts was significantly higher than the rating on familiarity with the advanced light concepts, N=66, $z = -4.407$, $p < .01$, r= -.542, a large effect size according to Cohen (1988). Of the 66 participants, 41 were familiar with the basic concepts, 14 with the advanced concepts and there were 11 ties. The mean rank of familiarity with the basic concepts of light was 31.61, while the mean rank of familiarity with the advanced light concepts was 17.43.

Table 4.2

Teachers' Familiarity with Basic and Advanced Light Concepts

Concept type	Mean	S.D.	Mean Rank	N	Rank	*Z*	*Sig.*	*Effect size*
Basic concepts	80.01	14.33	31.61	41	Negative			
Advanced concepts	72.42	17.38	17.43	14	Positive	-4.407	.000	-.542
				11	Ties			

N=66

These results suggest that this group of teachers was more familiar with the basic than advanced light concepts.

Differences in Familiarity with Light Concepts within Teacher Groups

Wilcoxon tests were performed to find out if there were differences within teacher group variables of grade taught, number of science courses taken in high school, years of teaching experience, and number of science courses taken in college on familiarity with basic and advanced light concepts.

Grade taught groups

Table 4.3 shows that the rating on familiarity with the basic light concepts was significantly higher than the rating on familiarity with the advanced light concepts, N = 27, z = -3.47, p = .001, r = -.668, a large effect size, for the group of teachers who taught elementary grades. Of the 27 teachers, 19 were familiar with basic concepts, 4 were familiar with advanced concepts. There were 4 ties.

Table 4.3

Familiarity with Basic and Advanced Light Concepts Based on Grade Taught Group

Group		**Concept type**	**Mean**	**S.D.**	**Mean Rank**	**N**	**Rank**	***Z***	***Sig.***	***Effect size***
Grade Taught	Elementary	Basic	76.90	15.61	13.26	19	Negative	-3.47	.001*	-.668
		Advanced	65.92	20.03	6.00	4	Positive			
						4	Ties			
						27	Total			
	Middle and above	Basic	82.17	13.14	18.48	22	Negative	-2.67	.008*	-.428
		Advanced	76.92	13.84	12.15	10	Positive			
						7	Ties			
						39	Total			

*Significant at p < .05

Similarly, the rating on familiarity with the basic light concepts was significantly higher than the rating on familiarity with the advanced light concepts, N = 39, z = -2.67, p = .008, r = -.428, a medium to large effect size, for the group of teachers who taught middle and above grades. Of the 39 teachers, 22 were familiar with the basic concepts, 10 were familiar with the advanced concepts and there were 7 ties.

These results imply that both elementary and middle school and above grade teachers were more familiar with the basic than advanced light concepts.

Number of science courses taken in high school groups

As shown in Table 4.4 below the rating on familiarity with the basic light concepts was significantly higher than the rating on familiarity with advanced light concepts, N = 27, z = -2.61, p = .009, r = -.502, a large effect size, for the group of teachers who had taken few (1-3) science courses in high school. Of the 27 teachers, 16 were familiar with basic concepts, 6 were familiar with advanced concepts and there were 5 ties.

Table 4.4

Familiarity with Basic and Advanced Light Concepts Based on Science Courses in High School

Group		**Concept type**	**Mean**	**S.D.**	**Mean Rank**	**N**	**Rank**	***Z***	***Sig.***	***Effect size***
Number of science courses taken in high school	1-3 courses (Few)	Basic	77.25	14.31	12.94	16	Negative	-2.61	.009*	-.502
		Advanced	69.75	17.64	7.67	6	Positive			
						5	Ties			
						27	Total			
	4+ courses (Many)	Basic	81.93	14.21	19.24	25	Negative	-3.58	.000*	-.573
		Advanced	74.27	17.18	10.00	8	Positive			
						6	Ties			
						39	Total			

*Significant at p < .05

Similarly, the rating on familiarity with the basic light concepts was significantly higher than the rating on familiarity with advanced light concepts, N = 39, z = -2.67, p = .008, r = -.428, a medium to large effect size, for the group of teachers who had taken many (4+) science courses in high school. Of the 39 teachers, 25 were familiar with basic concepts, 8 were familiar with advanced concepts and there were 6 ties.

These results suggest that within the group of teachers who had taken few or many science courses in high school, teachers were more familiar with the basic than advanced light concepts.

Teaching experience groups

Table 4.5 below shows that the rating on familiarity with the basic light concepts was significantly higher than the rating on familiarity with advanced light concepts, N = 29, z = -2.22, p = .027, r = -.412, a large effect size, for the group of teachers who had few (1-5) years teaching experience. Of the 29 teachers, 16 were familiar with basic concepts, 8 were familiar with advanced concepts and there were 5 ties.

Table 4.5

Familiarity with Basic and Advanced Light Concepts based on Teaching Experience

Group		**Concept type**	**Mean**	**S.D.**	**Mean Rank**	**N**	**Rank**	***Z***	***Sig.***	***Effect size***
Teaching Experience	1-5 years (Few)	Basic	81.61	14.44	14.22	16	Negative	-2.22	.027*	-.412
		Advanced	75.52	17.55	9.06	8	Positive			
						5	Ties			
						29	Total			
	6-10 years (Moderate)	Basic	78.15	13.16	7.67	12	Negative	-2.48	.013*	-.602
		Advanced	71.37	17.44	6.50	2	Positive			
						3	Ties			
						17	Total			
	11+ years (Many)	Basic	79.29	15.55	10.77	13	Negative	-3.01	.003*	-.673
		Advanced	68.83	17.14	3.25	4	Positive			
						3	Ties			
						20	Total			

*Significant at p < .05

Similarly, the rating on familiarity with basic light concepts was significantly higher than the rating on familiarity with advanced light concepts, N = 17, z = -2.48, p = .013, r = -.602, a large effect size, for the group of teachers who had moderate (6-10) years teaching experience. Of the

17 teachers, 12 were familiar with basic concepts, 2 were familiar with advanced concepts and there were 3 ties. Similarly, the rating on familiarity with basic light concepts was significantly higher than the rating on familiarity with advanced light concepts, $N = 20$, $z = -3.01$, $p = .003$, $r = -.673$, a large effect size, for the group of teachers who had many (11+) years teaching experience. Of the 20 teachers, 13 were familiar with basic concepts, 4 were familiar with advanced concepts and there were 3 ties.

The results stated above suggest that teachers were more familiar with basic than advanced light concepts, despite their differences in teaching experience.

Number of science courses taken in college or university groups

Table 4.6 shows there was no significant difference between the ratings on familiarity with basic and advanced light concepts, $N = 19$, $z = -1.04$, $p = .300$, $r = -.239$, which is small to medium effect size, for a group of teachers who had taken more than 7 science courses at college or university level. Of the 19 teachers, 7 were familiar with basic concepts, 7 were familiar with advanced concepts and there were 5 ties.

Table 4.6

Familiarity with Basic and Advanced Light Concepts based on Science Courses in College

Group		**Concept type**	**Mean**	**S.D.**	**Mean Rank**	**N**	**Rank**	***Z***	***Sig.***	***Effect size***
Number of science courses taken in college/ university	1-3 courses (Few)	Basic	83.21	14.32	8.93	15	Negative	-2.72	.006*	-.624
		Advanced	73.86	16.78	9.50	2	Positive			
						2	Ties			
						19	Total			
	4-6 courses (Moderate)	Basic	77.21	15.94	14.74	19	Negative	-3.72	.000*	-.703
		Advanced	67.62	19.24	4.00	5	Positive			
						4	Ties			
						28	Total			
	7+ courses (Many)	Basic	80.95	11.45	9.86	7	Negative	-1.04	.300	-.239
		Advanced	78.07	13.49	5.14	7	Positive			
						5	Ties			
						19	Total			

*Significant at $p < .05$

However, the rating on familiarity with basic light concepts was significantly higher than the rating on familiarity with advanced light concepts, N = 19, *z* = -2.72, *p* = .006, *r* = -.624, a large effect according to Cohen (1988), for the group of teachers who had taken few (1-3) science courses in college or university. Similarly, the rating on familiarity with basic light concepts was significantly higher than the rating on familiarity with advanced light concepts, N = 28, *z* =-3.72, *p* = .000, *r* = -.703, a large effect size according to Cohen (1988), for the group of teachers who had taken moderate (4-6) science courses in college or university.

These results suggest that teachers who had taken many science courses in college or university, had the same level of familiarity with basic and advanced light concepts. On the other hand teachers who had taken few and moderate numbers of science courses in college or university were more familiar with basic than advanced light concepts.

Differences in Familiarity with Light Concepts between Teacher Groups

Mann-Whitney U tests were conducted to compare the teachers' ratings on familiarity with basic, advanced, and all light concepts between teachers' group variables of grade taught and number of science courses taken in high school.

Grade taught groups

As shown in Table 4.7 Mann Whitney test revealed no significant difference between elementary grade teachers' mean rank (M= 29.81) and middle and above grade teachers' mean rank (M= 36.05) on familiarity with basic light concepts, U = 427, p = .19, r = -.161, which is small to medium effect size according to Cohen (1988).

Table 4.7

Familiarity with Light Concepts between Groups of Grade Taught

Group		N	Mean Rank	Sum of Ranks	*U*	*W*	*Z*	*sig.*	Effect Size	Concepts
Grade taught	Elementary	27	29.81	805.00	427.0	805.0	-1.307	.191	-.161	Basic
	middle and above	39	36.05	1406.00						
	Elementary	27	26.72	721.50	343.5	721.5	-2.401	.016*	-.296	Advanced
	middle and above	39	38.19	1489.50						
	Elementary	27	27.89	753.00	375.0	753.0	-1.979	.048*	-.244	All
	middle and above	39	37.38	1458.00						

N=66, *Significant at p ≤ .05

However, there was a significant difference in the mean ranks of elementary grade teachers (M=26.72) and middle and above grade teachers (M=38.19) on familiarity with advanced light concepts, U = 343.5, p = .016, r = -.296, which is considered a medium effect size. Likewise, elementary and middle and above grade teachers differed significantly on familiarity with all light concepts. Mean ranks for elementary and middle and above grade teachers were 27.89 and 37.38, respectively, U = 375, p = .048, r = -.244, which is considered a medium effect size.

These results suggest that elementary and middle and above grade teachers were not different on their ratings of familiarity with basic light concepts. However, middle and above grade teachers were more familiar with advanced and all light concepts than elementary grade teachers.

Number of science courses taken in high school groups

As shown in Table 4.8, teachers who had taken few (1-3) and those who had taken moderate (4+) number of science courses in high school did not differ significantly on familiarity with basic light concepts, U = 418.5, p = .156, r = -.175, a small effect size. The mean ranks were 29.50 and 36.27, respectively. Similarly, teachers who had taken few (1-3) and those who had taken moderate (4+) number of science courses in high school did not differ significantly on familiarity with advanced light concepts, U = 432.0, p = .215, r = -.153, a small effect size. The mean ranks were 30.00 and 35.92, respectively. Likewise, teachers who had taken few (1-3) and those who had taken moderate (4+) number of science courses in high school did not differ significantly on familiarity will all concepts, U = 429.5, p = .205, r = -.156, a small effect size. The mean ranks were 29.91 and 35.99, respectively.

Table 4.8

Familiarity with Light Concepts between Groups of Science Courses in High School

Group		N	Mean Rank	Sum of Ranks	*U*	*W*	*Z*	*sig.*	Effect Size	Concepts
Number of science courses taken in high school	1-3 (Few) courses	27	29.50	796.50	418.5	796.5	-1.419	.156	-.175	Basic
	4+ (Moderate) courses	39	36.27	1414.50						
	1-3 (Few) courses	27	30.00	810.00	432.0	810.0	-1.240	.215	-.153	Advanced
	4+ (Moderate) courses	39	35.92	1401.00						
	1-3 (Few) courses	27	29.91	807.50	429.5	807.5	-1.267	.205	-.156	All
	4+ (Moderate) courses	39	35.99	1403.50						

N=66

These results imply that the teachers who had taken few (1-3) and those who had taken moderate (4+) number of science courses in high school their mean ratings of familiarity with basic light concepts did not differ statistically. Similarly, the teachers mean ratings of familiarity with advanced and all light concepts did not differ statistically for teachers who had taken few (1-3) and moderate (4+) number of science courses in high school.

Differences in Familiarity with Light Concepts among Groups

Kruskal-Wallis tests were conducted to compare the teachers' ratings on familiarity with basic, advanced, and all light concepts among group variables of teaching experience, number of science courses taken in college or university, and the teachers' project.

Teaching experience groups

As shown in Table 4.9, Kruskal-Wallis analysis of variance indicated that the three teachers' teaching experience groups did not differ significantly on familiarity with basic light concepts, χ^2(2, N = 66) = .706, *p* = .703, advanced light concepts, χ^2(2, N = 66) = 1.700, *p* = .428, and all the light concepts, χ^2(2, N = 66) = 1.482, *p*=.477.

Table 4.9

Familiarity with Light Concepts among Groups of Teaching Experience

Group		N	Mean Rank	χ^2	*df*	*sig.*	Concepts
Teaching Experience	1-5 years	29	35.48	.706	2	.703	Basic
	6-10 years	17	30.65				
	11+ years	20	33.05				
	1-5 years	29	36.90	1.700	2	.428	Advanced
	6-10 years	17	31.68				
	11+ years	20	30.13				
	1-5 years	29	36.74	1.482	2	.477	All
	6-10 years	17	30.79				
	11+ years	20	31.10				

N=66, *Significant at p < .05

These results suggest that in spite of the differences in number of years of teaching experience teachers' mean ratings on each of familiarity with basic, advanced and all light concepts did not differ statistically.

Number of science courses taken in college or university groups

As shown in Table 4.10 the Kruskal-Wallis tests indicated that the three teacher sub-groups of the number of science courses taken in college or university did not differ significantly on their familiarity with basic light concepts, χ^2(2, N = 66) = 1.878, p = .391, advanced light concepts, χ^2(2, N = 66) = 3.650, p = .161, and all light concepts, χ^2(2, N = 66) = 2.711, p = .258.

Table 4.10

Familiarity with Light Concepts among Groups of Science Courses in College

Group		N	Mean Rank	χ^2	*df*	*sig.*	Concepts
Number of science courses taken in college/ university	1-3	19	37.76	1.878	2	.391	Basic
	4-6	28	30.09				
	7+	19	34.26				
	1-3	19	36.00	3.650	2	.161	Advanced
	4-6	28	28.39				
	7+	19	38.53				
	1-3	19	36.55	2.711	2	.258	All
	4-6	28	28.98				
	7+	19	37.11				

N=66, *Significant at $p < .05$

These results imply that in spite of differences in the number of science courses the teachers had taken in college or university their mean ratings of interest in basic, advanced, and all light concepts were not statistically different.

Project groups

As shown in Table 4.11 the three projects did not differ significantly on familiarity with basic light concepts, $\chi^2(2, N = 66) = 5.497, p = .064$.

Table 4.11

Familiarity with Light Concepts among Sub Groups of Projects

Group		N	Mean Rank	χ^2	*df*	*sig.*	Concepts
Project	PIASCS	22	34.50	5.497	2	.064	Basic
	SIPAMS	18	24.97				
	SMART	26	38.56				
	PIASCS	22	28.39	7.359	2	.025*	Advanced
	SIPAMS	18	28.33				
	SMART	26	41.40				
	PIASCS	22	30.89	6.299	2	.043*	All
	SIPAMS	18	26.53				
	SMART	26	40.54				

N=66, *Significant at $p < .05$

However, the Kruskal-Wallis analysis of variance indicated that the three projects differed significantly on familiarity with advanced light concepts, χ^2(2, N = 66) = 7.359, p = .025, and on familiarity with all light concepts, χ^2(2, N = 66) = 6.299, p = .043.

These results suggest that the teachers in the three projects had similar levels of familiarity with basic light concepts. However, there were differences among the three project groups on the teachers' familiarity with advanced and all light concepts.

Therefore, in order to evaluate pairwise differences among the projects on familiarity with advanced and all light concepts, three Mann-Whitney (M-W) tests were performed to compare each pair of project mean ranks on familiarity with advanced and all light concepts. The Bonferonni approach was used to control for type I error across tests.

Table 4.12

Familiarity with Light Concepts between Projects Post Hoc Man-Whitney Tests

Group		N	Mean Rank	Sum of Ranks	*U*	*W*	*Z*	*sig.*	Effect Size	Concepts
Project	PIASCS SIPAMS	22 18	20.30 20.75	446.50 373.50	193.500	446.500	-.123	.902	-.019	Advanced
	SIPAMS SMART	18 26	17.08 26.25	307.50 682.50	136.500	307.500	- 2.342	.019	-.353	Advanced
	PIASCS SMART	22 26	19.59 28.65	431.00 745.00	178.000	431.000	- 2.245	.025	-.324	Advanced
	PIASCS SIPAMS	22 18	21.61 19.14	475.50 344.50	173.500	344.500	-.667	.504	-.106	All
	SIPAMS SMART	18 26	16.89 26.38	304.00 686.00	133.000	304.000	- 2.416	.016*	-.364	All
	PIASCS SMART	22 26	20.77 27.65	457.00 719.00	204.000	457.000	- 1.700	.089	-.245	All

*Significant at p< .017

Post hoc Mann-Whitney tests compared the three projects on familiarity with advanced and all light concepts, using a Bonferonni corrected *p* value of .017 to indicate statistical significance. The threshold statistical significance of .05 was divided by 3 (number of tests done) to adjust the alpha value to .017. The results in table 4.12 show that only the mean rank of teachers in

SMART project (M=26.38, n=26) was significantly higher in all light concepts than that of teachers in SIPAMS project (M=16.89, n=18), z = -2.416, p = .016, r = - .364, a medium to large effect size according to Cohen (1988).

These posthoc test results suggest that the teachers in the SMART project were more familiar with all light concepts assessed in this study than the teachers in the PIASCS and SIPAMS projects. This difference in the level of familiarity with all light concepts among the three project groups could be attributed to that the teachers in the SMART project had taken a science course that covered the nature of light one semester before participating in this research. The course was part of the degree program offered through the SMART project.

Summary of Teachers' Familiarity with Light Concepts

The purpose of this chapter was to present results to answer research question # 1: *To what extent are middle school in-service teachers familiar with the concepts of light emphasized in school science curriculum?* Overall, most teachers indicated that they were familiar with the light concepts assessed in this study but did not understand their meanings. In particular, the teachers were more familiar with basic than advanced light concepts.

Differences between teacher groups

Table 4.13 below indicates that there were significant differences between elementary & middle and above grade teacher groups on their familiarity with advanced and all light concepts. However, there were no significant differences between the teacher groups that had taken few (1-3) and moderate (4+) science courses in high school.

Table 4.13

Differences between Teachers' Groups on Basic, Advanced, and All Light concepts

	Significance difference			
Groups	Basic concepts	Advanced concepts	All concepts	Familiarity Level
Elementary & middle and above grade teachers	NS	S	S	Middle and above grade teachers more with advanced and all
Few (1-3) & moderate (4+) science courses in high school	NS	NS	NS	Same

NS= Not Significant; S= Significant

Differences among teacher groups

Table 4.14 shows that there were two significant differences among teacher groups on familiarity with advanced and all light concepts. The teachers in the three projects expressed different levels of familiarity with advanced and all light concepts.

Table 4.14

Differences among Teachers' Groups on Basic, Advanced, and All Light Concepts

	Significance difference			
Groups	Basic concepts	Advanced concepts	All concepts	Familiarity levels
Teachers with 1-5, 6-10 and more than 11 years of teaching experience	NS	NS	NS	Same
Teachers who had taken 1-3, 4-6, and more than 7 science courses in college or university	NS	NS	NS	Same
Teachers who belonged to PIASCS, SIPAMS, and SMART	NS	S	S	Different

NS= Not Significant, S= Significant

However, post hoc tests conducted to evaluate the pairwise differences among the three projects revealed that teachers in the SMART project were more familiar with the light concepts than the teachers in the PIASCS and SIPAMS projects. This difference may be attributed to the fact that teachers in the SMART project had taken a science course that covered the topic of light before participating in this research.

Differences within teacher groups

Table 4.15 below provides a summary of the differences within teacher groups on their familiarity with basic and advanced light concepts. As shown in the table there was only one non-significant difference within teacher groups. Teachers who had taken many science courses in college or university did not differ significantly in their levels of familiarity with basic and advanced light concepts. The rest of the groups were more familiar with basic than advanced light concepts.

Table 4.15

Differences within Teachers' Groups on Basic and Advanced Light Concepts

	Significance difference	
Groups	Between basic and advanced concepts	Familiarity level
Elementary grade teachers	S	More with basic
Middle and above grade teachers	S	More with basic
Teachers who had taken1-3 science courses in high school	S	More with basic
Teachers who had taken more than 4 science courses in high school	S	More with basic
Teachers with 1-5 years of teaching experience	S	More with basic
Teachers with 6-10 years of teaching experience	S	More with basic
Teachers with 11+ years of teaching experience	S	More with basic
Teachers who had taken 1-3science courses in college or university	S	More with basic
Teachers who had taken 4-6, science courses in college or university	S	More with basic
Teachers who had taken more than 7 science courses in college or university	NS	Same

NS= Not Significant, S= Significant

Finally, these results show that most teachers were familiar with the light concepts but they did not understand their meanings. In particular, most teachers were more familiar with basic than advanced light concepts. Except for the group of teachers who had taken many science courses in college the rest of the teacher groups were more familiar with basic than advanced light concepts. Group comparison revealed significant differences in familiarity levels between grade taught groups and among project groups. However, there were no significant differences in familiarity levels between other teacher groups.

CHAPTER 5

TEACHERS' INTEREST IN LIGHT CONCEPTS

Introduction

This chapter presents results to answer research question # 2: *To what extent are middle school in-service teachers interested in learning more about the concepts of light?* First, the chapter presents results of whole group's interest in light concepts. Second, the chapter presents results of between groups comparisons of interest in light concepts. Third, the chapter presents results for within groups comparisons of interest in light concepts. The chapter ends with a summary of the results on teachers' interest in the light concepts assessed in this study.

Teachers' Interest in Light Concepts

As shown in Table 5.1, most teachers were interested in learning more about the light concepts assessed in this study. Specifically, an average of 55.8 % of the teachers indicated that they were interested in learning more about the light concepts, 28.63 % were very interested in learning more about the concepts, and 15.61 % were not at all interested in learning more about the concepts.

Table 5.1

Percentages of Teachers' Choices of Interest in Light Concepts (N=66)

Concept	Type of concept	Not at all interested in learning more	Interested in learning more	Very interested in learning more
		%	%	%
The refraction of light	Basic	12.1	62.1	25.8
The reflection of light	Basic	13.6	60.6	25.8
Vision (how an eye is able to see objects)	Basic	12.1	59.1	28.8
The formation of shadows	Basic	13.6	59.1	27.3
Why opaque objects appear in the color they do in white light.	Basic	15.2	57.6	27.3
Why opaque objects appear in the color they do in colored lights	Basic	15.2	57.6	27.3
Light travels at a greater sped than an airplane	Basic	15.2	56.1	28.8
Average on Basic concepts		13.86	58.89	27.3
The electromagnetic spectrum	Advanced	10.6	59.1	30.3
Light as transverse waves	Advanced	15.2	57.6	27.3
Color filters	Advanced	15.2	56.1	28.8
Wavelength of waves	Advanced	15.2	56.1	28.8
Amplitude of waves	Advanced	16.7	54.5	28.8
Trough of waves	Advanced	19.7	54.5	25.8
Crest of waves	Advanced	19.7	53.0	27.3
Luminous objects	Advanced	18.2	50.0	31.8
Light as a form of energy	Advanced	15.2	48.5	36.4
Non-luminous objects	Advanced	22.7	47.0	30.3
Average on Advanced concepts		16.84	53.64	29.56
Average on all concepts		15.61	55.8	28.63

Table 5.1also shows that 58.89 % of the teachers indicated that they were interested in learning more about the basic light concepts 53.64 % of them indicated that they were interested in learning more about the advanced light concepts. However, an average of 27.3 % of the teachers indicated that they were very interested in learning more about the basic light concepts while 29.56 % indicated that they were very interested in learning more about the advanced light concepts. On the other hand, an average of 13.86 % indicated that they were not at all interested

in learning more about the basic light concepts while 16.84 % indicated that they were not at all interested in learning more about the advanced light concepts.

These results suggest that most of the teachers were interested in learning more about the light concepts assessed in this study. In particular, they were slightly more interested in learning more about the basic than advanced light concepts.

Difference between Teachers' Interest in Basic and Advanced Light Concepts

A Wilcoxon test was performed to find out if there was a significant difference between the teachers' interest in learning more about basic and advanced light concepts within the whole group of teachers in this study. The results in table 5.2 show that there was no significant difference between the teachers' ratings on interest in in learning more about basic and advanced light concepts, N=66, $z = -.573$, $p= .57$, $r= -.071$, a small effect size according to Cohen (1988). Of the 66 participants 17 were interested in the basic light concepts, 12 in the advanced light concepts and there were 37 ties. The mean rank of interest in learning more about the basic light concepts was 14.35, while the mean rank of interest in learning more about the advanced light concepts was 15.92.

Table 5.2

Interest in Basic and Advanced Light Concepts within the Whole Group

Concept type	Mean	S.D.	Mean Rank	N	Rank	*Z*	*Sig.*	*Effect size*
Basic concepts	71.14	18.88	14.35	17	Negative			
Advanced concepts	70.91	20.49	15.92	12	Positive	-.573	.566	-.071
				37	Ties			

N=66

These results suggest that this group of teachers were interested in learning more about both the basic and advanced light concepts.

Differences in Interest in light concepts within Teacher Groups

Wilcoxon tests were performed to find out if there were differences within the teachers' groups on interest in learning more about basic and advanced light concepts. The teacher group variables that were considered in this section were grade taught, number of science courses taken in high school, teaching experience, and number of science courses taken at college level.

Grade taught groups

Table 5.3 shows that there was no significant difference between the rating on teachers' interest in learning more about basic and advanced light concepts, N = 27, z = -1.362, p = .173, r = -.262, a small effect size, for teachers who taught elementary grades. Of the 27 teachers, 5 were interested in learning more about basic concepts, 2 were interested in learning more about advanced concepts. There were 20 ties.

Table 5.3

Interest in Basic and Advanced Light Concepts within Grade Taught Group

Group		Concept type	Mean	S.D.	Mean Rank	N	Rank	*Z*	*Sig.*	*Effect size*
Grade Taught	Elementary	Basic	73.90	18.93	4.40	5	Negative	-1.362	.173	-.262
		Advanced	72.35	21.76	3.00	2	Positive			
						20	Ties			
						27	Total			
	Middle and above	Basic	69.23	18.85	10.54	12	Negative	.000	1.000	.000
		Advanced	69.92	19.79	12.65	10	Positive			
						17	Ties			
						39	Total			

*Significant at $p \leq .05$

Similarly, there was no significant difference between the rating on teachers' interest in learning more about basic and advanced light concepts, N = 39, z = .000, p = 1.000, r = .000, a small effect size, for teachers who taught middle and above grades. Of the 39 teachers, 12 were interested in learning more about the basic concepts, 10 were interested in learning more about the advanced concepts, and there were 17 ties.

These results imply that elementary grade teachers expressed the same level of interest in learning more about both basic and advanced light concepts. Correspondingly, middle and above grade teachers expressed the same level of interest in learning more about both basic and advanced light concepts.

Number of science courses taken in high school groups

Table 5.4 shows that there was no significant difference between the rating on teachers' interest in learning more about basic and advanced light concepts, N = 27, z = -.628, p = .530, r = -.121, a small effect size, for teachers who had taken few (1-3) science courses in high school. Of the 27 teachers, 6 were interested in learning more about basic concepts, 8 were interested in learning more about advanced concepts and there were 13 ties.

Table 5.4

Interest in Basic and Advanced Light Concepts Based on Science Courses in High School

Sub group		Concept type	Mean	S.D.	Mean Rank	N	Rank	*Z*	*Sig.*	*Effect size*
Number of science courses taken in high school	1-3 courses (Few)	Basic	71.78	20.41	7.08	6	Negative	-.628	.530	-.121
		Advanced	73.33	20.82	7.81	8	Positive			
						13	Ties			
						27	Total			
	4+ courses (Many)	Basic	70.70	18.00	7.86	11	Negative	-1.507	.132	-.241
		Advanced	69.23	20.35	8.38	4	Positive			
						24	Ties			
						39	Total			

*Significant at $p \leq .05$

Similarly, there was no significant difference between the rating on teachers' interest in learning more about basic and advanced light concepts, N = 39, z = -1.507, p = .132, r = -.241, a small to medium effect size, for teachers who had taken many (4+) science courses in high school. Of the 39 teachers, 11 were interested in learning more about basic concepts, 4 were interested in learning more about advanced concepts and there were 24 ties.

These results suggest that within each of the groups of teachers who had taken few or many science courses in high school, teachers expressed the same level of interest in learning more about both basic and advanced light concepts.

Teaching experience groups

Table 5.5 shows there was no significant difference between the rating on the teachers' interest in learning more about basic and advanced light concepts, N = 29, z = -1.938, p = .05, r = -.360, which is a medium effect size, for the group of teachers who had 1-5 years teaching experience. Of the 29 teachers, 3 were interested in learning more about basic concepts, 7 were interested in learning more about advanced concepts and there were 19 ties. Similarly, there was no significant difference between the ratings on the teachers' interest in learning more about basic and advanced light concepts, N = 29, z = -1.782, p = .075, r = -.432, a medium to large effect size, for the group of teachers who had moderate (6 – 10) years of teaching experience. Of the 17 teachers, 5 were interested in learning more about basic concepts, 1 was interested in learning more about advanced concepts and there were 11 ties.

Table 5.5

Interest in Basic and Advanced Light Concepts Based on Teaching Experience

Sub group		Concept type	Mean	S.D.	Mean Rank	N	Rank	*Z*	*Sig.*	*Effect size*
Teaching Experience	1-5 years (few)	Basic	72.09	16.53	2.83	3	Negative	-1.938	.05	-.360
		Advanced	74.60	17.87	6.64	7	Positive			
						19	Ties			
						29	Total			
	6-10 years (Moderate)	Basic	71.43	20.34	3.80	5	Negative	-1.782	.075	-.432
		Advanced	68.43	21.96	2.00	1	Positive			
						11	Ties			
						17	Total			
	11+ years (Many)	Basic	69.53	21.54	6.50	9	Negative	-.910	.363	-.203
		Advanced	67.67	22.84	8.13	4	Positive			
						7	Ties			
						20	Total			

Significant at $p < .05$

Correspondingly, there was no significant difference between the ratings on the teachers' interest in learning more about basic and advanced light concepts, N = 29, z = -.910, p = .363, r = -.203, a medium effect size, for the group of teachers who had 11+ years of teaching experience. Of the 20 teachers, 9 were interested in learning more about basic concepts, 4 were interested in learning more about advanced concepts and there were 7 ties.

These results suggest that each group of teachers who had few, moderate, and many years of teaching experience had the same level of interest in learning more about basic and advanced light concepts.

Number of science courses taken in college or university groups

Table 5.6 shows there was no significant difference between the rating on the teachers' interest in learning more about basic and advanced light concepts, N = 19, z = -.169, p = .866, r = -.039, which is a small effect size, for the group of teachers who had taken few (1-3) science courses in college or university. Of the 19 teachers, 3 were interested in learning more about basic concepts, 4 were interested in learning more about advanced concepts and there were 12 ties.

Table 5.6

Interest in Basic and Advanced Light Concepts Based on Science Courses in College

Sub group		Concept type	Mean	S.D.	Mean Rank	N	Rank	*Z*	*Sig.*	*Effect size*
Number of science courses taken in college/ university	1-3 courses (Few)	Basic	70.93	21.29	5.00	3	Negative	-.169	.866	-.039
		Advanced	70.18	25.08	3.25	4	Positive			
						12	Ties			
						19	Total			
	4-6 courses (Moderate)	Basic	67.35	18.41	6.72	9	Negative	-.503	.615	-.095
		Advanced	67.14	18.67	8.90	5	Positive			
						14	Ties			
						28	Total			
	7+ courses (Many)	Basic	76.94	16.36	3.60	5	Negative	.000	1.000	.000
		Advanced	77.19	17.29	6.00	3	Positive			
						11	Ties			
						19	Total			

Significant at p <.05

Similarly, there was no significant difference between the ratings on the teachers' interest in learning more about basic and advanced light concepts, N = 28, z = -.503, p = .615, r = -.095, a small effect size, for the group of teachers who had taken Moderate number (4-6) of science courses in college or university. Of the 28 teachers, 9 were interested in learning more about basic concepts, 5 were interested in learning more about advanced concepts and there were 14 ties. Similarly, there was no significant difference between the ratings on the teachers' interest in learning more about basic and advanced light concepts, N = 19, z = -.000, p = 1.000, r = .000, a small effect size, for the group of teachers who had taken many (7+) science courses in college or high school. Of the 19 teachers, 5 were interested in learning more about basic concepts, 3were interested in learning more about advanced concepts and there were 11 ties.

These results imply that teachers' interest in learning more about basic and advanced light concepts was the same despite having taken different numbers of science courses in college or university.

Differences in Interest in light concepts between Teacher Groups

Mann-Whitney U tests were conducted to compare the teachers' ratings on interest in learning more about basic, advanced, and all light concepts between teacher group variables of grade taught and number of science courses taken in high school.

Grade taught groups

Table 5.7 shows that teachers who taught elementary grades did not have a significantly higher mean rank (M= 34.89) than that of the teachers who taught middle and above grades (M= 32.54) on basic light concepts, U = 489, p = .612, r = -.062, which is a small effect size according to Cohen (1988).

Table 5.7

Interest in Light Concepts between Groups of Grade Taught

Sub Group		N	Mean Rank	Sum of Ranks	*U*	*W*	*Z*	*sig.*	Effect Size	Concepts
Grade taught	Elementary	27	34.89	942.00	489.0	1269.0	-.507	.612	-.062	Basic
	Middle and above	39	32.54	1269.00						
	Elementary	27	34.89	942.00	489.0	1269.0	-.508	.612	-.063	Advanced
	Middle and above	39	32.54	1269.00						
	Elementary	27	34.78	939.00	492.0	1272.0	-.461	.645	-.057	All
	Middle and above	39	32.54	1272.00						

N=66

Similarly, there was no significant difference in the mean ranks of the teachers who taught elementary grades (M=34.89) and teachers who taught middle and above grades teachers (M=32.54) on advanced light concepts, U = 489, p = .612, r = -.063, which is considered a small effect size. Similarly, teachers who taught elementary and those who taught middle and above grades did not differ significantly in their rating of interest in learning more about all light concepts, U = 492, p = .645, r = -.057, a small effect size. Mean ranks for elementary and middle and above grade teachers were 34.78 and 32.62, respectively.

These results suggest that the group of elementary grade teachers, just like the group of middle and above grade teachers each had the same level of interest in learning more about light concepts assessed in this study.

Number of science courses taken in high school groups

Table 5.8 also shows that teachers who had taken few (1-3) and those who had taken moderate number (4+) of science courses in high school did not differ significantly on their rating of interest in learning more about basic light concepts, U = 471.5, p = .457, r = -.092, a small effect size. The mean ranks were 35.54 and 32.09, respectively. Similarly, teachers who had taken few (1-3) science courses and those who had taken moderate number (4+)science courses in high school did not differ significantly on their rating of interest in learning more about advanced light concepts, U = 455.5, p = .337, r = -.118, a small effect size. The mean ranks were 36.13 and 31.68, respectively. Similarly, teachers who took 1-3 and those who took 4+ science courses in high school did not differ significantly on their rating of interest in learning more about all light concepts, U = 454.0, p = .333, r = -.119, small to medium effect size. The mean ranks were 36.19 and 31.64, respectively.

These results suggest that the teachers' mean ratings on interest in basic, advanced and all light concepts were the same for the groups of teachers who had taken few or many science courses in high school.

Table 5.8

Interest in Light Concepts between Groups of Science Courses in High School

Sub Group		N	Mean Rank	Sum of Ranks	*U*	*W*	*Z*	*sig.*	Effect Size	Concepts
Number of science courses taken in high school	1-3 (Few) courses	27	35.54	959.50	471.5	1251.5	-.744	.457	-.092	Basic
	4+ (moderate) courses	39	32.09	1251.50						
	1-3 (Few) courses	27	36.13	975.50	455.5	1235.5	-.961	.337	-.118	Advanced
	4+ courses (moderate)	39	31.68	1235.50						
	1-3 courses	27	36.19	977.00	454.0	1234.0	-.969	.333	-.119	All
	4+ courses (Moderate)	39	31.64	1234.00						

N=66

Differences in Interest in Light Concepts among Teacher Groups

Kruskal-Wallis tests were conducted to compare the teachers' ratings on interest in learning more about basic, advanced, and all light concepts among teacher group variables of teaching experience, number of science courses taken in college or university, and project where teachers belonged to.

Teaching experience groups

As shown in table 5.9, the Kruskal-Wallis analysis of variance indicated that the three teachers' teaching experience groups did not differ significantly on interest in basic light concepts, $\chi^2(2, N = 66) = .404$, $p = .817$, advanced light concepts, $\chi^2(2, N = 66) = 1.134$, $p = .567$, and all light concepts, $\chi^2(2, N = 66) = .683$, $p=.711$.

Table 5.9

Interest in Light Concepts among Groups of Teaching Experience

Sub Group		**N**	**Mean Rank**	χ^2	***df***	***sig.***	**Concepts**
Teaching Experience	1-5 years	29	34.09	.404	2	.817	Basic
	6-10 years	17	35.00				
	11+ years	20	31.38				
	1-5 years	29	36.21	1.134	2	.567	Advanced
	6-10 years	17	31.91				
	11+ years	20	30.93				
	1-5 years	29	35.47	.683	2	.711	All
	6-10 years	17	33.09				

N=66, *Significant at p ≤ .05

These results imply that in spite of the differences in the number of years of teaching experience each group of teachers expressed the same level of interest in learning more about basic, advanced and all light concepts.

Number of science courses taken in college or university groups

In Table 5.10 the Kruskal-Wallis analysis of variance indicates that the three teacher groups of the number of science courses taken in college or university did not differ significantly on their interest in basic light concepts, $\chi^2(2, N = 66) = 2.564$, p = .278, advanced light concepts, $\chi^2(2, N = 66) = 1.931$, p = .381, and all light concepts, $\chi^2(2, N = 66) = 2.355$, p = .308.

Table 5.10

Interest in Light Concepts among Groups of Science Courses in College

Group		**N**	**Mean Rank**	χ^2	***df***	***sig.***	**Concepts**
Number of science courses taken in college/ university	1-3	19	34.21	2.564	2	.278	Basic
	4-6	28	29.68				
	7+	19	38.42				
	1-3	19	33.68	1.931	2	.381	Advanced
	4-6	28	30.34				
	7+	19	37.97				
	1-3	19	33.66	2.355	2	.308	All
	4-6	28	29.98				
	7+	19	38.53				

N=66, *Significant at $p \leq .05$

These results imply that in spite of the differences in the number of science courses teachers had taken at college and university level their mean ratings of interest in basic, advanced and all concepts were not statistically different.

Project groups

As shown in Table 5.11, the three projects did not differ significantly on interest in learning more about basic light concepts, $\chi^2(2, N = 66) = 5.697$, p = .058, advanced light concepts, $\chi^2(2, N = 66) = 5.750$, p = .056, and all light concepts, $\chi^2(2, N = 66) = 6.010$,p = .050.

Table 5.11

Interest in Light Concepts among Groups of Project

Sub Group		**N**	**Mean Rank**	χ^2	***df***	***sig.***	**Concepts**
Project	PIASCS	22	25.82	5.697	2	.058	Basic
	SIPAMS	18	37.75				
	SMART	26	37.06				
	PIASCS	22	25.93	5.750	2	.056	Advanced
	SIPAMS	18	35.69				
	SMART	26	38.38				
	PIASCS	22	25.52	6.010	2	.050	All
	SIPAMS	18	36.92				
	SMART	26	37.88				

N=66, Significant at $p < .05$

These results suggest that the teachers who belonged to PIASCS, SIPAMS, and SMART expressed the same level of interest in learning more about all light concepts.

Summary of the Results on Teachers' Interest in Light Concepts

The purpose of this chapter was to present results to answer research question 2: *To what extent are middle school in-service teachers interested in learning more about the concepts of light?* Overall, most teachers indicated that they were interested in learning more about the light concepts assessed in this study. In particular, teachers were equally interested in learning more about both basic and advanced light concepts.

Differences between teacher groups

Table 5.12 below indicates that there were no significant differences between teacher groups on their interest in learning more about light concepts assessed in this study.

Table 5.12

Differences between Teacher Groups on Basic, Advanced, and All Light concepts

	Significance difference			
Groups	Basic concepts	Advanced concepts	All concepts	Interest level in learning more
Elementary & middle and above grade teachers	NS	NS	NS	Same
1-3 & more than 4 science courses in high school	NS	NS	NS	Same

NS= Not Significant

Differences among teacher groups

Table 5.13, shows that there was no significant difference among teacher groups on interest in learning more about basic, advanced, and all light concepts. The teachers in the three projects expressed the same levels of interest in learning more about the light concepts assessed in this study.

Table 5.13

Differences among Teacher Groups on Basic, Advanced, and All Light Concepts

	Significance difference			
Groups	Basic concepts	Advanced concepts	All concepts	Interest level in learning more
Teachers with 1-5, 6-10 and more than 11 years of teaching experience	NS	NS	NS	Same
Teachers who had taken 1-3, 4-6, and more than 7 science courses in college or university	NS	NS	NS	Same
Teachers who belonged to PIASCS, SIPAMS, and SMART	NS	NS	NS	Same

NS= Not Significant

Differences within teacher groups

Table 5.14 below provides a summary of the differences within teacher groups on their interest in learning more about basic and advanced concepts of light. As shown in the table there was only one significant difference within teacher groups. Teachers with few years of teaching experience had more interested in learning more about advanced (M= 74.60) than basic (M= 72.09) light concepts.

Table 5.14

Differences within Teacher Groups on Basic and Advanced Light Concepts

	Significance difference	
Groups	Between basic and advanced concepts	Interest level in learning more
Elementary grade teachers	NS	Same
Middle and above grade teachers	NS	Same
Teachers who had taken1-3 science courses in high school	NS	Same
Teachers who had taken more than 4 science courses in high school	NS	Same
Teachers with 1-5 years of teaching experience	NS	Same
Teachers with 6-10 years of teaching experience	NS	Same
Teachers with 11+ years of teaching experience	NS	Same
Teachers who had taken 1-3science courses in college or university	NS	Same
Teachers who had taken 4-6, science courses in college or university	NS	Same
Teachers who had taken more than 7 science courses in college or university	NS	Same

NS= Not Significant

Finally, these results show that most teachers were interested in learning more about the light concepts assessed in this study. In particular, most teachers were equally interested in learning more about both basic and advanced light concepts. All the teacher group variables revealed no significant difference in their levels of interest in learning more about light concepts assessed in this study.

CHAPTER 6

TEACHERS' CONCEPTUAL UNDERSTANDING OF LIGHT CONCEPTS

Introduction

The purpose of this chapter is to present the results on teachers' conceptual understanding of light concepts in order to answer Research Question # 3: *To what extent do middle school in-service teachers conceptually understand the concepts of light emphasized in school science curriculum?* First, the chapter presents results of whole group's conceptual understanding of light concepts. Second, the chapter presents results of between groups conceptual understanding of light concepts. Third, the chapter presents results for within groups comparisons of conceptual understanding of light concepts. Then, the chapter ends with a summary of the results on teachers' conceptual understanding of the light concepts assessed in this study.

Teachers' Understanding of Light Concepts

As shown in Table 6.1, the overall average shows that 56.86 % of the teachers gave incorrect responses, 18.12 % gave partially correct responses, and 25.01 % gave correct responses to the questions on conceptual understanding of light concepts assessed in this study. Table 6.1 also shows that on average, 49.33 % of the teachers provided incorrect responses, and 22.31 % provided partially correct responses, and 28.36 % provided correct responses on basic light concepts. On the advanced light concepts, 64.38 % of the teachers provided incorrect responses, 13.93 % provided partially correct responses, and 28.36 % provided correct responses.

Table 6.1

Percentages of Teachers' Conceptual Understanding of Light Concepts

Concept	Type of concept	Incorrect	Partially Correct	Correct
		%	%	%
The formation of shadows	Basic	22.7	10.6	66.7
The reflection of light	Basic	31.8	6.1	62.1
The refraction of light	Basic	54.5	6.1	39.4
Vision (how an eye is able to see objects)	Basic	40.9	48.5	10.6
Light travels at a greater speed than an airplane	Basic	24.2	66.7	9.1
Appearance of opaque colored objects in white light.	Basic	81.8	10.6	7.6
Appearance of colored opaque objects in colored lights.	Basic	89.4	7.6	3.0
Average on basic concepts		49.33	22.31	28.36
Trough of waves	Advanced	51.5	1.5	47.0
Crest of waves	Advanced	62.1	1.5	36.4
Luminous objects	Advanced	33.3	33.3	33.3
Non-luminous objects	Advanced	34.8	31.8	33.3
Wavelength of waves	Advanced	68.2	4.5	27.3
The electromagnetic spectrum	Advanced	74.2	1.5	24.2
Color filters	Advanced	83.3	9.1	7.6
Light as a form of energy	Advanced	47.0	47.0	6.0
Amplitude of waves	Advanced	92.4	6.1	1.5
Light as transverse waves	Advanced	97.0	3.0	0.0
Average on advanced concepts		64.38	13.93	21.66
Average on all concepts		56.86	18.12	25.01

N=66

These results suggest that most teachers had poor conceptual understanding of most light concepts assessed in this study. In particular, most teachers had a poor conceptual understanding of advanced than basic light concepts.

Difference between Teachers' Understanding of Basic and Advanced Light Concepts

A paired samples t-test was performed to find out if there was a significant difference between teachers' conceptual understanding of basic and advanced light concepts within the whole group of teachers in the study. The results in table 6.2 show that the teachers' score on conceptual understanding of advanced light concepts (M = 26.81, SD = 22.13) was significantly lower than the score on conceptual understanding of basic light concepts (M = 42.10, SD = 20.74); *t* (65) = 6.315, p < .01, *d* = .777, a large effect size according to Cohen (1988).

Table 6.2

Teachers' understanding of Basic and Advanced Light Concepts

Concept type	Mean Score	S.D.	N	*t*	*df*	*Sig.*	*Effect size* (*d*)
Basic concepts	42.10	20.74	66	6.315	65	.000	.777
Advanced concepts	26.81	22.13	66				

These results suggest that this group of teachers had more conceptual understanding of the basic than advanced light concepts.

Differences in Understanding of Light Concepts between Groups

Independent samples t-tests were conducted to compare the teachers' scores on conceptual understanding of basic, advanced, and all light concepts between teacher group variables of grade taught and number of science courses taken in high school.

Grades taught

Table 6.3 revealed that there was no significant difference in the mean scores of elementary grade teachers (M=41.01, SD = 27.13) and middle and above grade teachers (M=42.86, SD = 15.20) on the conceptual understanding of basic light concepts, t(37.32) = -.321, p = .750, *d* = -.087, which is considered a small effect size.

Table 6.3

Conceptual Understanding of Light Concepts between Groups of Grade Taught

Group		N	Mean Score	SD	*t*	*df*	Mean difference	*sig.*	Effect Size (*d*)	Concepts
Grade Taught	Elementary	27	41.01	27.13	-.321	37.32[a]	-1.852	.750	-.087	Basic
	Middle and above	39	42.86	15.20						
	Elementary	27	28.52	25.56	-.516	64	2.877	.607	.127	Advanced
	Middle and above	39	25.64	19.67						
	Elementary	27	33.67	24.69	.175	38.84[a]	.931	.862	.047	All
	Middle and above	39	32.73	14.77						

N=66, [a]The *t* and *df* were adjusted because variance were not equal.

Similarly, elementary and middle and above grade teachers did not differ significantly on the conceptual understanding of advanced light concepts. Mean scores for elementary and middle and above grade teachers were 28.52 (SD = 25.56) and 25.64 (SD = 19.67), respectively, t(64) = -.516, p = .607, *d* = .127, which is a small effect size. Likewise, there was no significant difference in the mean scores of elementary grade teachers (M= 33.67, SD = 24.69) and middle and above grade teachers (M= 32.73, SD = 14.77) on the conceptual understanding of all light concepts, t (38.84) = .175, p = .862, *d* = .047, which is a very small effect size according to Cohen (1988).

These results imply that that was no statistical differences between elementary, and middle and above grade teachers' conceptual understanding of the light concepts assessed in this study.

Number of science courses taken in high school

Table 6.4 shows that teachers who had taken few (1-3) science courses and those who had taken many (4+) number of science courses in high school did not differ significantly on conceptual understanding of basic light concepts, t(64) = .159, p = .874, *d* = .040, a small effect size. The mean scores were 42.59 (SD = 21.75) and 41.76 (SD = 20.30), respectively. Similarly, the teachers who had taken few (1-3) and those who had taken many (4+) number of science courses in high school did not differ significantly on conceptual understanding of advanced light concepts, t(64) = -1.07, p = .291, *d* = -.271, which is a medium effect size . The mean scores were 23.33 (SD = 20.14) and 29.23 (SD = 23.35), respectively. Equally, the teachers who had taken few (1-3) and those who had taken many (4+) number of science courses in high school did not differ significantly on the conceptual understanding of all light concepts, t(64) = -.645, p = .522, *d* = -.163, a small effect size. The mean scores were 31.26 (SD = 18.15) and 34.39 (SD = 20.15) respectively.

Table 6.4

Conceptual Understanding of Light Concepts between Groups of Science Courses in High School

Group		N	Mean Score	SD	*t*	*df*	Mean difference	*sig.*	Effect Size (*d*)	Concepts
Number of science courses taken in high school	1-3 (Few) courses	27	42.59	21.75	.159	64	.834	.874	.040	Basic
	4+ (Many) courses	39	41.76	20.30						
	1-3 (Few) courses	27	23.33	20.14	-1.07	64	-5.90	.291	-.271	Advanced
	4+ (Many) courses	39	29.23	23.35						
	1-3 (Few) courses	27	31.26	18.15	-.645	64	-3.125	.522	-.163	All
	4+ (Many) courses	39	34.39	20.15						

N=66

These results suggest that the mean scores on the conceptual understanding of basic, advanced and all light concepts were not statistically different for teachers who had taken few or many science courses in high school.

Differences in Understanding in Light Concepts among Groups

One-way ANOVA tests were conducted to compare the teachers' scores on conceptual understanding of basic, advanced, and all light concepts among group variables of teaching experience, number of science courses taken in college or university, and the teachers' project.

Teaching experience

As shown in Table 6.5, Analysis of Variance (ANOVA) indicated that the three teachers' teaching experience groups did not differ significantly on conceptual understanding of basic light concepts, $F(2, 63) = 1.215$, $p = .303$, advanced light concepts, $F(2, 63) = .689$, $p=.506$, and all light concepts, $F(2, 63) = .880$, $p = .420$.

Table 6.5

Conceptual Understanding of Light Concepts among Sub Groups of Teaching Experience

Group		N	Mean Score	SD	*df*	F	*sig.*	Concepts
Teaching Experience	1-5 years	29	37.93	18.12	2	1.215	.303	Basic
	6-10 years	17	47.48	23.41	63			
	11+ years	20	43.57	21.73				
	Total	66	42.10	20.74				
	1-5 years	29	25.86	20.05	2	.689	.506	Advanced
	6-10 years	17	32.06	27.16	63			
	11+ years	20	23.75	20.64				
	Total	66	26.81	22.13				
	1-5 years	29	38.83	17.29	2	.880	.420	All
	6-10 years	17	38.41	22.75	63			
	11+ years	20	31.91	19.00				
	Total	66	33.11	19.28				

Significant at $p < .05$

These results suggest that in spite of the differences in the numbers of years of their teaching experience the teachers' conceptual understanding of the basic, advanced and all light concepts were not statistically different.

Number of science courses taken in college or university

In Table 6.6 the Analysis of Variance (ANOVA) indicated that the three teacher groups of the number of science courses taken in college or university did not differ significantly on their conceptual understanding of basic light concepts, $F (2, 63) = .330$, $p = .720$, advanced light concepts, $F (2, 63) = .605$, $p = .549$, and all light concepts, $F (2, 63) = .510$, $p = .603$.

Table 6.6

Conceptual Understanding of Light Concepts among Groups of Science Courses in College

Group		N	Mean Score	SD	*df*	F	*sig.*	Concepts
Number of science courses taken in college/ university	1-3	19	42.11	22.70	2	.330	.720	Basic
	4-6	28	40.05	17.96	63			
	7+	19	45.11	23.21				
	Total	66	42.10	20.74				
	1-3	19	23.16	21.62	2	.605	.549	Advanced
	4-6	28	26.43	21.12	63			
	7+	19	31.05	24.47				
	Total	66	26.82	22.13				
	1-3	19	30.96	20.71	2	.510	.603	All
	4-6	28	32.04	16.70	63			
	7+	19	36.84	21.76				
	Total	66	33.11	19.28				

*Significant at $p < .05$

These results suggest that in spite of the differences in the numbers of science courses the teachers had taken in college or university their means on conceptual understanding of the basic, advanced and all light concepts were not statistically different.

Project

As shown in Table 6.7, the three projects did not differ significantly on conceptual understanding of basic light concepts, $F(2, 63) = 2.010$, $p = 0143$, advanced light concepts, F (2, 63), $p = .068$, and all light concepts, $F(2, 63) = 3.090$, $p = .052$.

Table 6.7

Conceptual Understanding of Light Concepts among Sub Groups of Project

Sub Group		N	Mean Score	SD	*df*	F	*sig.*	Concepts
Project	PIASCS	22	39.94	22.98	2	2.010	.143	Basic
	SIPAMS	18	36.11	20.57	63			
	SMART	26	48.08	17.91				
	Total	66	42.10	20.74				
	PIASCS	22	21.82	18.10	2	2.812	.068	Advanced
	SIPAMS	18	21.67	25.44	63			
	SMART	26	34.62	21.30				
	Total	66	26.82	22.13				
	PIASCS	22	29.28	17.87	2	3.090	.052	All
	SIPAMS	18	27.62	21.71	63			
	SMART	26	40.16	17.07				
	Total	66	33.11	19.28				

N=66, *Significant at $p < .05$

These results suggest that the teachers in the three projects had similar level of conceptual understanding of the light concepts assessed in this study.

Differences in Understanding of Light Concepts within Groups

Paired samples t-tests were performed to find out if there were differences in conceptual understanding of basic and advanced light concepts within teachers' group variables of grade taught, number of science courses taken in high school, teaching experience, and number of science courses taken in college or university.

Elementary and middle and above school teachers

Table 6.8 shows that the score on conceptual understanding of advanced light concepts (M=28.52, SD=25.56) was significantly lower than the score on conceptual understanding of basic light concepts (41.01, SD=27.13); t (26) = 3.620, p = .001, r = .697, a large effect size, for teachers who taught elementary grades.

Table 6.8

Conceptual Understanding of Basic and Advanced Light Concepts within Grade Taught Group

Group		Concept type	Mean Score	S.D.	N	*t*	*df*	*Sig.*	*Effect size*
Grade Taught	Elementary	Basic	41.01	27.13	27	3.620	26	.001*	.697
		Advanced	28.52	25.56	27				
	Middle and above	Basic	42.86	15.20	39	5.173	38	.000*	.828
		Advanced	25.64	19.67	39				

*Significant at $p < .05$

Similarly, the score on conceptual understanding of advanced light concepts (M=25.64, SD=19.67) was significantly lower than the score on conceptual understanding of basic light concepts (M=42.86, 15.20); *t* (38) = 5.173, p = .000, *d* = .828, a large effect size, for teachers who taught middle and above grades.

These results suggest that within elementary and middle school teacher groups, teachers had poor conceptual understanding of the advanced than basic light concepts.

Number of science courses taken in high school

Table 6.9 shows that the score on conceptual understanding of advanced light concepts (M = 23.33, SD = 20.14) was significantly lower than the score on conceptual understanding of basic light concepts (M =42.59, SD = 21.75); *t* (26) = 4.832, p = .000, *d* = .930, a large effect size, for teachers who had taken few (1-3) science courses in high school.

Table 6.9

Conceptual Understanding of Basic and Advanced Light Concepts Based on Science Courses in High School Group

Group		Concept type	Mean Score	S.D.	N	*t*	*df*	*Sig.*	*Effect size*
Number of science courses taken in high school	1-3 courses (Few)	Basic	42.59	21.75	27	4.832	26	.000*	.930
		Advanced	23.33	20.14	27				
	4+ courses (Many)	Basic	41.76	20.30	39	4.190	38	.000*	.671
		Advanced	29.23	23.35	39				

*Significant at $p < .05$

Correspondingly, the score on conceptual understanding of advanced light concepts (M = 29.23, SD = 23.35) was significantly lower than the score on conceptual understanding of basic light concepts (M = 41.76, SD = 20.30); t (38) = 4.190, p = .000, *d* = .671, a large effect size, for teachers who taught middle and above grades.

These results suggest that within groups of teachers who had taken few and many science courses in high school, teachers had less conceptual understanding of advanced than basic light concepts.

Teaching experience

Table 6.10 shows that the score on conceptual understanding of advanced light concepts (M = 25.86, SD = 20.05) was significantly lower than the score on conceptual understanding of basic light concepts (M = 37.93, SD = 18.12); t (28) = 3.749, p = .001, *d* = .696, a large effect size, for teachers who had few (1-5) years teaching experience. Similarly, the score on conceptual understanding of advanced light concepts (M = 32.06, SD = 27.16) was significantly lower than the score on conceptual understanding of basic light concepts (M = 47.48, SD =

23.41); t (16) = 2.624, p = .018, *d* = .636, a large effect size, for teachers who had moderate (6-10) years teaching experience.

Table 6.10

Conceptual Understanding of Basic and Advanced Light Concepts Based on Teaching Experience

Group		Concept type	Mean Score	S.D.	N	*t*	*df*	*Sig.*	*Effect size*
Teaching Experience	1-5 years (Few)	Basic	37.93	18.12	29	3.749	28	.001*	.696
		Advanced	25.86	20.05	29				
	6-10 years (Moderate)	Basic	47.48	23.41	17	2.624	16	.018*	.636
		Advanced	32.06	27.16	17				
	11+ years (Many)	Basic	43.57	21.73	20	4.756	19	.000*	.809
		Advanced	23.75	20.64	20				

*Significant at p < .05

Likewise, the score on conceptual understanding of advanced light concepts (M = 23.75, SD = 20.64) was significantly lower than the score on conceptual understanding of basic light concepts (M = 43.57, SD = 21.73); t (19) = 4.756, p = .000, *d* =.809, a large effect size, for teachers who had many (11+) years teaching experience.

These results suggest that the both groups of teachers had less conceptual understanding of advanced than basic light concepts, despite their differences in the numbers of years of teaching experience.

Number of science courses taken in college

Table 6.11 shows there was a significant difference between the scores on conceptual understanding of basic (M = 42.11, SD = 22.70) and advanced (M = 23.16, SD = 21.62) light concepts; t (18) = 5.338, p = .000, *d* =.773, which is large effect size, for the group of teachers who had taken few (1-3) science courses at college or university level. In the same way, the score on conceptual understanding of advanced light concepts (M = 26.42, SD = 21.12) was significantly lower than the score on conceptual understanding of basic light concepts (M = 40.05, SD = 17.96); t (27) = 3.291, *p* = .003, *d* = .622, a large effect according to Cohen (1988), for the group of teachers who had taken moderate (4-6) science courses in college or university.

Table 6.11

Conceptual Understanding of Basic and Advanced Light Concepts Based on Science Courses in College

Group		Concept type	Mean Score	S.D.	N	*t*	*df*	*Sig.*	*Effect size*
Number of science courses taken in college/ university	1-3 courses (Few)	Basic	42.11	22.70	19	5.338	18	.000*	.773
		Advanced	23.16	21.62	19				
	4-6 courses (Moderate)	Basic	40.05	17.96	28	3.291	27	.003*	.622
		Advanced	26.42	21.12	28				
	7+ courses (Many)	Basic	45.11	23.21	19	3.003	18	.008*	.689
		Advanced	31.05	24.47	19				

*Significant at $p < .05$

Similarly, the score on conceptual understanding of advanced light concepts (M = 31.05, SD = 24.47) was significantly lower than the score on conceptual understanding of basic light concepts (M = 45.11, SD = 23.21); t (18) = 3.003, *p* = .008, *d*= .689, a large effect size according to Cohen (1988), for the group of teachers who had taken many (7+) science courses in college or university.

These results suggest that teachers had a less conceptual understanding of advanced than advanced light concepts despite having taken different numbers of science courses in college or university.

Summary

The purpose of this chapter was to present the results on teachers' conceptual understanding of light concepts in order to answer Research Question # 3: *To what extent do middle school in-service teachers conceptually understand the concepts of light emphasized in school science curriculum?* Overall, most teachers, had poor conceptual understanding of light concepts assessed in this study. In particular, teachers had less conceptual understanding of advanced than basic light concepts.

Differences between teacher groups: As shown in Table 6.12 there were no significant differences between teacher groups on their conceptual understanding of light concepts assessed in this study.

Table 6.12

Differences between Teacher Groups on Basic, Advanced, and All Light concepts

	Significance difference			
Groups	Basic concepts	Advanced concepts	All concepts	Conceptual understanding level
Elementary & middle and above grade teachers	NS	NS	NS	No Significant Difference
1-3 & more than 4 science courses in high school	NS	NS	NS	No Significant Difference

NS= Not Significant

Differences among teacher groups: As shown in Table 6.13 there was no significant difference among teacher groups in their conceptual understanding of light concepts.

Table 6.13

Differences among Teacher Groups on Basic, Advanced, and All Light Concepts

	Significance difference			
Groups	Basic concepts	Advanced concepts	All concepts	Interest level in learning more
Teachers with 1-5, 6-10 and more than 11 years of teaching experience	NS	NS	NS	No Significant Difference
Teachers who had taken 1-3, 4-6, and more than 7 science courses in college or university	NS	NS	NS	No Significant Difference
Teachers who belonged to PIASCS, SIPAMS, and SMART	NS	NS	NS	No Significant Difference

NS= Not Significant

Differences within teacher groups: As shown in Table 6.14 below, there were significant differences within all the teacher groups. The teachers within all the groups had less conceptual understanding of advanced than basic light concepts.

Table 6.14

Differences within Teacher Groups on Basic and Advanced Light Concepts

	Significance difference	
Groups	Between basic and advanced light concepts	Conceptual Understanding
Elementary grade teachers	S	More in basic than advanced light concepts
Middle and above grade teachers	S	More in basic than advanced light concepts
Teachers who had taken1-3 science courses in high school	S	More in basic than advanced light concepts
Teachers who had taken more than 4 science courses in high school	S	More in basic than advanced light concepts
Teachers with 1-5 years of teaching experience	S	More in basic than advanced light concepts
Teachers with 6-10 years of teaching experience	S	More in basic than advanced light concepts
Teachers with 11+ years of teaching experience	S	More in basic than advanced light concepts
Teachers who had taken 1-3science courses in college or university	S	More in basic than advanced light concepts
Teachers who had taken 4-6, science courses in college or university	S	More in basic than advanced light concepts
Teachers who had taken more than 7 science courses in college or university	S	More in basic than advanced light concepts

S= Significant

Finally, the results presented in this chapter show that most teachers had poor conceptual understanding of the light concepts assessed in this study. In particular, most teachers had less conceptual understanding of advanced than basic light concepts. The between and among teacher groups comparisons revealed no significant differences in teachers' levels of conceptual understanding of the light concepts. However, within teacher group variables revealed significant differences between the teachers' conceptual understanding of basic and advanced light concepts- teachers were less knowledgeable of advanced than basic light concepts.

CHAPTER 7

TEACHERS' PERFORMANCE ON LIGHT CONCEPTS AND RELATIONSHIP WITH OTHER VARIABLES

Introduction

The purpose of this chapter is to present results on teachers' performance on a two tier test on light concepts   in order to answer Research Questions # 4 and # 5: *What is the performance level of middle school in-service teachers on the concepts of light emphasized in school science curriculum? To what extent are middle school in-service teachers' familiarity, interest, conceptual understanding, performance, and pedagogical ideas for light related?* First, the chapter presents the results of whole group's performance on the test. Second, the chapter presents the results of between groups comparisons of performance on light concepts. Third, the chapter presents the results for among groups comparisons of performance on light concepts. Fourth, the chapter represents the results of the detailed analysis of teachers' responses to the two-tier test items. The chapter also presents the results of the relationship among factors. The chapter ends with a summary of the results on teachers' performance on the light concepts assessed in this study.

Teachers' Performance on Light Test

Each item in the test had two-tiers: the multiple choice question and reason for the answer. A response for each item was considered correct when a participant answered both tiers of the item correctly. A response was considered to be incorrect for the item if either the multiple choice answer or the reason or both were wrong. A correctly answered item was scored '1' while an incorrectly answered item was scored '0'. As shown in Table 7.1, the overall average shows that 65.41 % of the teachers gave incorrect responses, and 34.58 % gave correct responses to the questions on the performance test of the light concepts.

Table 7.1

Percentages of Teachers' Performance on the Two Tier Light Test

Item	Light ideas tested	Incorrect %	Correct %
15	A girl seeing an image of a flower when she is positioned in front of a mirror.	100	0.0
16	A girl seeing an image of a flower when she is not positioned in front of a mirror (i.e. at an angle).	98.5	1.5
19	Image formed when the top half of a lens is covered.	97.0	3.0
21	Appearance of a red rose in yellow light.	97.0	3.0
14	The possibility of seeing more of oneself in a mirror.	92.4	7.6
3	Shadow is formed when light is blocked by an object.	86.4	13.6
9	Illumination by a lighted lamp above an obstruction	84.8	15.2
24	Comparing shadows formed when shining light on a card and filter.	83.3	16.7
8	Visibility of a lighted lamp above an obstruction.	77.3	22.3
10	The effect of the shape of an opaque lamp shade on the direction of light rays.	77.3	22.7
18	The effect of removing a lens between an object and the screen.	75.8	24.2
4	How a boy sees a non-luminous object (flower).	72.7	27.3
17	The effect of refraction in water.	68.2	31.8
5	How a boy sees a luminous object (flame).	65.2	34.8
20	Effect of shinning white light on a red glass.	59.1	40.9
22	Why a blue book appears blue in white light.	56.1	43.9
6	Distribution of light by a covered source.	53.0	47.0
23	Effect of light from a flashlight falling on a red filter.	51.5	48.5
11	Vision of cats in the dark.	42.4	57.6
13	The visibility of colors and objects when a candle is extinguished.	34.8	65.2
1	Light propagation during the day	28.8	71.2
2	Light propagation at night.	28.8	71.2
7	Distribution of light by an open source.	27.3	72.7
12	Human vision in the dark.	12.1	87.9
Average		65.41	34.58

N=66

These results suggest that most teachers performed poorly on the two tier light test. For example, all teachers (100%) provided incorrect response to test item 15 that tested their knowledge about how an image of the flower is seen in a mirror and the size of the image of the flower, when an observer is in front of a mirror. On test item 16, which tested the same teachers' knowledge as on item 15 except that the observer was not in front of the mirror, 98.5 % of the teachers provided incorrect response. Furthermore, 97 % of the teachers provided incorrect responses on test items 19 and 21. Item 19 tested the teachers' knowledge about the type of image that is formed when the top half of a lens is covered while item 21 tested the teachers' knowledge about how a red rose would appear in yellow light. Also, most teachers provided incorrect responses on several other items such as 14 (92.4 %), 3 (86.4 %), 9 (84.8 %), and 24 (83.3 %).

However, most teachers performed well on few test items. For example, 87.9 % of the teachers provided correct responses on item 12, which tested their knowledge of how humans view objects in the dark. Others were items 7 (72.7 %), 2 (71.2 %), and 1 (71.2 %).

Differences between Groups

Independent samples t-tests were conducted to compare the teachers' performance scores on the two tier light test between teacher group variables of grade taught and number of science courses taken in high school.

Grades taught

Table 7.2 revealed that there was no significant difference in the mean scores of elementary grade teachers (M= 33.49, SD = 13.40) and middle and above grade teachers (M= 35.36, SD = 13.48) in the performance on the two tier light test, t (64) = -.557, p = .579, *d* = -.994, which is a large effect size according to Cohen (1988).

Table 7.2

Performance on the Two Tier Light Test between Groups of Grade Taught

Group		**N**	**Mean Score**	**SD**	***t***	***df***	**Mean difference**	***sig.***	**Effect Size (*d*)**
Grade taught	Elementary	27	33.49	13.40	-.557	64	-1.875	.579	-.994
	Middle and above	39	35.36	13.48					

N=66

These results imply that the performance of elementary and middle and above grade teachers on the two tier light test was not significantly different.

Number of science courses taken in high school

Table 7.3 shows that teachers who had taken few (1-3) science courses and those who had taken many (4+) science courses in high school did not differ significantly in their performance on the two tier light test, t (64) = -.635, p = .528, *d* = -.159, a small effect size. The mean scores were 33.33 (SD = 13.28) and 35.47 (SD = 13.55) respectively.

Table 7.3

Performance on the Two Tier Light Test between Groups of Science Courses in High School

Group		**N**	**Mean Score**	**SD**	***t***	***df***	**Mean difference**	***sig.***	**Effect Size (*d*)**
Number of science courses taken in high school	1-3 (Few) courses	27	33.33	13.28	-.635	64	-2.1373	.528	-.159
	4+ (Many) courses	39	35.47	13.55					

N=66

These results suggest that the mean scores on the performance on the two tier light test were not statistically different for teachers who had taken few or many science courses in high school.

Differences among Groups

One-way ANOVA tests were conducted to compare the teachers' scores on their performance on the two tier light test among group variables of teaching experience, number of science courses taken in college or university, and the teachers' project.

Teaching experience

As shown in Table 7.4, Analysis of Variance (ANOVA) indicated that the three teachers' teaching experience groups did not differ significantly in their performance on the two tier light test, $F(2, 63) = 1.648$, $p = .201$.

Table 7.4

Performance on Two Tier Light Test among Groups of Teaching Experience

Group		**N**	**Mean Score**	**SD**	***df***	**F**	***sig.***
Teaching Experience	1-5 years	29	34.48	11.13	2	1.648	.201
	6-10 years	17	38.97	13.34	63		
	11+ years	20	31.04	15.79			
	Total	66	34.60	13.38			

*Significant at p < .05

These results suggest that in spite of the differences in the numbers of years of teaching experience the teachers' performance on the two tier light test were not statistically different.

Number of science courses taken in college

In Table 7.5 the Analysis of Variance (ANOVA) indicated that the three teacher groups of the number of science courses taken in college or university did not differ significantly on their performance on the two tier light test, F(2, 63) = 1.114, p = .335.

Table 7.5

Performance on the two tier light test among Groups of Science Courses in College

Group		**N**	**Mean Score**	**SD**	***df***	**F**	***sig.***
Number of science courses taken in college/ university	1-3	19	38.16	13.20	2	1.114	.335
	4-6	28	34.08	13.56	63		
	7+	19	31.80	13.19			
	Total	66	34.60	13.38			

*Significant at p < .05

These results suggest that in spite of the differences in the numbers of science courses the teachers had taken in college their means on performance on the light test were not statistically different.

Project

As shown in Table 7.6, One Way ANOVA showed that the three projects did not differ significantly on performance on the two tier light test, F (2, 63) = 2.606, p = .082.

Table 7.6

Performance on the Two Tier Light Test among Groups of Project

Sub Group		**N**	**Mean Score**	**SD**	***df***	**F**	***sig.***
Project	PIASCS	22	29.55	15.16	2	2.606	.082
	SIPAMS	18	35.88	11.80	63		
	SMART	26	37.98	11.92			
	Total	66	34.60	13.38			

*Significant at $p < .05$

These results suggest that the teachers in the three projects had similar level of performance on the light test.

Detailed Analysis of Teachers' Responses

A more detailed analysis was conducted to identify the pattern of teachers' responses and their reasons for such responses. The test items were classified into nine strands : The way light travels; The visibility of non-luminous and luminous objects; The distribution of light from a light source; Vision; Mirror images; Refraction images; Filters; Color appearance of objects; and Shadow formation. Then, the teachers' responses were coded as correct or incorrect. A correct response was one where a teacher chose a correct multiple choice answer and a correct reason. An incorrect response was one where a teacher chose a correct multiple choice answer and an incorrect reason or an incorrect multiple choice answer and a correct reason or both incorrect multiple choice answer and reason. Then, the percentages of teachers' responses were calculated for each test item.

The way light travels

In this strand, the test items assessed teachers' knowledge about how light travels from a light bulb to other objects during the day and night. The results show that most teachers did better on test items 1 and 2 than on test items 8 and 9.

Table 7.7

Percentage of Teachers' Responses on the Way Light Travels

Item	**CACR**	**CAIR**	**IACR**	**IAIR**
1	71.2	18.2	6.1	4.5
2	71.2	21.2	4.5	3.0
8	22.7	45.4	3.0	28.7
9	15.2	34.9	6.1	43.8

CACR= Correct Answer and Correct Reason, CAIR= Correct Answer and Incorrect Reason, IACR= Incorrect Answer and Correct Reason, IAIR= Incorrect Answer and Incorrect Reason

On test items 1 and 2, most teachers correctly subscribed to a scientifically correct idea that light from a bulb travels in all directions. In contrast, on test Items 8 and 9, most teachers subscribed to an erroneous idea that light does not travel in straight lines in all directions. For example, on items 8 and 9 most teachers chose the correct multiple choice answers but chose the same incorrect reason in each item that said "Light from the lamp would reach all points above the height of the obstructing wall". Some teachers chose incorrect multiple choice answers and reasons- Such responses showed their lack of understanding of how light travels from a light bulb to other objects during day and night.

These results suggest that most teachers understood that light from a bulb travels in all directions. However, some teachers lacked the idea that light travels in straight lines in all directions from the lamp during the day or night time, and only scatters or diffuses around obstructions.

Visibility of non-luminous and luminous objects

In this strand, the test items assessed the teachers' understanding of how a boy was able to see a flower (non-luminous object) and a flame (luminous object). As shown in Table 7.8 most teachers provided incorrect responses to items 4 and 5. For both test items 4 and 5, most teachers did not subscribe to the scientifically correct idea that the boy is able to see the objects because light emanates from the object and is received by his eye.   Some teachers chose the correct multiple choice answers for items 4 and 5 but they chose incorrect reasons such as "The boy was able to see the flower because there were bundles of rays from the object (flower or flame)"; and "The object was located within the region of the boy's vision".

Table 7.8

Percentages of Teachers' Responses on the visibility of non-luminous and luminous objects

Item	**CACR**	**CAIR**	**IACR**	**IAIR**
4	27.3	25.7	9.1	39.3
5	34.8	19.7	16.7	28.8

CACR= Correct Answer and Correct Reason, CAIR= Correct Answer and Incorrect Reason, IACR= Incorrect Answer and Correct Reason, IAIR= Incorrect Answer and Incorrect Reason

These results suggest that the teachers lacked the understanding that non-luminous and luminous objects are visible because light from them is received by an eye. Therefore, most teachers subscribed to scientifically incorrect ideas that objects can be visible even without the eye being actively involved and that objects need to be within the active region of an eye's vision.

The distribution of light from a light source

In this strand, the test items assessed the teachers' knowledge of how covered and open light sources distribute light to surroundings. Table 7.9 shows that most teachers performed better on item 7 than items 6 and 10. The performance on item 7(open source) indicates that most teachers chose the correct multiple choice answer and the correct reason that said "Light is spreading from the light source". However, on item 6 (covered source) most teachers chose the incorrect multiple choice answer and reason that said "Light is spreading from the light source". Similarly, on item 10 (covered source) most teachers chose the incorrect multiple choice answer and incorrect reason that said "light is seen as rays that indicate the direction of light".

Table 7.9

Percentages of Teachers' Responses on the Distribution of Light from a Light Source

Item	CACR	CAIR	IACR	IAIR
6	47.0	21.2	6.1	25.7
7	72.7	7.5	12.1	7.5
10	22.7	3.0	33.3	40.8

CACR= Correct Answer and Correct Reason, CAIR= Correct Answer and Incorrect Reason, IACR= Incorrect Answer and Correct Reason, IAIR= Incorrect Answer and Incorrect Reason

These results suggest that most teachers had a correct understanding of how light is distributed from an open source. However, they lacked the understanding of how light is distributed from a covered source.

Vision

In this strand, the teachers were assessed on their knowledge of the vision of a boy and a cat in a completely dark room including the visibility of colors after a candle is extinguished in a room perfectly sealed to external light. As shown in Table 7.10, most teachers had correct responses on all the items in this strand. For example on item 13, most teachers chose the correct multiple choice answer which was “We cannot see anything” and correct reason that said “Light must be present for objects to be visible”.

However, some teachers chose incorrect multiple choice and answers and reasons. For example, on item 11 some teachers chose the incorrect answer which was “Felix the cat would see the box quite clearly” and an incorrect reason that said “the cat would be able to see in the dark after adjusting its eyes to the darkness”.

Table 7.10

Percentage of Teachers’ Responses on Vision

Item	CACR	CAIR	IACR	IAIR
11	57.6	1.5	3.0	37.8
12	87.9	0.0	0.0	12.1
13	65.2	1.5	1.5	31.8

CACR= Correct Answer and Correct Reason, CAIR= Correct Answer and Incorrect Reason, IACR= Incorrect Answer and Correct Reason, IAIR= Incorrect Answer and Incorrect Reason

These results suggest that most teachers understand that light is required for cats and humans to see objects and colors in the dark. However, some teachers incorrectly believed that cats see in the dark after adjusting their eyes.

Mirror images

In this strand, the teachers were assessed on their knowledge about the nature, position, and type of images formed by mirrors. Table 7.11 shows that most teachers chose incorrect responses on all the items in this strand. For example, none of the teachers (0%) got item 15 correct. On item 14, in response to a question about how a girl (Sue) would see more of herself in a mirror, most teachers chose an incorrect multiple choice answer that said “she should move the mirror backwards away from her” and the incorrect reason that said “Light from more parts of her body is reflected from the surface of the mirror”. Similarly, on item 15, most teachers chose an incorrect multiple choice answer and the incorrect reason that said “The mirror reflects the rays from the flower and so the image of the flower is on the mirror”. On item 16, most teachers chose an incorrect multiple choice answer and the incorrect reason that said “Sue sees the flower because the ray is thrown back by the mirror into her eye. So she sees not an image but the reflected flower itself”.

Table 7.11

Percentage of Teachers' Responses on Mirror Images

Item	CACR	CAIR	IACR	IAIR
14	7.6	0.0	16.6	75.8
15	0.0	7.6	6.1	86.3
16	1.5	4.5	4.5	89.2

CACR= Correct Answer and Correct Reason, CAIR= Correct Answer and Incorrect Reason, IACR= Incorrect Answer and Correct Reason, IAIR= Incorrect Answer and Incorrect Reason

These results suggest that most teachers did not have sound understanding of the nature, type and position of images formed by mirrors. First, in order for a human being to see more of his/her body, one should tilt the mirror because more parts of his/her body would be reflected from the surface of the mirror. Second, an image is located behind the mirror in the extended lines of reflected rays from the mirror to the eyes but the rays seem to come from the point of intersection behind the mirror's surface.

Refraction images

In this strand, the test items assessed the teachers on their knowledge of the nature, type and position of images formed by the refraction in water and lenses. Table 7.12 shows that most teachers chose incorrect answers in all the items. In particular, more teachers chose incorrect answers on item 19 than on items 17 and 18. On item 19, in response to a question when a lens is covered half way, most teachers chose an incorrect multiple choice answer and an incorrect reason that said " Only light from the lower half of the object can pass through the lens to form a half image". On items 17 and 18, most teachers chose incorrect responses that indicated that most teachers did not have an understanding of the type, position, and nature of images formed by refraction in water and lenses.

Table 7.12

Percentage of Teachers' Responses on Refraction Images

Item	CACR	CAIR	IACR	IAIR
17	31.8	6.1	33.4	28.7
18	24.2	7.6	15.1	53.1
19	3.0	1.5	6.1	89.4

CACR= Correct Answer and Correct Reason, CAIR= Correct Answer and Incorrect Reason, IACR= Incorrect Answer and Correct Reason, IAIR= Incorrect Answer and Incorrect Reason

From these results, it is clear that (a) teachers lacked sound knowledge of the nature, type and position of images formed by refraction in water and lenses, and (b) teachers lacked an understanding of an image formed when the top half of a lens is covered. First, most teachers did not subscribe to the scientifically correct explanation that refraction occurs at the surface of water for light to be directed to the eyes of an observer because the propagation of light is different in air and water. Second, most teachers did not subscribe to the scientifically correct idea that a lens is necessary for the formation of an image. Third, most teachers did not subscribe to the scientifically correct explanation that even if a lens is covered half way, a full but less bright image would be formed on the screen because light travels in all directions from all points of the object and strikes every point on the lens.

Filters

In this strand, the teachers were assessed on their knowledge of the action of filters on white light. As shown in Table 7.13, most teachers chose incorrect responses on both items 20 and 23. On item 20, most teachers chose an incorrect multiple choice answer that said "The red glass lets all the light through, but it stops all the colors except red" but they chose a correct reason that said "Red glass absorbs all the components of white light, except red light". On the other hand, on item 23 most teachers chose the correct multiple choice answer, but chose an incorrect reason that said "White light passing through the filter is 'painted' by the filter".

Table 7.13

Percentage of Teachers' Responses on Filters

Item	**CACR**	**CAIR**	**IACR**	**IAIR**
20	40.9	10.6	21.2	27.3
23	48.5	42.5	0.0	9.0

CACR= Correct Answer and Correct Reason, CAIR= Correct Answer and Incorrect Reason, IACR= Incorrect Answer and Correct Reason, IAIR= Incorrect Answer and Incorrect Reason

These results suggest that most teachers lacked an understanding of the action of filters on white light. In particular, most teachers did not know that red glass absorbs the components of white light except red light. Similarly, most teachers did not know that when white light from a flash light falls on a red filter only red light passes through it.

Color appearance of objects

In this strand, the test items assessed the teachers' knowledge on why objects appear the colors that they do in white and colored lights. The results in Table 7.14 show that most teachers chose incorrect responses for both items 21 and 22. On item 21, most teachers chose an incorrect multiple choice answer and an incorrect reason that said "The rose has a different color and therefore it reflects a mixture of colors". On the other hand, on item 22 most teachers chose the correct multiple choice answer, but they chose an incorrect reason that said "The light reflects the blue color of the book".

Table 7.14

Percentage of Teachers' Responses on Color Appearance of Objects

Item	**CACR**	**CAIR**	**IACR**	**IAIR**
21	6.1	1.5	4.5	87.9
22	43.9	31.8	10.6	13.6

CACR= Correct Answer and Correct Reason, CAIR= Correct Answer and Incorrect Reason, IACR= Incorrect Answer and Correct Reason, IAIR= Incorrect Answer and Incorrect Reason

These results suggest that most teachers did not understand why objects appear the colors they do in white and colored lights. First, most teachers did not subscribe to the scientifically correct explanation that the red rose would appear black in yellow sodium light because the yellow light is absorbed by the red rose- no light emerges or is reflected from the rose when yellow light falls on it. Second, most teachers did not subscribe to the scientifically correct explanation that when we see a blue book, the book reflects blue light and absorbs other colors because the color of an object depends on the rays that are reflected from the object to our eyes.

Shadows

In this strand, the teachers were assessed on their knowledge of shadows formed by opaque and transparent objects. As shown in Table 7.15 most teachers chose incorrect answers for both items 3 and 24. On item 3 most teachers chose an incorrect multiple choice answer and an incorrect reason that said “Light fills up space”. Similarly, on item 24 most teachers chose an incorrect multiple choice answer and an incorrect reason that said “A shadow is the absence of light. Where there is no light there is no color”.

Table 7.15

Percentage of Teachers' Responses on Shadow Formation

Item	**CACR**	**CAIR**	**IACR**	**IAIR**
3	13.6	7.6	1.5	77.2
24	16.7	6.1	6.1	71.2

CACR= Correct Answer and Correct Reason, CAIR= Correct Answer and Incorrect Reason, IACR= Incorrect Answer and Correct Reason, IAIR= Incorrect Answer and Incorrect Reason

On item 3 most teachers did not subscribe to the scientifically correct idea that light would only be present in the sections before where the man in the diagram was standing because the man would form a shadow and block the light from proceeding beyond where he was standing. Similarly, on item 24 most teachers did not subscribe to the idea that a green filter can make a green shadow because it allows green light to pass through it. These results suggest that teachers lacked the understanding that an opaque object forms a shadow by blocking all light and that a transparent object forms a colored shadow depending on the light it allows.

Relationship among Factors

To find out how familiarity, interest, conceptual knowledge, and performance related with each other, correlation coefficients were computed using the T-scores. The raw scores were converted to T-scores in order to provide a metric that is similar to all the scales. Using the

Bonferonni approach to control for type I error across the six correlations, a *p*-value of less than 0.01 (0.05/6 =0.008 ≈ 0.01) was required for significance. The results of the correlation analysis presented in Table 7.16 below show that 1 out of the six correlations was statistically significant. The correlation that was statistically significant was between performance and conceptual understanding. There was a positive linear association between performance and understanding scores, r (64) = .50, p = .000.

Table 7.16

Correlation among Familiarity, Interest, Conceptual Understanding, and Performance Scores

	Familiarity	**Interest**	**Conceptual understanding**
Interest	.001		
Conceptual Understanding	.214	.189	
Performance	.105	.027	.497*

*$p < 0.01$

In general, the results suggest that increased conceptual understanding among teachers results into increased performance on light test.

Summary

The purpose of this chapter was to present the results on teachers' performance on the two tier light test in order to answer Research Question # 4: *What is the performance level of middle school in-service teachers on the concepts of light emphasized in school science curriculum?* Overall, most teachers, performed poorly on the two tier light test.

Differences between teacher groups: As shown in Table 7.17 there were no significant differences between teacher groups on their performance of the light concepts assessed in this study.

Table 7.17

Differences between Teacher Groups on Light Items

Groups	Significance difference	Performance level
Elementary & middle and above grade teachers	NS	No Significant difference
1-3 & more than 4 science courses in high school	NS	No Significant difference

NS= Not Significant

Differences among teacher groups: Table 7.18 shows that there was no significant difference among teacher groups on about the conceptual understanding of light concepts.

Table 7.18

Differences among Teachers' Groups on Light Items

Groups	Significance difference	Performance level
Teachers with 1-5, 6-10 and more than 11 years of teaching experience	NS	No Significant difference
Teachers who had taken 1-3, 4-6, and more than 7 science courses in college or university	NS	No Significant difference
Teachers who belonged to PIASCS, SIPAMS, and SMART	NS	No Significant difference

NS= Not Significant

Detailed analysis of teachers' responses:

The way light travels: Most teachers understood that light from a bulb travels in all directions. However, some teachers lacked the idea that light travels in straight lines in all directions from the lamp during the day or night time, and only scatters or diffuses around obstructions.

Visibility of non-luminous and luminous objects: Most teachers subscribed to incorrect ideas that objects can be visible even without the eye being actively involved and that objects need to be within the active region of an eye's vision.

Therefore, most teachers lacked the understanding that non-luminous and luminous objects are visible because light from them is received by an eye.

Distribution of light from a light source: Most teachers had a correct understanding of how light is distributed from an open source but they lacked the understanding of how light is distributed from a covered source.

Vision: Most teachers understood that light is required for cats and humans to see objects and colors in the dark. However, some teachers had a misconception that cats see in the dark after adjusting their eyes.

Mirror images: Most teachers did not have sound understanding of the nature, type and position of images formed by mirrors. They did not subscribe to the scientifically correct explanation that mirror images are located behind the mirror in the extended lines of reflected rays from the mirror to the eyes.

Refraction images: Most teachers showed lack of understanding of the nature, type and position of images formed by refraction in water and lenses. In addition, most teachers lacked an understanding of an image formed when the top half of a lens is covered. As such, they did not subscribe to the scientifically correct explanations that refraction occurs at the surface of water directing light from an object to the eye, a lens is necessary for image to be formed, and a lens forms a full but less bright image even if it is covered half way.

Filters: Most teachers lacked the understanding of the action of filters on white light. They did not subscribe to the idea that a filter stops all the other colors of light and allows only its own color to pass through.

Color appearance of objects: Most teachers did not know why objects appear the colors they do in white and colored lights. They did not subscribe to the scientific explanation that objects appear the color of light that they reflect and that they absorb all the other colored lights.

Shadow formation: Most teachers lacked the understanding that an opaque object forms a shadow by blocking all light and that a transparent object forms a colored shadow depending on the light it allows.

Relationship among factors

There was a positive linear association between performance and conceptual understanding scores, r (64) = .50, p = .000. Therefore performance scores increased with conceptual understanding scores. The other relationships were not significant. For example, there was no significant relationship between conceptual understanding and familiarity; and between performance and familiarity.

CHAPTER 8

TEACHERS' ABILITY TO IDENTIFY MISCONCEPTIONS AND PEDAGOGICAL IDEAS

Introduction

The purpose of this chapter is to present the results on teachers' ability to identify misconceptions on light and pedagogical ideas in order to answer Research Questions # 5 and # 6: *To what extent are middle school in-service teachers able to identify students' misconceptions on light? How do middle school in-service teachers envision addressing the identified misconceptions about light in middle school classrooms?* First, the chapter presents the results of the teachers' experiences with the topic of light. Second, the chapter presents the results of the teachers' descriptions of some basic concepts of light they expected their students to learn. Third, the chapter presents the results of the teachers' ability to identify students' misconceptions and pedagogical ideas for addressing the misconceptions in nine scenarios. The chapter ends with a summary of the results.

Questionnaire

Forty (40) teachers responded to a open items questionnaire (See Appendix G) and provided written responses to the items (see Appendix J). First, the teachers were asked to write about their experiences with the topic of light, and descriptions of light. Teachers were also asked to state the basic concepts of light they expected their students to learn. Then, the teachers were asked to identify students' misconceptions on light presented in nine scenarios and describe the best instructional practices they would use to address the identified misconceptions in a middle school science classroom.

Teachers' Experiences with the Topic of Light

Two recurring general categories emerged from the participants' responses on whether they had learned the topic of light before they responded to this questionnaire, and these categories were: *Can remember and Can't remember.*

Can remember: Under this category twenty (20) teachers remembered learning the topic of light in *formal settings (high school and college courses), through reading science textbooks, through teaching, and through Instructional support to individual students* the topic in schools. These categories are illustrated by the excerpts presented below. *Formal settings*: For example, teacher # 1 wrote, "Studied the speed of light, shadows in grade school". This excerpt suggests that the teacher was able to remember what was covered in grade school. *Through reading science textbooks:* Teacher # 10 wrote, "Junior high school read about it in the textbook". This excerpt suggests that this teacher was able to remember learning about the topic of light through reading a textbook. However, the teachers did not provide a lot of details of what they covered on the topic of light in school and college courses.

Some teachers claimed they did not cover enough work and as such had difficulties to recall the details they covered. For example, teacher # 19 wrote "I remember covering light … but not into great detail". Teacher # 13 wrote, "We did an experiment with some light bulbs but do not really remember the experiment." Teacher # 29 wrote, "… in high school. I always found it interesting, but apparently have never really learned exactly how it works"

These excerpts suggest that the teachers learned the topic of light and even did some experiments, but they were not able to remember the content covered. This could be attributed to lack of covering the content in great detail or teachers' negative attitude towards science. *Through Teaching*: Under this category, some teachers said they learned more about the concepts of light through teaching the topic in schools. For example, Teacher # 7 wrote, “I must have studied light as a kid, but I don’t really remember learning it well until I taught it as a teacher.” Another teacher wrote:

> Yes. I have studied it in physics class during my college courses, but I also teach a small unit over light in my classes. I enjoyed learning about light and its properties. It helped me to further understand and explain observations of the world around me. (Teacher # 27)

Here the teacher underscores the benefit of learning the topic of light through college courses and teaching the topic in schools. Unlike teacher #7, teacher #27 learned the topic of light in college courses and enjoyed it. However, both teacher # and # 27 claimed they gained a better understanding of the concepts on light through teaching the topic of light in schools.

Instructional support: Furthermore, some teachers gained more understanding of light through providing instructional support to some students. For example, teacher # 38 wrote, “Never. I supported a student in general science at 9th grade level and gained a minimal amount of knowledge…”. The teacher claims to have gained a minimal amount of the knowledge by supporting a 9th grade student even without doing the topic of light in high school or college.

It is evident in the excerpts above that some teachers remembered learning about light in school and college and on their own through reading science textbooks. Furthermore, some teachers learned more about the topic of light through teaching the topic to their students in science classrooms.

Can’t remember*: Under this category* there were two sub-categories: *Can’t remember learning it all and Can’t recall what was covered*. For example, teacher # 4 wrote, “I don’t remember studying light at all”; and teacher # 32 wrote, “I am sure that I have but I don’t remember which ones and obviously if I don’t remember it wasn’t very interesting to me”.

These excerpts suggest that some teachers indicated that they could not remember learning about light at all. However, some teachers did not remember the content that was covered.

Teachers' description of Light

Teachers were asked to describe light. A correct response to this question was expected to include key terms found in the following definition of light: *Light* is the part of the electromagnetic spectrum (energy) which can be detected by a human eye and is responsible for the sense of sight. (Taffel, 1992, p. 710; Victor, Kellough & Tai, 2008, p. 487). However, a description with a verbatim was not required.

The recurring categories in this section were: *Light as Energy, Light as source of energy, Characteristics of light, Light as responsible for vision, and Incorrect ideas of light*.

Light as energy: Under this category, the teachers stated that light is a form of energy. They expressed this by directly using the term energy in their description of light. For example, teacher # 28 wrote, "illuminating energy". This excerpt suggest that teacher # 28 recognized that light is one of the forms of energy. Indeed, scientists would agree that light is the only type of energy we can see.

Light as source of energy: Some teachers erroneously perceived light as a source of energy. For example, teacher # 2, "Light is a source of energy that comes from either natural sources such as the sun, fire, heat, …". This excerpt suggest that some teachers subscribed to the idea that a form of energy can also be the source of energy.

Characteristics of light: Under this category, most teachers described light in terms of its characteristics such as *reflection, travels in straight lines, rays, waves, and wavelength*. For example teacher # 29 wrote that "It is a reflection off an object". However, others combined the description of light as energy and the characteristics of light. For example, teacher # 21 wrote, “Light is the reflection of energy which illuminates things.”

These excerpts suggest that some teachers knew about the characteristics of light and described it by stating its individual characteristcs.

Light as responsible for vision: Under this category some teachers recognized that light was responsible for how we see objects. For example teacher # 3 stated, “Light allows you to see”. This excerpt suggests that the teacher was aware that without light an eye can not see anything. Although the excerpt may imply that an eye detects the light, the teacher does not explicitly indicate whether light is a form of energy or not.

Incorrect ideas of light: Some teachers expressed their ideas of light that were contrary to the scientifically correct ideas. They used phrases such as “light is filtered color”, and “light brightens whatever is around”. For example, teacher # 27 wrote, “Light is an electromagnetic wave emitted from illuminated objects” This excerpt suggests that teacher # 27 had an idea of what light is but did not demostrate an understanding that light was part of the electromagnetic waves . In addition, teacher # 27 holds the view that light is emitted from illuminated objects instead of being reflected or being emitted from luminous objects.

These results suggest that most teachers did not provide a correct description of light. In contrast, most teachers recognized that light is one of the forms of energy, but were unable to describe it fully as a form of energy that can be seen or aids people to see objects. Instead, some teachers just stated individual characteristics of light. As such, their statements on characteristics of light did not results into complete description of light.

Light concepts Teachers Expect Students to Learn

Teachers stated the following concepts of light they expected their students to learn in middle school: *Reflection (13); Propagation of light (11); Refraction (8); Light as energy (7); Visible light specturm (7); Wave nature of Light (7); Color appearance of objects (5) and Absoprtion (5).* The number after each concept represent the number of teachers who mentioned it. Some teachers mentioned more than one concepts and some teachers did not mention any concept.

These responses indicate that the teachers were aware of the basic concepts of light that are covered in middle school science courses and emphasized in National Science Education Standards. As such, they expected their students to learn about them. Although the teachers listed the concepts of light students should learn in middle school they were unable to describe or discuss them.

Identifying Students' Misconceptions and Pedagogical Ideas

Teachers were presented with nine scenarios on the topic of light. In each scenario, teachers were asked to (a) identify the misconception students displayed in a given statement (b) describe the currently accepted scientific explanation of the phenomenon that the students did not understand and (c) explain how they would address the identified misconception using best instructional practices. The results for each scenario are presented in three parts: Identification of misconceptions; Teachers' explanation, and Teachers' pedagogical ideas for addressing the identified misconceptions.

Vision

Scenario # 1: In replying to a question about how an eye is able to see an object, your student mentions that the eye emits light in order for people or animals to see an object. In addition, other students in class agree and provide evidence that they use phrases such as ‘her eyes shine’, ‘his face radiates light’, ‘she casts a glance’. Describe the currently accepted scientific explanation of the phenomenon that the students do not understand. Explain how you would address this misconception using best instructional practices.

Identification of misconception: Most teachers (24 out ot 40) were able to identify students’ misconception in this scenario. For example teacher # 28 wrote, “Light does not shine from our eyes. Light is reflected off of a surface into our eyes”. This excerpt suggests that the teacher was able to point out that the students were incorrect in thinking that the eye emits light. Some teachers also realized that the lack of scientific language among students could have been responsible for the students’ thinking that an eye emits light. For example teacher # 14 wrote,

> First, I would tell the student that "her eyes shine" "his face radiates light" are just figures of speech and that it does relate to how people actually see. I have a poster that has a diagram of an eye on it. I would pull it out and show them that iris controls how much light enters the eye. That light doesn't come out of the eye it is going in the eye

This excerpt suggests that the teacher was able to recognize that everyday language phrases could be responsible for students’ misconception that an eye emits light. Therefore, the teacher held the scientific view of vision that an eye does not emit light, instead the eye receives light reflected by objects or sent by light sources.

Teachers’ Explanation: Twenty two (22 out 40) teachers provided correct explanations, eight teachers wrote incorrect explanations and ten teachers did not provide any explanations. *Correct explanation:* These explanations had key words on how a human eye sees an object. For example teacher # 27 wrote that, Light is not emitted from our eyes, but bounces (reflects) from an object that it strikes, or is emitted from a source. Our eyes simply catch the rays and organize them through a lens into a visible image.

This excerpt shows that the teacher explained correctly that an eye sees objects when light is reflected off objects. The teacher emphasized that light in form of rays enters an eye through the lens and that the eye does not emit light.

Incorrect explanations: These explanations revealed teachers' lack of understanding of the concept of vision. For example teacher # 26 wrote, "I would explain that the eye may seem to emit light but really it is reflecting light". The excerpt shows that the teacher held the view that in order for human beings to see the objects, light needs to be reflected by the eye. This shows that the teachers believed that human eyes see because light comes from the eye and not reflected from the object into the eyes.

No Explanations: Some teachers did not give any explanations. Although they were able to identify the students' misconception they were not able to explain the phenomenon. For example teacher # 4 stated, "The student's misconception is that the eye emits light. I am not for sure how to explain it." This excerpt clearly indicates that the teacher had an idea that an eye does not emit light but was unable to explain the phenomenon.

Pedagogical ideas: The predomonant pedagogical ideas suggested by the teachers for adressing the students misconception about vision were: *Lecture (10) , Experiment (10), Using Technology (8), Reading off the textbook (3), Demonstration (2), Language integration (2) , and Discrepant events (1).*

Lecture: Under this theme teachers suggested ways of addressing the identified misconceptions by mentioning terms such as tell, mention, explain and talk. For example teacher # 40 wrote "I would explain how the eye does not emit light but that it is seeing the reflection of light on an object. I would talk about how we cannot see things when light is not present”. This excerpt suggests that the teacher would assume authority of knowledge of subject matter and use knowledge transmission mode of instruction to address the misconception among students.

Experiment: Some teachers suggested a student-based approach through activities to verify the concepts on vision. Such instructional mode is within the lower level of inquiry. For example teacher # 17 wrote, “We would have to do an experiment with a lens to help show that light passes through but doesn't come from the lens itself.” This excerpt indicates that the teacher would involve the students in an activity that would make them realize that their perception of vision was not scientific.

Demonstration: However, some teachers viewed an experiment in terms of a demonstration. For example teacher # 29 wrote “I would somehow conduct an experiment that proves how the eye doesn't emit light, but instead the eye takes in the reflection caused by light”.

Using Technology: Some teachers suggested the use of technology to explain the light concepts on vision. For example teacher # 28 wrote “We could also use an iPod app to see the parts of the eye and how they work. There are also simulations that can be found on the internet that could show them what happens”. This excerpt indicates that the teacher would search for appropriate materials on internet to show the students. However, teachers’ responses   were not specific on what the students were supposed to be doing or how they would use the technology. However, their responses seem to suggest that the technology will do the teaching and not used as supplements to the activities.

Reading off the textbook: Some teachers suggested using textbooks to show the students how human eyes see objects For example teacher # 25 wrote “I would pull information from a book”. This excerpt suggests that the teacher would read the book and give the information to the students, most likely through a lecture. The use of a textbook is good if students are asked to read and summarize the concepts in their own words.

Speed of light and airplane

Scenario # 2: In replying to a question on what travels faster between light and an airplane,your student says that it is an airplane. Describe the currently accepted scientific explanation of the phenomenon that the students do not understand. Explain how you would address this misconception using best instructional practices.

Identification of misconception: Most teachers (30 out of 40) were able to identify the students' misconception in this scenario. For example teacher # 36 wrote, "Light travels faster than any object" and teacher # 29 wrote, "Light definitely travels much faster than an airplane. It is faster than we are able to see, therefore, proving it is faster than a plane." These excerpts suggest that the teachers were able to identify that the student was incorrect by thinking that an airplane travels faster than light. Also the teachers believed that nothing travels faster than the speed of light. This implies that the teachers believed that for as long as an object can be seen moving by an eye then it is not travelling at the speed greater than light.

Teachers' Explanation: Twenty eight teachers provided correct explanations, and 12 teachers did not provide the explanations. For example teacher # 15 wrote, "Light travels at 186,000 miles/sec obviously the plane it not going to travel that fast." This teacher recalled a theoretical value of speed of light and is able to compare it to any likely speed of an airplane. Furthermore, the teachers were able to explain that light is faster than objects that can be touched or seen. For example teacher # 20 wrote,

> The student thinks that an airplane, which is a physical object that they can touch, is faster because they can see it easier. I would explain that light is faster than the eye can process, and the airplane is slower because your eye can keep up with it.

This excerpt shows that the teacher acknowledged that students often think that an airplane travels faster than light because students can easily observe and detect the high speed of an airplane but they cannot easily observe and detect the high speed of light.

However, some teachers did not give any explanations. Although they were able to identify the students' misconception they were not able to explain the phenomenon. For example teacher # 8 stated, "Light travels faster than anything else but I don't know why." This indicates that the teacher may have an idea that light travels faster than an airplane, but was unable to explain it.

Pedagogical ideas: The pedagogical ideas mentioned by the teachers for adressing the students misconception about the comparing the speeds of light and an airplane were: *Using Technology (16) , Lecture (10) , Unfeasible experiments (6), Reading off the textbook (3), Discussion (2), Demonstration (2), and Field trip (1).*

Using Technology: Most teachers suggested the use of technology as an effective way to address the identified student misconception on the comparison of the speed of light and the speed of an air plane. The technology mostly suggested by the teachers are: *BrainPop, simulations, and animations*. For example teacher # 3 wrote that "I would find a Brain POP or simulation that explains this" and teacher # 19 wrote "I would show the students a video clip or animation to describe the process". This approach is appropriate but requires prior selection of the sites and monitoring of the students during the lesson.

Lecture: Some teachers suggested a transmission mode of instruction to explain and describe that light travels faster than any other known physical object so far. Such an instruction mode is teacher-centred. For example teacher # 13 wrote “I would explain that light travels at a speed far higher than an airplane ever will”. This excerpt suggests that the teacher would just tell the students what the teacher understands about the speed of light and the speed of an airplane.

Unfeasible Experiments: Some teachers suggested involving students doing an activities to verify that light travels faster than an airplane. Such instructional mode is within the lower level of inquiry. However, the choice of the experiments need to be carefully done so as to choose the most plausible ones. For example teacher # 7 wrote

> I would have the kids make paper airplanes and then divide them into pairs. Each pair would have one person with a paper airplane and the other would have a flashlight. Then I would give them paper and them record which gets to the wall faster, the paper airplane, or the light from the flashlight.

This excerpt suggests that the teacher had a good intention of engaging the students in a hands-on activity to verify that light travels faster than an air plane. However, the plausibility of the experiment required more sophisticated materials to measure the speed of light and the paper airplane. As such, this activity is not feasible in middle school classroom.

Reading off the textbook: Some teachers suggested the use of textbook. For example teacher # 18 wrote “We could reference our earth science textbook, or our physics textbook chapters regarding the properties of light and properties of motion”. This excerpt suggests that the teacher together with the students would read the textbook and put together the required information to answer the question about what travels faster between light and an airplane.

Reflection by mirrors

Scenario # 3: During an experiment with mirrors, one of your students concludes that when light hits the surface of a smooth, flat object like a mirror, light is reflected in all directions. Describe the currently accepted scientific explanation of the phenomenon that the students do not understand. Explain how you would address this misconception using best instructional practices.

Identification of misconception: Most teachers (28 out ot 40) were not able to identify the student's misconception in this scenario. For example, Teacher # 38 wrote, "Light is reflected in all directions due to the smooth surface. A mirror is very reflective in nature as is aluminum." This excerpt suggests that the teacher had the same erroneous conception of reflection of light as the student. This implies that the teacher was not able to point out that the student was incorrect in thinking that light is reflected in all directions by a mirror.

Some teachers had incomplete understanding of light reflection by mirrors. For example teacher # 13 wrote, "I could explain that it will travel in all directions but only reflect in a certain manner based on the size of the mirror" This excerpt suggests that the teacher was not able to identify the misconception held by the student. Therefore, the teacher also showed lack of understanding that a light ray is not reflected in all directions, but it is reflected at a specific angle which is equal to the angle of an incoming ray.

Teachers' Explanation: Seven (7) teachers wrote correct explanations, 13 teachers wrote incorrect explanations and the rest of the teachers did not provide explanations.

Correct explanations: For example teacher # 32 wrote, "When light from one direction hits a mirror, it is reflected at another angle, depending on what angle it came from when it hit the mirror." This excerpt shows that the teacher had a correct idea that light is reflected at a specific angle equal to the angle of an incoming ray. However, most teachers' explanations were not very explicit.

Incorrect explanations: These explanations revealed teachers' misconceptions and lack of understanding of the concept of reflection of light by mirrors. For example teacher # 1 wrote, "Light is not reflected off the mirror it is refracted which means it is bent.". The excerpt shows that the teacher holds the view that light rays on mirror surfaces are refracted instead of being reflected.

No Explanations: Some teachers did not give any explanations of reflection on mirror surfaces. For example teacher # 33 stated, "I don't know. " This excerpt indicated that the teacher did not have the idea that a mirror reflects light at a specific angle equal to the angle of an incoming ray.

Pedagogical ideas: The pedagogical ideas mentioned by the teachers for adressing the students misconception about reflection by mirrors were: *Experiment (21), Lecture (3) , Using Technology (3) , Reading off the textbook (3), and Demonstration (3).*

Experiment: The use of experiment was suggested by most teachers to address the identified student misconception on reflection by mirrors. However, the suggested experiments involved students doing an activity to verify the concepts on reflection of mirror surfaces. For example teacher # 34 wrote "Do a reflection experiment using a mirror and flashlights to test the idea".

Lecture: Some teachers suggested a transmission mode of instruction where the teacher would explain or talk about the reflection of light from a mirror surface. For example teacher # 13 wrote "I could explain that it will travels in all directions but only reflect in a certain manner based on the size of the mirror. This mode of instruction would be appropriate if the intention is to give a lot of information to a large group of students within a short time but not if the intention is develop students' inquiry skills.

Using Technology: Some suggested the use of technology but with no specific activity. For example teacher # 18 wrote "We could use Internet animations, if there are any available". This excerpt suggests that the teacher would love to use technology but was not aware of the specific activities to use.

Reading off the textbook: Some teachers suggested the use of a textbook. For example teacher # 3 wrote "I would show them in our Science textbook where it talks about light reflecting off different surfaces". This excerpt suggests that the teacher would direct the students to a page in the textbook but may not engage the students in the thinking process to understand the concept of reflection.

Demonstration: Some teachers suggested the use of demonstration. For example teacher # 2 wrote "Light reflected from a mirror is reflected in only one direction. We would turn off the lights and go to the darkest corner of the room and use a flashlight and mirror to prove this point". This excerpt shows that the teacher would decide to show the students how light is reflected from a mirror surface. However, demonstrations are ideal when there are limited resources for individual or group experiments in class.

Refraction by lenses

Scenario # 4: During an activity with a hand lens, one of your students explain that an object (e.g. a butterfly) looks bigger when viewed through the lens because a lens scatters light. Describe the currently accepted scientific explanation of the phenomenon that the students do not understand. Explain how you would address this misconception using best instructional practices.

Identification of misconception: Most teachers (35 out ot 40) were not able to identify the students' misconception in this scenario. For example teacher # 20 wrote, "The student believes the magnifying glass is connected to light. The truth is that the image changes because of the shape of the magnifying glass". This excerpt suggests that the teacher was not able to identify that the students' misconception was that the lens does not scatter but it refracts the light. However, the teacher recognizes that a lens acts as a magnifying glass but does not seem to understand why. The teachers were able to mention the operations of a lens as concentrating light to a focus point and making objects larger but could not identify that the lens actually refracts the light. For example teacher # 30 wrote, "A hand lens is concave which magnifies the object because it concentrates the light rays giving the appearance of magnification". This excerpt clearly suggests that the teacher understands how a lens interacts with light but was unable to identify that it works because light is refracted and not scattered.

Teachers' Explanation: Four teachers wrote correct explanations, eighteen teachers wrote incorrect explanations and eighteen teachers did not write any explanations.

Correct explanations: For example teacher # 22 wrote, "The student is most likely accurate in his or her thought process, but the correct term would be refracts, not scatters". This excerpt suggests that the teacher thinks that the student understands the phenomenon of refraction but incorrectly uses the term scatters instead of refracts. This shows that the teacher was able to identify that the student wrongly called refraction of light as scattering of light.

Incorrect explanations: These explanations revealed the teachers' misconceptions and lack of understanding of the concept of the refraction of light by lenses. For example teacher # 32 wrote, "A lens, unless a magnifying glass, will not magnify an image to any extent. A lens is just like looking through a piece of glass.". This excerpt shows that the teacher thought that there was a difference between a lens and a magnifying glass. Further, the teacher acknowledged that a magnifying glass would enlarge an object. However, the teacher did not seem to understand that light passing through a lens is refracted in order for an object to be enlarged.

Pedagogical ideas: The pedagogical ideas suggested by the teachers for adressing the students misconception about refraction of light by lenses were: *Experiment (12), Lecture (3) , Using Technology (4) , Reading off the textbook (3), Exploration (1) and Discussion (1).*

Experiment: Most teachers suggested a hands-on mode of instruction as an effective way to address the identified student misconception on refraction of light by lenses. This is a student-based approach by involving students doing an activity to verify the concepts on refraction of light by a lens. Such instruction mode is within the lower level of inquiry. For example teacher # 27 wrote “I would have them move the hand lens back and forth and observe how the image changes in size showing that the light rays are bent at different angles depending on the place that they strike the lens”. This excerpt suggests that the teachers would allow the students to be involved in the experiment while the teacher would be directing the students on what to pay attention to. However, some teachers suggested the use of experiments but did not give the details of what students were expected to be doing. For example teacher # 31 wrote “Have the student do an experiment using convex”.

Lecture: Some teachers suggested the use of a lecture as a mode of instruction to transmit the information to the students. For example teacher # 14 wrote “I would explain that a lens refract light that passes through them”. This excerpt suggests that the teacher would use exposition to illustrate the process of refraction of light when passing through a lens.

Using Technology: Some teachers suggested using technology to find lessons that would help students understand refraction of light through a lens. For example teacher # 15 wrote "I would use the internet to find experiments or simulations to show what was going on".

Reading off the textbook: Some teachers suggested the use of textbooks. For example teacher # 18 wrote "If a textbook we have available addresses this we would reference this" This excerpt suggests that the teacher would check the textbook to find out if it had information on the refraction of light passing through a lens.

Formation of shadows

Scenario # 5: During an activity on the formation of shadows, in response to a question about what a shadow is, your student explains that a shadow is a reflection of an object because an object such as a tree casts its shadow. Describe the currently accepted scientific explanation of the phenomenon that the students do not understand. Explain how you would address this misconception using best instructional practices.

Identification of misconception: Most teachers (21 out ot 40) were able to identify the student's misconception in this scenario. For example teacher # 8 wrote, "The light cannot shine through the object and so a shadow is a result of no light passing through." This excerpt suggests that the teacher was able to point out that the student was incorrect in stating that a shadow is a reflection of an object because an object such as a tree casts its shadow.

Teacher # 35 wrote, "A shadow is caused by the light being blocked so there is no light which causes it to be black." This excerpt suggests that the teacher was able to recognize that a shadow is formed due to light being blocked by an object. Therefore, the teacher held the scientific view of a shadow formed by an opaque object because light has been blocked.

Teachers' Explanation: Ninenteen teachers provided correct explanations, four gave incorrect explanations and seventeen did not write any explanations at all.

Correct explanations: For example teacher # 20 wrote, "The student is under the impression that shadows are created by light when they are a result of a lack of light or an obstruction of light". This excerpt shows that the teacher was able to explain that an opaque object creates a shadow by blocking light.

Incorrect explanations: The explanations revealed teachers' misconceptions and lack of understanding of the concept of vision. For example teacher # 1 wrote, "The shadow is the cast of the object opaque simply means it filters the light going through so an object will send light through normally through its material." The excerpt shows that the teacher holds the view that light passes through an opaque object to form a shadow.

No explanations: Teachers who did not give any explanation indicated that they were not conversant with the formation shadows. For example teacher # 16 stated, "I don't know." This indicates that the teacher did not have the knowledge of how shadows are formed.

Pedagogical ideas: The pedagogical ideas mentioned by the teachers for adressing the students misconception about vision were: *Experiment (18), Using Technology (5) , Lecture (4), Discussion (2), and Demonstration (1).*

Experiment: Most teachers suggested a hands-on mode of instruction as an effective way to address the identified student misconception on the formation of shadows. Some teachers suggested a student-based approach by involving students doing an activity to verify the concepts on the formation of shadows. For example teacher # 2 wrote

> We might use a Venn diagram to show commonalities between the two concepts as we explore them hands-on and to point out the larger differences. We would

specifically note that a mirror projects an image forward while a shadow projects the shape of the image behind".

Using Technology: Some teachers suggested the use of technology to explain the light concepts on shadow formation. However, teachers' responses implied that the technology will be used in form of simulations, animations and video shows for students to prove that their ideas were incorrect. For example teacher # 11 wrote "I would show a video about shadows" and teacher # 21 wrote "I would like to find a simulation or animation to help illustrate this". These excerpts suggest that the teachers would direct the students to specific activities. This requires effective prior planning and also involving students in discussion before and after the activities.

Lecture: Some teachers suggested the use of lecture by way of mentioning that they would explain. For example teacher # 40 wrote "I would simply explain that a shadow is the absence of light, not a reflection of anything". This excerpt indicates that the teacher thinks teaching is simply giving out information on what the teacher knows about the subject matter.

Color appearance of opaque objects

Scenario # 6: In reply to a question on why an opaque object appears the color it does, a student explains that the ability of an opaque body to reflect one color of light and absorb others is called reflection. Describe the currently accepted scientific explanation of the phenomenon that the students do not understand. Explain how you would address this misconception using best instructional practices.

Identification of misconception: Most teachers (39 out of 40) were not able to identify the student's misconception in this scenario. For example teacher # 22 wrote, "I am not sure what is wrong with this statement." This excerpt suggests that the teacher was not able to identify that the student was not correct in calling the ability of an opaque body to reflect one color of light and absorb others as reflection instead of selective reflection. The correct view to this scenario is that the opaque object selects the color to be reflected which is the color it appears. Therefore, this ability is called selective reflection and not just reflection.

Teachers' Explanation: No teacher provided a correct explanation, six teachers provided incorrect explanations and thirty four teachers did not provide any explanations.

Incorrect explanations: Teachers' lack of understanding of the concept of color appearance of opaque objects was evident in some responses. For example teacher # 13 wrote, "Opaque objects absorb dark colors which give it a light color." And teacher # 26 wrote "The ability of an opaque body to reflect one color of light and absorb others is called refraction." These excerpts show that the teachers did not understand why objects appear the color they do. Specifically, the teachers could not explain selective reflection.

No explanations: Most teachers did not give any explanations with some citing that they did not know, others saying they were not sure, and others just mentioned pedagogical ideas. For example teacher # 17 stated, "I know it's not called reflection but not sure what the process is or how I would explain it." This excerpt indicates that the teacher did not have enough content knowledge to explain the process of selective reflection. However, the teacher acknowledged that it was not reflection process. Others just mentioned a pedagogical idea. For example teacher # 11 wrote "I would do a simulation." This excerpt indicates that the teacher as not able to explain but only stated a pedagogical idea.

Pedagogical ideas: Many teachers did not suggest any pedagogical ideas. However, the pedagogical ideas suggested by few teachers for adressing the students misconception about vision are: *Experiment (9), Using Technology (7), Demonstration (2), Discussion (2), and Reading off the textbook (1).*

Experiment: Most teachers suggested a hands-on mode of instruction as an effective way to address the identified student misconception on the color appearance of opaque objects. Some teachers suggested a student-based approach by involving students doing an activity to explore the concepts on the color appearance of opaque objects. For example teacher # 29 wrote "I would have the students try it out on their own while I look up the information myself. I would have them share their findings with the class." This excerpt suggests that the teacher would ask the students to be engaged in an open inquiry activity on this concept. Such instruction mode is within the higher level of inquiry and appropriate to students who have science process skills. However, it requires the teachers' understanding of the subject matter to offer guidance to students. In addition, some experiments suggested by teachers were not related to the concept of selective reflection. For example teacher # 7 wrote "I would probably use a sponge and water to show how a sponge absorbs water and then make the connection that color being absorbed is much like that. It doesn't reflect off like a mirror, but absorbs".

Using Technology: Some teachers suggested the use of technology to explain the light concepts on color appearance of opaque objects. However, teachers' responses implied that the technology would be used in form of simulations, animations and BrainPop. For example teacher # 3 wrote "I would find a Brain POP or simulation to address this concept" and teacher # 21 wrote "simulations and animations would be a great help". These excerpts show that the teachers would choose to use technology without a deeper sense of how and what the students would learn.

Action of filters

Scenario # 7: In reply to a question why a transparent material appears the color it does, a student explains that the ability of a transparent material to transmit one color of light and absorb others is called transmission.   Describe the currently accepted scientific explanation of the phenomenon that the students do not understand. Explain how you would address this misconception using best instructional practices.

Identification of misconception: None of the teachers (40) was able to identify the student's misconception in this scenario. Most teachers did not know how to answer this question. For example teacher # 17 wrote, "I don't know how to answer this question." This excerpt suggests that the teacher was not able to point out that the student was incorrect by stating that the ability of a transparent material to transmit one color of light and absorb others is called transmission. The process was not <u>just</u> transmission but selective transmission.

Teachers' Explanation: No teacher provided a correct explanation, six teachers gave incorrect explanations, six teachers gave partially correct explanations, and twenty eight teachers did not provide any explanations.

Incorrect explanations: Revealed teachers' lack of understanding of the concept of the action of filters. For example teacher # 25 wrote, "The reason that a transparent material transmits one type of light is because the light is scattered because the object is not translucent." The excerpt shows that the teacher could not explain why a colored transparent material would transmit one type of light and absorb the others.

Partially incorrect: The explanations provided by some teachers indicated that the teachers had some understanding of transmission but could not explain clearly that the ability of a transparent material to transmit one color of light and absorb others is called selective transmission. For example teacher # 31 wrote “Transparent objects allow some of the light to pass through them”. This excerpt indicates that the teacher has an idea that a transparent material does not transmit all the light but could not explain exactly what happens.

Pedagogical ideas: Many teachers did not suggest any pedagogical ideas. However the pedagogical ideas mentioned by some teachers for adressing the students misconception about the action of a filter on light were: *Experiment (8), Using Technology (6), Discussion (1), Brain storming (1) and Learning cycles (1).*

Experiment: Most teachers suggested the use of experiments to address the identified student misconception on the action of a color filter on light. Although the teachers suggested involving students in doing activities they did not provide details of addressing the student misconception in the scenario. For example teacher # 24 wrote “I would use experimentation with light spectrum and prisms.” This excerpt indicated that the teacher had an idea of materials to use for this experiment but did not give the details of what the students were expected to do.

Using Technology: Some teachers suggested the use of technology to explain the light concepts on the action of filters on light. However, teachers’ responses implied a lack focus of what students were expected to learn. For example teacher # 9 wrote “Simulation/Internet” and teacher # 15 wrote “find an internet site that shows an example of this process”. These excerpts suggest that the teachers may not have been sure of concrete technology activities to use for students to address the misconception in the scenario.

Light as a form of energy

Scenario # 8: In response to a question asking students to write about what they know about light, a large number of your students repeatedly mention that light is not a form of energy, and that it is just something that is present in order to aid us see objects. Describe the currently accepted scientific explanation of the phenomenon that the students do not understand. Explain how you would address this misconception using best instructional practices.

Identification of misconception: Most teachers (30 out ot 40) were able to identify the students' misconception in this scenario. For example teacher # 36 wrote, "Light is a form of energy that moves and it is not gained or lost but it changes forms". This excerpt suggests that the teacher was able to identify that the students were incorrect mentioning that light was not a form of energy.

Teachers' Explanation: Twenty three teachers wrote correct explanations, eight teachers gave incorrect explanations and nine teachers did not write any explanations.

Correct explanations: In these explanations the teachers were able to mention that light was a form of energy that could be changed to other forms such as electrical, mechanical and sound. For example teacher # 6 wrote, "Show them solar panels and how they can make something work. Changing light energy into mechanical energy." This excerpt shows that the teacher was able to explain that light was a form of energy because it can be changed from one form to another.

Incorrect explanations: Revealed the teachers' lack of understanding of the concept of light as a form of energy. For example teacher # 2 wrote,

> We would demonstrate that light is energy by reminding students of the fact that a fire has light and a fire is absolutely energy. What changes a candle to hot wax? Light energy in the form of heat. We would brainstorm all of the ways light energy and heat work in our daily lives.

This excerpt shows that the teacher was not able to differentiate between light as a form of energy that can be converted from one form to another and light as a form of energy that is different from heat energy.

Pedagogical ideas: The pedagogical ideas mentioned by the teachers for adressing the students misconception about vision were: *Lecture (11), Demonstration (7), Using Technology (6) , Experiment (3) and Discussion (3).*

Lecture: Most teachers suggested a transmission mode of instruction as an effective way to address the identified student misconception that light was not a form of energy. In this mode of instruction the teachers would be involved in explaining and mentioning to students why light should be considered as a form of energy. For example teacher # 7 wrote “I would go back and review our lessons on the Sun and how all life depends on the Sun's energy for life”. This excerpt indicates how the teacher would spend time telling the students about linking light energy from the sun to other forms of energy.

Demonstration: Some teachers suggested that they would perform demonstrations that would help the students realize that light is a form of energy. For example teacher # 20 wrote “I would bring in a solar powered object and show them how it is powered only by light”.

Using Technology: Some teachers suggested the use of technology to explain the concept that light is a form of energy. However, teachers’ responses implied that the technology will be used in form of simulations, animations and BrainPop. For example teacher # 15 wrote “Direct them to simulations that show light as a form of energy”. This excerpt shows that the teacher would direct students to use technology to learn about light as a form of energy.

Experiment: The suggested experiments involved students doing a hands-on activity to verify that light energy can be converted into heat energy. For example teacher # 27 wrote

> I would then have them take a white box and a black box and place it on the playground. We would monitor the temperature of each box. I would ask them if light is not energy, how is it that the black box is warmer. They would conclude that light is energy and can be felt as heat.

This excerpt indicates that the teacher would engage the students in a hands-on activity while asking them questions to think about what they would be doing. The teacher would involve probing questions to keep students thinking and involved in the experiment until they would reach a conclusion.

Discussion: Some teachers suggested to engage the students in an oral discussion on light as energy. For example teacher # 18 wrote “We would discuss solar panels, sunburns, suntans, how hot your car gets in the summer, photosynthesis, etc. These are the ideas students know that will demonstrate that sun in fact produces energy”. This excerpt suggests that the teacher would lead the students into a discussion on situations that illustrate light as energy.

Luminous and illuminated bodies

Scenario # 9: In response to a question about listing examples of luminous and illuminated bodies, students working in groups comment as follows: Examples of luminous bodies are desks, chairs and tables, and examples of illuminated bodies are the sun, stars and various artificial light sources. Describe the currently accepted scientific explanation of the phenomenon that the students do not understand. Explain how you would address this misconception using best instructional practices.

Identification of misconception: Most teachers (23 out ot 40) were not able to identify the student’s misconception in this scenario. Some teachers mentioned that they never learned about luminous and illuminated bodies. For example teacher # 18 wrote, “I don't remember studying this, so I am not sure this would come up." This excerpt suggests that the teacher never studied the concepts of luminous and illuminated bodies. As such, the teacher was not able to identify that the students had interchanged the classification of luminous and illuminated bodies.

However, almost half teachers (17 out of 40) teachers were able to identify the students' misconception. For example Teacher # 8 wrote, "I think these two ideas are reversed. If an object is a source of light, it would be a luminous object. If the object reflects light, it would be an illuminated object." This excerpt suggests that the teacher was able to recognize that the students had classified the luminous and illuminated bodies opposite from the scientific way of classifying them.

Teachers' Explanation: Seventeen teachers wrote correct explanations, three teachers gave incorrect explanations and twenty teachers did not write any explanations.

Correct explanations: The teachers who gave correct explanations understood the correct classification of luminous and illuminated bodies. For example teacher # 21 wrote, "I think those should be reversed. The sun, stars, etc. are luminous and the desks, etc. are illuminated bodies. Luminous would mean they are creating their own light and the other would be they are being lit up by light energy". This excerpt shows that the teacher was able to explain the difference between luminous and illuminated bodies that the students did not understand in the given scenario.

Incorrect explanations: Revealed the teachers' misconceptions and lack of understanding of the concepts of luminous and illuminated bodies. For example teacher # 38 wrote, "Luminous: reflects light easily; diamonds; prisms. Illuminated items: items that reflect light due to light energy bouncing off other items." This excerpt shows that the teacher was not clear on the difference between luminous and illuminated bodies.

Pedagogical ideas: The pedagogical ideas mentioned by the teachers for adressing the students misconception about luminous and illuminated bodies were: *Lecture (8), Experiment (6), and Using Technology (6).*

Lecture: Most teachers suggested a transmission mode of instruction as an effective way to address the identified students' misconception on luminous and illuminated bodies. The teachers suggested that they would explain to the students and clarify the vocabulary. Such instruction mode is good for giving out a lot of information to a large group of students within a short time but would impact very little on the students' cognitive development. For example teacher # 31 wrote

> Objects that are luminous give off a source of energy or light. Illuminated bodies are objects that we can see because light is reflected from their surface. The moon is a good example. When we see it in the day time we don't see light coming from it, but we can see it at night because it is reflecting the light from the sun. Talk to the students about the phases of the moon and eclipse.

This excerpt suggests that the teacher would give out information about luminous and illuminated bodies to the students without engaging them in thinking. The teacher suggested clarifying the concept of luminous and illuminated bodies by using an example – in this case the phase of the moon and eclipse.

Experiment: Some teachers suggested the use of experiments to address students' misconceptions about luminous and illuminated bodies. They mostly suggested the use of confirmation inquiry. For example teacher # 7 wrote

> I would turn off the lights and let them see that furniture in the classroom does not shine. They are not luminous. I would explain that the sun, stars, and artificial light sources are

luminous. That they can see the furniture when I turn the lights back on because of the lights.

This excerpt suggests that the teacher would engage the students in a verification activity in order for them to realize that their classification of the luminous and illuminated bodies was not scientific approach. However, this mode of instruction belongs to the lowest level of inquiry.

Using Technology: Some teachers suggested the use of technology to explain the light concepts on luminous and illuminated bodies. For example teacher # 15 wrote “I would use the internet to find simulations to show luminous and illuminated bodies”. This excerpt suggests that the teacher may not have been aware of what was available on internet to explain luminous and illuminated bodies. Other teachers just mentioned about the use of technology without elaborating how it was going to be done. For example teacher # 11 wrote “Simulation and video”.

Summary

The purpose of this chapter was to present results on teachers’ ability to identify misconceptions and pedagogical ideas in order to answer Research Questions # 5 and # 6: *To what extent are middle school in-service teachers able to identify students’ misconceptions on light? How do middle school in-service teachers envision addressing the identified misconceptions about light in middle school classrooms?* The chapter has also presented results on the teachers’ experiences with light concepts, their understanding of light and descriptions of light concepts they expected their students to learn.

Teachers’ experiences with light concepts: Some teachers remembered learning about light in formal settings (high school and college courses), through reading science textbooks, through teaching it to their students in science classrooms, and through Instructional support to individual students. However, some teachers didn't remembering learning light at all while others mentioned bad experience with the topic of light in science courses.

Teachers' understanding of light: Most teachers provided incorrect descriptions of light. However, most teachers recognized that light is one of the forms of energy, but were unable to describe it fully as a form of energy that can be seen or aids people to see objects. Instead, some teachers stated individual characteristics of light. As such, their statements on characteristics of light did not result into complete description of light.

Light concepts teachers expected students to learn: Teachers listed the basic concepts of light that are covered in middle school science courses and emphasized in the National Science Education Standards but they were unable to describe or discuss them.

Identifying students' misconceptions and pedagogical ideas: Table 8.1 shows teachers' ability to identify students misconceptions and their pedagogical ideas addressing the identified misconceptions in the nine scenarios.

Table 8.1

Teachers' misconception identificcation, explanations and pedagogical ideas

Scenario #	Misconception identification	Explanation	Suggested Pedagogical ideas for addressing misconceptions
1. Vision	Most teachers ***identified*** the misconception	About half of the teachers provided ***correct explanation***	Lecture, Experiment, Technology, Text book, Discrepant events, Demonstration, Language Integration
2. Speed of light and airplane	Most teachers ***identified*** the misconception	More than half the teachers provided ***correct explanation***	Technology, Lecture, Experiment, Textbook, Discussion, Field Trip, Demonstration
3. Reflection by mirrors	Most teachers did **not *identify*** the misconception	Less than 10 the teachers provided ***correct explanation***	Experiment, Lecture, Technology, Textbook
4. Refraction by lenses	Most teachers did **not identify** the misconception	Only Four teachers provided correct explanation	Experiment, Lecture, Technology, Textbook, Exploration, Discussion
5. Formation of shadows	Most teachers ***identified*** the misconception	About half of the teachers provided ***correct explanation***	Experiment, Technology Lecture, Demonstration, Discussion
6. Color appearance of opaque objects	Most teachers did ***not identify*** the misconception	***No teacher*** provided correct explanation	Experiment, Technology, Textbook, Discussion, Demonstration
7. Action of filters	***No teacher identified*** the misconception	***No teacher*** provided correct explanation	Experiment, Technology, Discussion, Brainstorming, Learning cycles.
8. Light as a form of energy	Most teachers ***identified*** the misconception	About half correct the teachers ***provided correct explanation***	Lecture, Demonstration, Technology, Experiment, Discussion
9. Luminous and illuminated bodies	Most teachers ***did not identified*** the misconception	About half correct the teachers ***provided correct explanation***	Lecture, Experiment, Technology.

CHAPTER 9

DISCUSSION AND CONCLUSIONS

Introduction

This chapter first presents the purpose of the study. Second, the chapter presents a summary of the findings of the study. Third, the chapter discusses the relationship of the current study to previous research. Fourth, the chapter discusses the theoretical implications. Fifth, the chapter states implications for practice. Sixth, the chapter lists the recommendations for further research. Seventh, the chapter discusses the limitations of the study. The chapter ends with conclusions.

Purpose of the Study

The purpose of this study was threefold: Examine middle school teachers' familiarity with, interest in, conceptual knowledge of and performance on light; Examine their ability to identify misconceptions on light and their suggested pedagogical ideas to address the identified misconceptions; and Establish the relationship between the middle school teachers' interest, familiarity, conceptual understanding, performance, misconception identification, and pedagogical ideas for light.

Summary of the Results

Familiarity: Although most teachers said they were familiar with the light concepts emphasized in school science curriculum they did not understand their meanings. In particular, most teachers were more familiar with basic than advanced light concepts. Except for the group of teachers who had taken many science courses in college the rest of the teacher groups were more familiar with basic than advanced light concepts. Group comparison revealed significant differences in familiarity levels between grade taught groups and between professional development projects teachers belonged to. However, there were no significant differences in familiarity levels between other teacher sub-groups.

Interest: Most teachers were interested in learning more about the light concepts assessed in this study. In particular, most teachers were equally interested in learning more about basic and advanced light concepts. All the teacher group variables revealed no significant difference in their levels of interest in learning more about light concepts assessed in this study.

Conceptual Understanding: Most teachers had low conceptual understanding of the light concepts assessed in this study. In particular, most teachers had less conceptual understanding of advanced than basic light concepts. The between and among teacher groups comparisons revealed no significant differences in teachers' levels of conceptual understanding of the light concepts. However, within teacher group variables revealed significant differences between the teachers' conceptual understanding of basic and advanced light concepts- teachers were less knowledgeable of advanced than basic light concepts.

Performance: Most teachers, performed poorly on a two tier light test. There were no significant differences between teacher groups on their performance of the light concepts assessed in this study. There was no significant difference among teacher groups on their performance of light concepts. Detailed analysis of teachers' responses revealed teachers' lack of understanding the concept of visibility of non-luminous objects, mirror images, refraction images, filters, color appearance of objects, and shadow formation. However, some teachers had some understanding of the way light travels, distribution of light from a light source, and vision.

Experience with Light: Results on teachers' experiences with light concepts revealed that some teachers remembered learning about light in formal settings (high school and college courses), through reading science textbooks, through teaching it to their students in science classrooms, and through instructional support to individual students. However, some teachers didn't remember learning light at all while others mentioned bad experience with the topic of light in science courses.

Description of Light: Results on teachers' description of light revealed that most teachers did not understand the concept of light. However, most teachers recognized that light is one of the forms of energy, but were unable to describe it fully as a form of energy that can be seen or aids people to see objects. Instead, some teachers stated individual characteristics of light. As such, their statements on the characteristics of light did not result into complete description of light. The teachers in this study listed the basic concepts of light that are covered in middle school science courses and emphasized in the National Science Education Standards but they were unable to describe or discuss them.

Identification of students Misconceptions: Most teachers were able to identify the students' misconceptions in the scenarios on vision, speed of light and airplane, formation of shadows, and light as a form of energy. On the other hand, most teachers were not able to identify the students' misconceptions in the scenarios on reflection by mirrors, refraction by lenses, color appearance of opaque objects, action of filters, and 'luminous and illuminated bodies'.

About half teachers provided correct explanations of students' misconceptions in the scenarios on vision, speed of light and airplane, formation of shadows, light as a form of energy, and 'luminous and illuminated bodies'. Less than ten teachers provided correct explanations of students' misconceptions in scenarios on reflection by mirrors and refraction by lenses. No teacher provided a correct explanation of students' misconceptions in scenarios on color appearance of opaque objects and action of filters.

Pedagogical Ideas: Teachers mostly suggested *experiments and technology integration (animations and simulations)* as the best instructional practices for addressing misconceptions in all the scenarios. Also teachers suggested a *lecture* as the best instructional practice for addressing students' misconceptions in seven scenarios. The remaining two scenarios were on color appearance of opaque objects and action of filters. The teachers suggested *discussion* as a pedagogical idea for addressing students' misconceptions in the scenarios on speed of light and airplane, refraction by lenses, formation of shadows, color appearance of opaque objects, action of filters, and light as a form of energy. They also suggested *performing demonstrations* to address students' misconceptions in the scenarios on vision, speed of light and airplane, formation of shadows, color appearance of opaque objects, and light as a form of energy. Further, the teachers suggested *reading off the textbook* as the best instructional practice for addressing students' misconceptions in the scenarios on vision, speed of light and airplane, reflection by mirrors, refraction by lenses, and color appearance of opaque objects.

The teachers also suggested use of *discrepant events* and *language integration* as effective instructional practices for addressing students' misconception in the scenario on vision. The teachers also suggested *brainstorming and learning cycles* as pedagogical ideas for addressing students' misconceptions on action of filters. They also suggested *field trip* to address students' misconceptions on speed of light and *exploration* for addressing the students' misconceptions on refraction by lenses.

Teachers' perceived and actual knowledge of light concepts: This study has revealed that the perceived knowledge that the middle school teachers reported on light concepts was different from their actual knowledge. For example, teachers' self-reported high level of familiarity with light concepts assessed was not consistent with their low performances on content tests.

However, there was a moderate correlation between teachers' performance and conceptual understanding of light concepts.

Relationship of the Current Study to Previous Research

Familiarity: The review of literature revealed that no study had been conducted on teachers' familiarity with light concepts. In particular, no study had been done on middle school teachers' familiarity with light concepts. Therefore, this study filled this gap in literature by revealing that most teachers reported high levels of familiarity with the light concepts emphasized in school science curriculum. However, the teachers in this study did not understand the meanings of the light concepts assessed. This finding is in contrast to earlier studies on students' familiarity with concepts in other fields. For example, Mullis, Martin, Beaton, Gonzalez, Kelly, & Smith (1997) reported that students who were familiar with the concepts in the official curriculum guides in mathematics performed better than the students who were not. Attwell & Battle (1999) and Dumais (2009) also reported that familiarity with technology was positively associated with learners' performance.

However, the high level of familiarity with light concepts reported in this study presents an opportunity for enhancing teachers' understanding of light concepts emphasized in school science curriculum. According to Warren, Ballenger, Ogonowski, Rosebery, & Hudicourt-Barnes (2001) when the students' familiarity with concepts is tapped, it can result into "robust understanding and achievement across a repertoire of performances and assessments of disciplinary knowledge and practice'' (page 548). Therefore, the teachers in this study have the potential to develop sound understanding of light concepts if they are taught well considering that most of them are already familiar with the light concepts for middle school level.

Interest: This study also found that this group of middle school teachers was interested in learning more about the light concepts assessed in this study. The fact that this group of teachers was predominantly white females makes this finding different from those reported in earlier studies. For example, Breakwell and Beardsell (1992) reported that males had more positive attitudes towards science than females. Lack of interest in science and technology has been cited as a matter of concern for any society attempting to raise its standards of scientific literacy (Osborne, Simon, & Collins, 2003). The high level of interest in learning more about light concepts expressed by these middle school teachers raises a lot of hope that these teachers can develop the desired understanding of light concepts if they are taught well about the topic. These teachers expressed a high level of personal interest in a science topic that previous studies have cited to be one of the least favorable topics among teachers (Osborne et al., 2003). This personal interest enhances individuals' acquisition of more and qualitatively different knowledge than individuals without it (Hidi, 1990).

Knowledge: On the other hand, the teachers' low conceptual understanding of the light concepts assessed in this study and the teachers' low performance on the two tier light test are in agreement with previous studies (Trundle, Atwood, & Christopher, 2002). For example, (Krall, Christopher, and Atwood (2009) reported that teachers over a broad range of ages and with diverse educational experiences have many conceptual difficulties with light concepts). Similar results have been reported among pre-service elementary teachers (Atwood, Christopher, & McNall, 2005; Bendall et al., 1993) and in-service elementary teachers (Atwood & Christopher, 2004; Greenwood & Scribner-MacLean, 1997).

Identifying Misconceptions: Unlike in previous studies, this study has documented the ability of middle school teachers to identify and explain some students' misconceptions.

Teachers also suggested pedagogical ideas for addressing the identified misconceptions. Despite the teachers' difficulties in understanding the light concepts assessed in this study, many teachers were able to identify the students' misconceptions in at least 4 out of 9 scenarios and provided correct explanations of students' misconceptions in at least 5 out of 9 scenarios.

Pedagogical Ideas: The teachers in this study suggested the use of experiments and technology for addressing students' misconceptions in all the 9 scenarios assessed in this study. Although in most cases the teachers lacked specific details of the suggested experiments and technology, the teachers' responses mainly focused on engaging students in hands-on activities to verify the concepts they had misconceptions on. Probably, the lack of sound understanding of light concepts confined the teachers' suggestions to verification level of inquiry. Similarly, previous research has postulated that the lack of conceptual understanding of various concepts among teachers has contributed to their perceived low competence for science teaching, and teachers' retention of many misconceptions found in school students (Summers & Kruger, 1992).

Some teachers suggested a lecture as effective instructional practice for addressing students in all scenarios except for scenarios on color appearance of opaque objects and action of filters. A lecture method requires activities to keep students from becoming passive and it also needs to be interspersed at appropriate times, to keep student attention focused (Bonwell, 1996). The teachers also suggested several other methods for specific scenarios. For example, the teachers suggested discussion instructional practice for addressing students' misconceptions expressed in the scenarios on speed of light and airplane, refraction by lenses, formation of shadows, color appearance of opaque objects, action of filters, and light as a form of energy. Also, they suggested demonstration instructional practice for addressing students' misconceptions expressed in the scenarios on vision, speed of light and airplane, formation of shadows, color appearance of opaque objects, and light as a form of energy; and textbook for the scenarios on vision, speed of light and airplane, reflection by mirrors, refraction by lenses, and color appearance of opaque objects. Others suggested the use of discrepant events and language integration, brainstorming and learning cycles, field trip and exploration instructional practices for addressing students' misconceptions on vision, action of filters, speed of light and airplane, and for refraction by lenses.

Relationship among variables: Correlations among the four constructs (familiarity, interest, conceptual understanding, and performance) were only significant between performance and conceptual understanding, r (64) = .50, p = .000. While this suggests that increased conceptual understanding among teachers results into increased performance on light test, the teachers' perceived and actual knowledge of light concepts were not consistent. There was no significant relationship between conceptual understanding and familiarity; and between performance and familiarity. To a large extent these results are in contrast with previous studies on familiarity and performance. For example, in mathematics, Mullis et al. (1997) reported that learners' familiarity with the concepts led to better performance. Additionally, in ICT, Attwell & Battle (1999) and Dumais (2009) reported that learners' familiarity with technology was positively associated with performance.

In view of these non-significant correlations between variables stated above, it is doubtful that these teachers had sound conceptual understanding and pedagogical ideas to effectively help their students develop the understanding of light concepts accentuated in the US national outlined science education standards. These teachers need the specialized knowledge for teaching derived from the content knowledge that is specifically employed to facilitate learning as it is concerned with how to make particular subject matter comprehensible to particular students (Magnusson & Palincsar, 2005). This suggests that due to insufficient conceptual understanding of light concepts, the teachers in this study had difficulties identifying the students' misconceptions as well as suggesting appropriate pedagogical ideas for effective instruction on light concepts.

Theoretical Implications of the Study

The results of this study are consistent with the tenets of constructivism framework described in chapter 1 on page 10. For example, these teachers' low conceptual understanding and low performance on the two tier light test were manifestations of the teachers' failure to have constructed correct knowledge about light concepts in their previous experiences such as science courses. Furthermore, the teachers' failure to provide detailed pedagogical ideas for addressing students' conceptions on light was due to their low prior knowledge about light and lack of prior knowledge on how to effectively teach the topic of light. Additionally, these teachers' responses on experiences with the topic of light revealed lack of appropriate prior knowledge. Yet, appropriate prior knowledge is an essential element in the constructivist process of learning (Scott, Asoko, & Driver, 1992; Scott, Dyson, & Gater, 1987). The constructivist theory of learning is not limited to formal learning; it also includes experiential learning (Dewey, 1916; 1938; Piaget, 1973).

However, the current state as revealed from the findings in this study, indicate that there is a great potential for this group of middle school teachers to develop their understanding of light concepts. The high level of familiarity with light concepts emphasized in school science curriculum would be their existing ideas on the topic that would be related to new ideas in order to construct appropriate knowledge about the nature of light. Similarly, the teachers' high level of interest in learning more about the light concepts would be the best stimulus to learning as it leads to intuitive and analytical thinking among learners (Bruner, 1960). If these teachers were given the right opportunities they would construct the desired knowledge about light concepts emphasized in school science curriculum either in formal settings (advanced college courses) or informal settings (workshops, teaching or reading off science textbooks). As the result, the teachers in this study would be able to identify and explain students' misconceptions clearly as well as suggest more elaborate and feasible pedagogical ideas for addressing students' misconceptions on light concepts.

Implications for Practice

The findings of this study have instructional implications related to these middle school teachers' performance on, conceptual and pedagogical knowledge of light. It is evident from the findings in this research that the teachers lacked adequate understanding of light concepts. Furthermore, the teachers' ability to identify and explain students' misconceptions of light concepts was low. Probably this was why their suggested pedagogical ideas for addressing the identified students' misconceptions were not explicit and feasible. These findings have important implications on teacher education and teaching and learning of light in schools. For example, there is a great need to recognize that most middle school teachers have low content knowledge of light. As such, science teachers' education courses need to have relevant science content and pedagogical strategies to enhance teachers' understanding of concepts and effective instructional practices for science teaching in schools. According to Van Driel et al. (1998), teachers need a thorough and coherent knowledge of subject matter in order for them to develop appropriate pedagogical ideas. Similarly, since these middle school teachers are familiar with and interested in learning more about light concepts, they need professional development programs that focus on developing teachers' knowledge of light, how children learn about light, and effective pedagogical knowledge for the topic of light in middle school science classroom.

Researchers need to develop appropriate research based pedagogical ideas on light concepts for specific groups of students. As such, there is need to focus on the professional issue of pedagogy through raising teachers' awareness of the conceptual difficulties in learning about light concepts. For example, Neale, Smith, and Johnson (1990) reported one study were some teachers successfully implemented a conceptual change unit on light and shadows. The teachers focused on students' prior conceptions of light and shadows and sought to provide the conditions under which these preconceptions were elicited and challenged so that students were able to construct more general, powerful, and correct conceptions.

Recommendations for Further Research

Although the written responses to an interview protocol were sufficient to provide the data on pedagogical ideas for light for this study, it is recommended that the study be replicated in a similar context with audio interviews. This may provide detailed information on teachers' suggested pedagogical ideas for addressing misconceptions on light. Face to face interviews provide interviewers with opportunity to ask participants to clarify their responses. Also, the interviewer has an opportunity to clarify a question the participant can't understand.

In addition to teachers providing their pedagogical ideas for addressing students' misconceptions on light future research should focus on classroom observations to assess the actual instructional practices on the topic of light in middle school science classrooms. Additionally, interviews should be conducted with the teachers to clarify some of the observations in the lessons.

Finally, future studies should examine middle school teachers' familiarity with, interest in, performance on, conceptual and pedagogical knowledge of other specific subject matter content such as sound, electricity, magnetism, motion and forces, and energy transformations. Such studies should be done over a period of time punctuated with interventions to determine the pre, during and post instruction status. Conducting such studies may assist researchers to offer appropriate guidance in science teaching and learning in middle school classrooms and teacher education.

Limitations

The findings in this study may have been influenced by any of the following limitations.

1. Potential differences in experiences, as well as science content background knowledge among the participants were not controlled in this study. This could have influenced their familiarity with, interest in, performance on, conceptual and pedagogical knowledge that were examined in this study. For example, the results show that teachers learned light in different contexts such as formal settings (high school and college courses), through reading science textbooks, through teaching it to their students, and through instructional support to individual students. Some teachers could not even remember learning light at all while others mentioned bad experience with the topic of light in science courses.
2. A sample of convenience was used. Therefore, the results of this study may not be generalized beyond this group of middle school teachers.
3. Participants are middle school teachers participating in math and science teacher professional development programs at Southern Illinois University Carbondale. It was not possible for the researcher to randomly choose participants from this group.

4. Participants were predominantly white and female. Therefore, results may not be generalized beyond this demographic group of participants.
5. Although classroom observations would have added a practical dimension of the participants' pedagogical ideas on light concepts, no lesson observations were conducted due to limited time teachers were available for this research project. Furthermore, at the time of data collection some teachers had already taught the topic of light to their students.
6. The pedagogical ideas suggested by the teachers were mainly their perceived ideas.

Conclusions

Research Question 1: To what extent are middle school in-service teachers familiar with the concepts of light emphasized in school science curriculum?

Answer: Generally, most teachers in this study said they were familiar with the light concepts emphasized in school science curriculum. In particular, the teachers were more familiar with basic than advanced light concepts.

Research Question 2: To what extent are middle school in-service teachers interested in learning more about the concepts of light?

Answer: Most teachers in this study were interested in learning more about the light concepts assessed in this study. In particular, most teachers were equally interested in learning more about basic and advanced light concepts.

Research Question 3: To what extent do middle school in-service teachers conceptually understand the concepts of light emphasized in school science curriculum?

Answer: Most teachers in this study had poor conceptual understanding of the light concepts assessed in this study. In particular, most teachers had less conceptual understanding of advanced than basic light concepts.

Research Question 4: What is the performance level of middle school in-service teachers on the concepts of light emphasized in school science curriculum?

Answer: Most teachers in this study, performed poorly on a two tier light test. Detailed analysis of teachers' responses revealed teachers' lack of understanding the concept of visibility of non-luminous objects, mirror images, refraction images, filters, color appearance of objects, and shadow formation. However, some teachers had some understanding of the way light travels, distribution of light from a light source, and vision.

Research Question 5: To what extent are middle school in-service teachers able to identify students' misconceptions on light?

Answer: Most teachers in this study were able to identify the students' misconceptions in the scenarios on vision, speed of light and airplane, formation of shadows, and light as a form of energy. On the other hand, most teachers were not able to identify the students' misconceptions in the scenarios on reflection by mirrors, refraction by lenses, color appearance of opaque objects, action of filters, and 'luminous and illuminated bodies'.

Research Question 6: How do middle school in-service teachers envision addressing the identified misconceptions about light in middle school classrooms?

Answer: Most teachers in this study suggested the use of pedagogical ideas that would involve students' active participation such as *experiments, technology integration (animations and simulations), discussion, exploration and field trip* as the best instructional practices for addressing identified misconception about light in middle school science classrooms. However, the suggested pedagogical ideas lacked details. Some teachers suggested pedagogical ideas that were teacher-centered such as *lecture, performing demonstrations, reading off the textbook, and language integration (vocabulary).* Some teachers suggested pedagogical ideas that involved the active interaction between the teacher and the students such as *discrepant events, learning cycles, and brainstorming.*

Research Question 7: To what extent are middle school in-service teachers' familiarity, interest, conceptual understanding, performance, and pedagogical ideas for light related?

Answer: There was significant positive relationship only between performance and conceptual understanding. Otherwise there was no significant relationship between conceptual understanding and familiarity; and between performance and familiarity. Consequently, the pedagogical ideas suggested by the teachers where not detailed and not explicit.

In conclusion, middle school teachers in this study reported high levels of familiarity with and more interest in learning about light concepts. However, these teachers had low conceptual knowledge and performance on light concepts. As such, these teachers' perceived knowledge of light concepts was different from their actual knowledge. These teachers identified students' misconceptions expressed in some scenarios on light. The teachers also suggested pedagogical ideas for addressing students' misconceptions expressed in some scenarios. However, these teachers were not elaborate in their pedagogical ideas. There was a moderate correlation between performance and conceptual understanding.

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APPENDICES

Appendix A

Southern Illinois University Carbondale

Research Development and Administration
Human Subjects Committee
www.siu.edu/orda/human
www.siuc.edu

To: Simeon Mbewe

From: Jane L. Swanson, Ph.D.
Chair, Human Subjects Committee

Date: June 6, 2011

Subject: *Middle school teachers' familiarity with, interest in, conceptual and pedagogical knowledge about, and performance on the Nature of Light*

Protocol Number: 11245

The referenced study has been reviewed and approved by the SIUC Human Subjects Committee.

This approval expires on 6/5/2012, one (1) year from the review date. Regulations make no provision for any grace period extending beyond the above expiration date. Investigators must plan ahead if they anticipate the need to continue their research past this period. The application should be submitted 30 days prior to expiration with sufficient protocol summary and status report details, including number of accrued subjects and whether any withdrew due to complaint or injury. If you should continue your research without an approved extension, you would be in non-compliance of federal regulations. You would risk having your research halted and the loss of any data collected while HSC approval has lapsed. Extensions will not be required to continue work on an approved project when all the data has been collected, there will be no more interaction or intervention with human subjects and **subject identifiers have been removed** (e.g. during the data analysis or report writing stages).

Also note that any future modifications to your protocol must be submitted to the Committee for review and approval prior to their implementation.

Your Form A approval is enclosed. Best wishes for a successful study.

This institution has an Assurance on file with the USDHHS Office of Human Research Protection. The Assurance number is 00005334.

JS:kr

Cc: Kevin Wise

Woody Hall, C-Wing – Mail Code 4709 ■ Southern Illinois University Carbondale
900 South Normal Avenue ■ Carbondale, Illinois 62901 ■ 618 | 453.4533 ■ Fax: 618 | 453.8038

Appendix B
RESEARCH DESCRIPTION

Middle School Teachers' Familiarity with, Interest in, Performance on, Conceptual and Pedagogical Knowledge of the Nature of Light.

DESCRIPTION OF THE RESEARCH

You are invited to participate in a research study investigating middle school teachers' familiarity with, interest in conceptual and pedagogical knowledge about, and performance on the Nature of Light. The purpose of this study is fourfold: to investigate how familiar middle school teachers are with concepts about the nature of light, to find out how interested middle school teachers are in learning about the concepts of light, to investigate and document the conceptual and pedagogical knowledge of middle school teachers about the nature of light, and to determine the performance level of middle school teachers on the concepts about the nature of light. In particular, this study will focus on the nature of light as covered in the standards for K-8.

This study will ask you to provide responses to four instruments: an interest and familiarity measure instrument – duration 20 minutes, a conceptual measure instrument – duration 20 minutes, a light propagation diagnostic instrument – duration 30 minutes and an interview protocol – duration 45 minutes. These instruments will be administered on four separate days during the period of the workshop. The interest and familiarity measure instrument will ask you to indicate to what extent you are interested in receiving information on and how familiar you are with concepts or phenomenon about the nature of light. The conceptual measure instrument will ask you to define or explain the concepts or phenomenon about the nature of light. The light propagation diagnostic instrument is a 24 item multiple choice test. The test will be graded and the results will only be used for research purposes. The interview protocol will be administered to selected students. Selection will be done with the help of the instructor or tutor based on the participation in the three measures. The interview will first ask you to identify and explain the misconceptions held by students in the given scenarios and secondly how you think you can teach your students to address the misconceptions portrayed by the students. The interview will take place in Pulliam 304 at your convenient time and day that you will be asked to arrange with the researcher. Tape recordings and transcripts will be made of these interviews, but your name will not be used in the research. Simeon Mbewe will administer all the instruments named in this study. The collection of data for this study is expected to be concluded by August 30, 2011.

All the written responses and the recorded interviews will be kept confidential within reasonable limits. Only the researcher and his team will have access to the data. In addition, the results will be kept in a secured location that will prevent unauthorized tampering or manipulation. The research data collected will be destroyed after the study is complete.

Appendix C

Recruitment script for subjects

Research Title: Middle School Teachers' Familiarity with, Interest in, Conceptual and Pedagogical Knowledge about, and Performance on the Nature of Light.

My name is Simeon Mbewe, a Doctoral student at Southern Illinois University – Carbondale, in the Department of Curriculum and Instruction and my specialty area is Science Education.

I am inviting you to participate in a research study investigating middle school teachers' familiarity with, interest in, conceptual and pedagogical knowledge about, and performance on the nature of light.

I am asking for your voluntary participation in this study which will have no effect on your course grade. This study has four parts: an interest and familiarity measure instrument – duration 20 minutes, a conceptual measure instrument – duration 20 minutes, a light propagation diagnostic instrument – duration 30 minutes and an interview protocol – duration 45 minutes. These instruments will be administered on four separate days during the period of the workshop. They cover K-8 curriculum related to the topic of light. You will not be required to write your name on any of the instruments, instead you will only be identified by a number that will be inserted on the instrument. The researcher will score and analyze all the responses.

I assure you that all reasonable steps will be taken by the researcher to protect your identity. Only the researcher and the research team will have access to the records, transcripts, and interview notes which will be kept in a locked file in the researchers' office (Room 304, Pulliam Hall). The marked scripts, the original interview recordings and transcripts of the interviews will be destroyed after the study is concluded.

If you have any questions or concerns about this study you can direct them to me (Simeon Mbewe, 618-525-3857, smbewe@siu.edu,) or my instructors (Dr. Frackson Mumba, 618-453-6162 or frackson@siu.edu and Dr. Kevin Wise, 618-453-6161 or kcwise@siu.edu).

Your participation will be greatly valued.

Thank you.

This study has been reviewed and approved by the SIUC Human Subjects Committee. Questions regarding your rights as a participant in this research may be addressed to the Committee Chairperson, Office of Research Development Administration, SIUC, Carbondale, Illinois 62901-4709. The telephone number is 618-453-4533. The email address is siuhsc@siu.edu

Appendix D

CONSENT FORM

Researcher: Simeon Mbewe, Doctoral Student, Southern Illinois University – Carbondale

Research Title: Middle School Teachers' Familiarity with, Interest in, Conceptual and Pedagogical Knowledge about, and Performance on the Nature of Light.

I (participant), agree to participate in this research project conducted by Simeon Mbewe, Doctoral Student, Department of Curriculum and Instruction.

I understand the purpose of this study is to investigate middle school teachers' familiarity with, interest in, conceptual and pedagogical knowledge about, and performance on the nature of light.

I understand my participation is strictly voluntary and that I may refuse to participate at any time. I understand that there are four parts in this study: an interest and familiarity measure instrument – duration 20 minutes, a conceptual measure instrument – duration 20 minutes, a light propagation diagnostic instrument – duration 30 minutes and an interview protocol – duration 45 minutes. These instruments will be administered on four separate days during the period of the workshop.

I understand that my responses to these instruments will be scored and analyzed, but that no identifying information will be included on the instruments.

I also understand I may be selected to participate in the interview. If I consent to participate in the interview, I will provide contact information so the researcher can schedule the interview. I also understand that I can choose to complete the instruments without participating in the interview.

If I choose to participate in the interview, I understand that the interview will take approximately 45 minutes. I understand that the interview will be audio-recorded, transcribed and that all identifying information will be removed. I understand that the original tapes will be destroyed after the study is concluded. I understand that only the researcher and research team will have access to the records, transcripts, and interview notes which will be kept in a locked file in the researchers' office (Room 304, Pulliam Hall).

I understand that the researcher will take all reasonable steps to protect my identity.

I understand questions or concerns about this study are to be directed to Simeon Mbewe, 618-525-3857, smbewe@siu.edu, or his instructors Dr. Frackson Mumba, 618-453-6162 or frackson@siu.edu and Dr. Kevin Wise, 618-453-6161 or kcwise@siu.edu.

I have read the information above and any questions I asked have been answered to my satisfaction. I understand a copy of this form will be made available to me for the relevant information and phone numbers.

I agree_______ I disagree ______to complete **the interest and familiarity measure.**

I agree_______ I disagree______ to complete **the conceptual measure.**

I agree_______ I disagree ______ to complete **the light propagation diagnostic instrument.**

I agree __________ I disagree__________ to be **interviewed.**

I agree __________ I disagree__________ to have my interview responses **recorded** on audio tape

I agree __________ I disagree__________ that Simeon Mbewe may **quote me** in his paper

If you consent to be interviewed, please share your email address and/or phone number so the interview can be scheduled at your convenient time:

Email: ____________________________________ Phone: ________________________

Signature:________________________________ DATE______/_______/_____________

PLEASE PRINT YOUR NAME____

This study has been reviewed and approved by the SIUC Human Subjects Committee. Questions regarding your rights as a participant in this research may be addressed to the Committee Chairperson, Office of Research Development Administration, SIUC, Carbondale, Illinois 62901-4709. The telephone number is 618-453-4533. The email address is siuhsc@siu.edu

Appendix E

FAMILIARITY AND INTEREST QUESTIONNAIRE

STUDENTS' FAMILIARTITY WITH AND INTEREST IN CONCEPTS OR PHENOMENA ON THE NATURE OF LIGHT

This is NOT a test, there is no Right or Wrong answers, and this will in NO WAY affect your grade in your science methods course. You will not be associated with your answers once you have completed the questionnaire. You will only be identified by the number written on the survey instrument.

SECTION 1: Demographic Information

Gender: Male: ☐ Female: ☐

Your subject area of certification: __________ Your teaching subject(s):__________________

Number of science courses you have taken in college/university: ________
Number of science courses you have taken in high school: _______

Circle the science courses you have previously taken in college/university:

Biology Science 210 A Chemistry Science 210 B

Earth Science Science Education Course CI 426 Physics
Science Education Course CI 427

Other(s) ______________________________________

Circle the science courses you are currently taking in college/university:

Biology Science 210 A Chemistry Science 210 B

Earth Science Science Education course CI 426 Physics
Science Education course CI 427

Other(s) _______________________________________

SECTION 2: Familiarity with concepts or phenomena about the nature of light.

We want to know if the following concepts or phenomena are familiar to you. In the table below, please mark if the concept is familiar to you and understandable or not.

Familiarity

Term	Concept or phenomenon is not familiar to me	Concept or phenomenon is familiar to me but not understood	Concept or phenomenon is familiar to me and I understand its meaning
1. Vision (how an eye is able to see objects)			
2. Light travels at a greater speed than an airplane			
3. The reflection of light			
4. The refraction of light			
5. The formation of shadows			
6. The electromagnetic spectrum			
7. Why opaque objects appear in the color they do in white light.			
8. Why opaque objects appear in the color they do in colored lights.			
9. Color filters			
10. Light as a form of energy			
11. Luminous objects			
12. Non-luminous objects			
13. Light as transverse waves			
14. Wavelength of waves			
15. Amplitude of waves			
16. Crest of waves			
17. Trough of waves			

SECTION 3: Interest in concepts or phenomena about the nature of light

We want to know to what extent you are interested in receiving information on the following concepts or phenomena. In the table below, please mark to what extent you are interested in receiving information on the concept or phenomenon.

Interest

Term	Not at all interested in receiving information	Interested in receiving more information	Very interested in receiving more information
1. Vision (how an eye is able to see objects)			
2. Light travels at a greater sped than an airplane			
3. The reflection of light			
4. The refraction of light			
5. The formation of shadows			
6. The electromagnetic spectrum			
7. Why opaque objects appear in the color they do in white light.			
8. Why opaque objects appear in the color they do in colored lights			
9. Color filters			
10. Light as a form of energy			
11. Luminous objects			
12. Non-luminous objects			
13. Light as transverse waves			
14. Wavelength of waves			
15. Amplitude of waves			
16. Crest of waves			
17. Trough of waves			

Thank you

Appendix F

CONCEPTUAL KNOWLEDGE TEST

STUDENTS' KNOWLEDGE ABOUT CONCEPTS OR PHENOMENA ABOUT THE NATURE OF LIGHT

Defining, describing or explaining the concepts or phenomena about the nature of light

To the best of your knowledge, define, describe or explain all the concepts or phenomena in the spaces provided.

Terms	Definition, Description or Explanation
1. Describe how an eye is able to see objects.	
2. Describe how light travels.	
3. What does the term 'reflection of light' mean to you?	
4. What does the term 'refraction of light' mean to you?	
5. Describe how a shadow is formed.	
6. What is an electromagnetic spectrum?	
7. Why do opaque objects appear in the color they do in white light?	
8. Why do opaque objects appear in the color they do in colored lights?	
9. How does a color filter work?	
10. What is your understanding of the idea that light is a form of energy?	
11. What is a luminous object?	
12. What is a non-luminous object?	
13. What is your understanding of the idea that light is a transverse wave?	
14. What does the term 'wavelength' mean to you?	
15. What does the term 'amplitude of light' mean to you?	
16. What does the term 'crest of light' mean to you?	
17. What does the term 'trough of light' mean to you?	

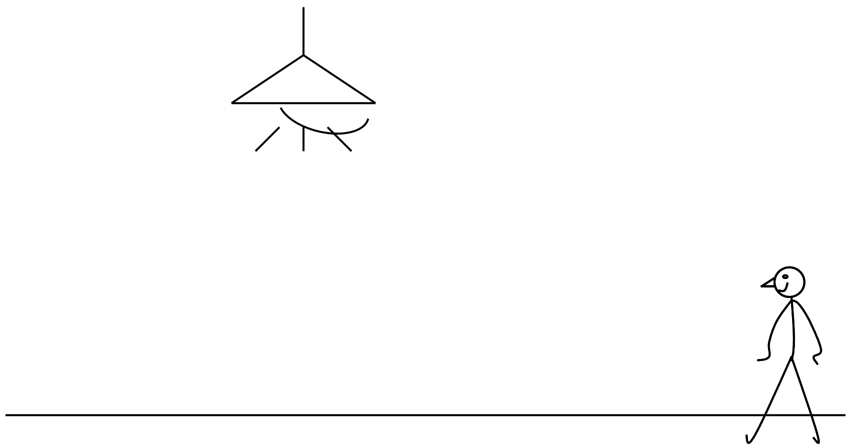
Thank you

Appendix G

MULTIPLE CHOICE TEST ON LIGHT

Two-tier multiple-choice diagnostic instrument on the properties of light

Item 1



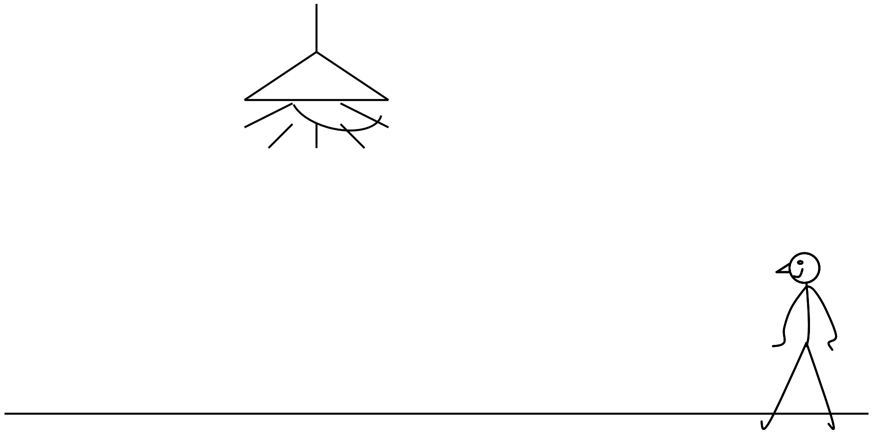
You have the light on during the day. The light from the bulb:

A. stays on the light bulb.
B. comes out about halfway towards you.
C. comes out as far as you are but no further.
D. comes out until it hits something.

The reason I chose my answer is because:

1. Light travels in all directions from the bulb.
2. Light does not travel at all during the day.
3. Light travels further at night than during the day.
4. Light travels about 1000 m during the day.
5. Light rays travel in a preferential way towards an object.

Item 2



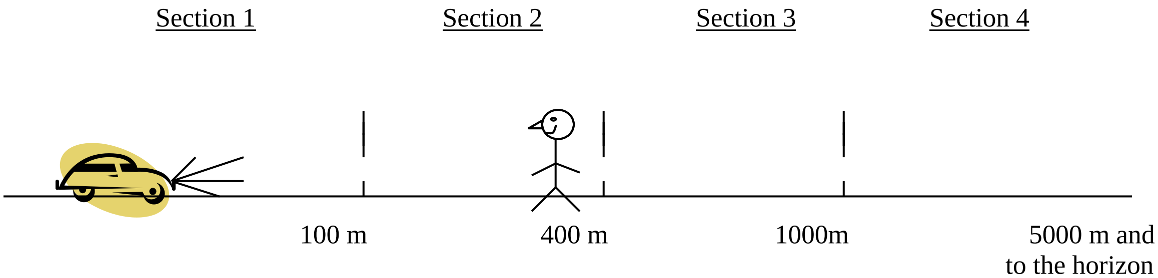
You have the light on during the night. The light from the bulb:

A. stays on the light bulb.
B. comes out about halfway towards you.
C. comes out as far as you are but no further.
D. comes out until it hits something.

The reason I chose my answer is because:

1. Light travels in all directions from the bulb.
2. Light does not travel at all during the night.
3. Light travels further at night than during the day.
4. Light travels about 1000 m at night.
5. Light rays travel in a preferential way towards an object.

Item 3



On a clear dark night a car is parked on a straight flat road. Its headlights are shining straight down the road. In which section of the road is there light?

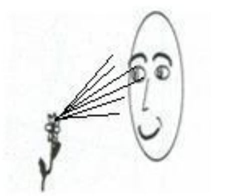
A. Section 1 only
B. Sections 1 and 2 only
C. Sections 1, 2 and 3 only
D. Sections 1, 2, 3 and 4

The reason I chose my answer is because:

1. Light travels an infinite distance.
2. The light is stopped by the man.
3. Light travels only about 1000 m.
4. Light fills up space.

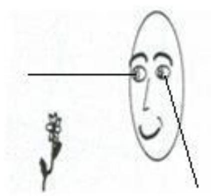
Item 4

Outside on a clear sunny day a boy sees a flower. How does he see the flower?

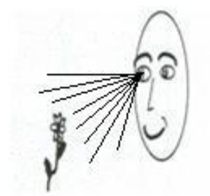


Also for both eyes and for more than one object point

A

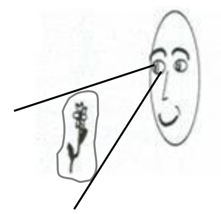


B



Also for both eyes

C



Also for both eyes

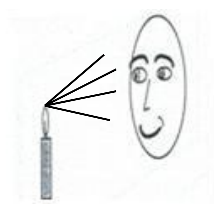
D

The reason I chose my answer is because:

1. There are bundles of rays from the object, and so the boy can see.
2. Bundles of rays are coming out from the boy’s eyes and so he is able to see the flower.
3. Light is not shown emanating from the light source, but is only present around the flower.
4. Light is shown emanating from the object and being received by the eye.
5. The object is located within the region of the boy’s vision.

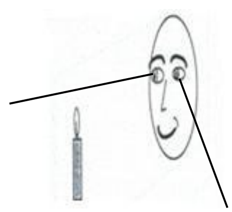
Item 5

The diagram shows a boy seeing the flame of a lit candle. Which of the following diagrams indicates how the boy is able to see the flame?

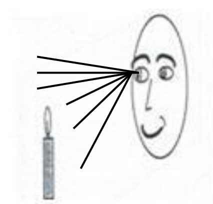


Also for both eyes and for more than one object point

A

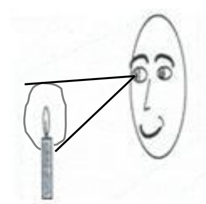


B



Also for both eyes

C



Also for both eyes

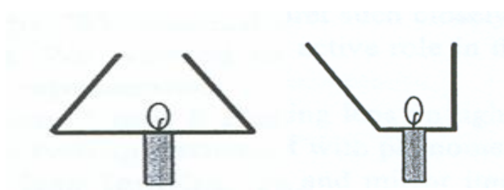
D

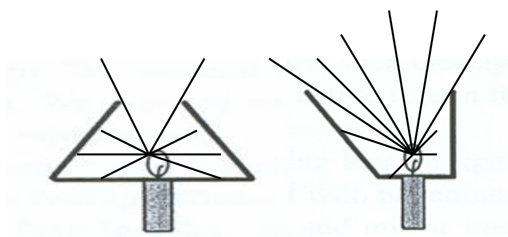
The reason I chose my answer is because:

1. There are bundles of rays from the object, and so the boy can see.
2. Bundles of rays are coming out from the boy's eyes and so he is able to see the candle flame.
3. Light is not shown emanating from the light source, but is only present around the candle flame.
4. Light is shown emanating from the object and being received by the eye.
5. The object is located within the region of the boy's vision.

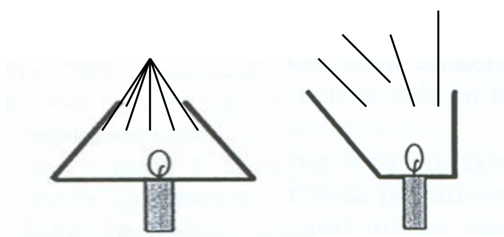
Item 6

Describe the light distribution by the candle in the two lamps below in which the candle is surrounded by an opaque lamp shade.

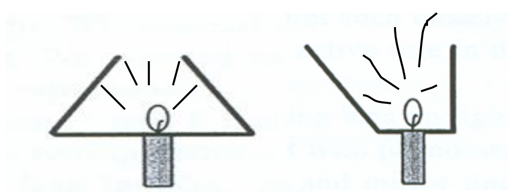




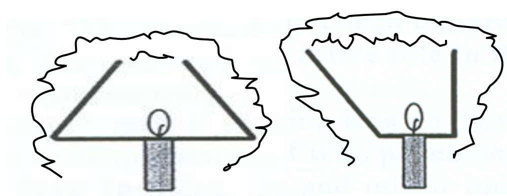
A



B



C



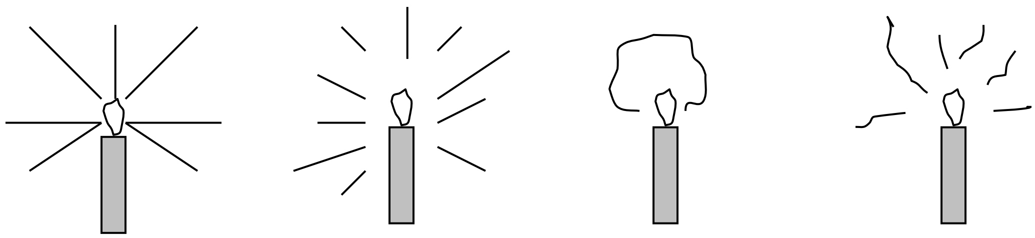
D

The reason I chose my answer is because:

1. Light is spreading from the light source.
2. Light is emanating from or around the light source in lines parallel to the barriers.
3. Light is distributed inside the barrier.
4. Light fills up space and goes around the outside of the barrier.

Item 7

Which of the diagrams below correctly shows the light distributed by the candle?

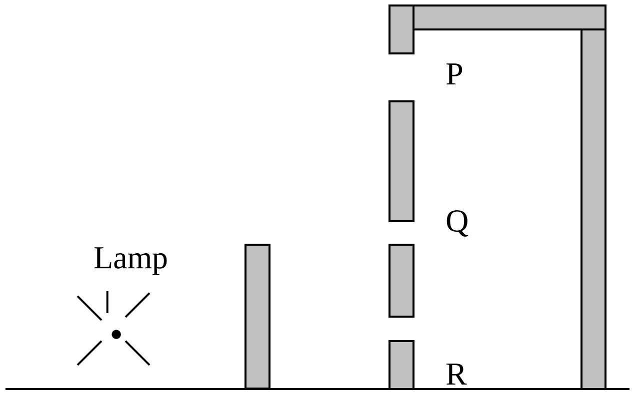


A B C D

The reason I chose my answer is because:

1. Light is spreading from the light source.
2. Light from the candle stays around the flame.
3. Light fills up space around the candle.
4. Light from the candle is not bright enough to be seen.

Item 8



P, Q and R represent windows

The diagram shows a lamp and a room with windows P, Q and R.
From which window can one see the lamp?

A. Window P B. Window Q C. Window R D. None E. All (P, Q and R)

The reason I chose my answer is because:

1. Light from the lamp would reach all points above the height of the obstructing wall.
2. Light would reach all windows by scattering or diffusion.
3. Light travels in straight lines in all directions from the lamp.
4. Light fills up the space in front of the wall.
5. Light is deflected around the wall forming a wide beam of light.

Item 9

Which windows are illuminated by the light of the lamp in the figure above?
A. Window P B. Window Q C. Window R D. None E. All (P, Q and R)

The reason I chose my answer is because:

1. Light from the lamp would reach all points above the height of the obstructing wall.
2. Light would reach all windows by scattering or diffusion.
3. Light travels in straight lines in all directions from the lamp.
4. Light fills up the space in front of the wall.
5. Light is deflected around the wall forming a wide beam of light.

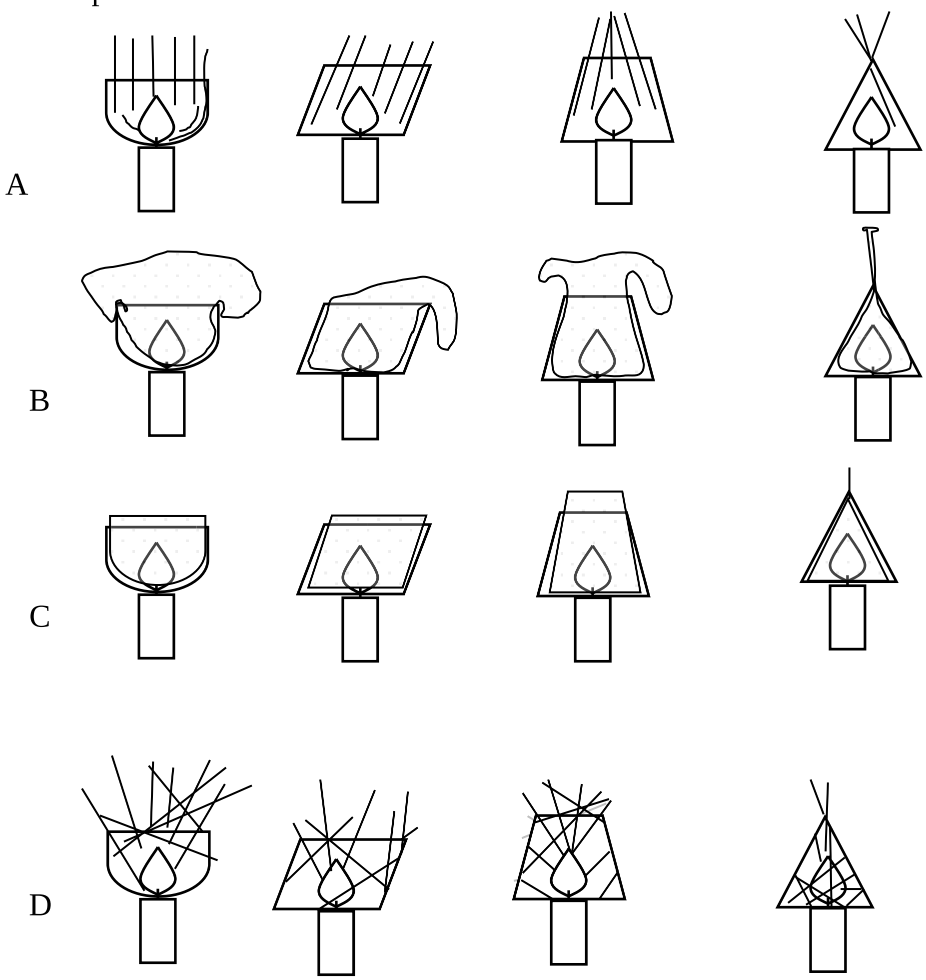
Item 10

A family intended to buy a new lamp for their living room. They see four lamps with opaque shades in an electrical store.

The father wants to know whether the lamps would be bright enough to light up a section of their living room.

In order to help him decide, each member of the family draws a row of pictures shown below to indicate how light come out of the lamps.

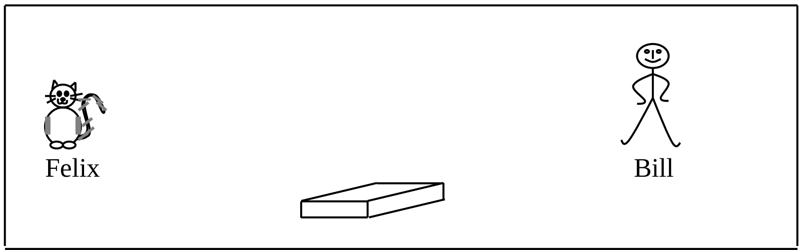
Which one of the rows represents the scientific view about how light is emitted through the top of the lampshades?



The reason I chose my answer is because:

1. Light fills up the space like a fluid or a gas would do.
2. Light is formed by the matter surrounding the source.
3. Light tries to avoid contact with matter.
4. Light is transmitted in all directions and is reflected when it hits matter.
5. Light is seen as rays that indicate the direction of light.

Item 11

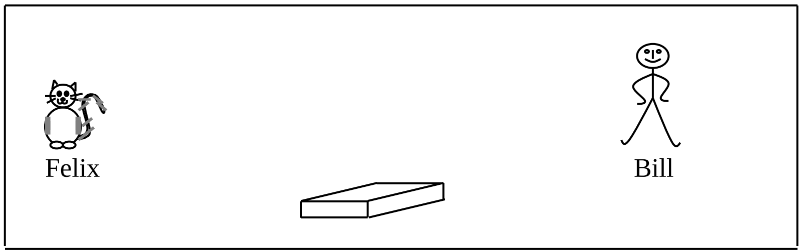


Felix the cat and Bill are in a completely dark room. There is no light in the room.
Felix the cat would:

A. not be able to see at all.
B. just be able to see the box.
C. see the box quite clearly.

The reason I chose my answer is because:
1. Light has to be reflected from the book to the cat's eyes.
2. Cats can see in the dark.
3. The cat is able to see objects by looking at them.
4. The cat will be able to see in the dark after adjusting its eyes to the darkness.

Item 12



This item is just like item 11. The room is still completely dark.
Bill would:
A. not be able to see the box at all.
B. just be able to see the box.
C. see the box quite clearly.

The reason I chose my answer is because:
1. We need light to be reflected to our eyes to be able to see in the dark.
2. People can just see in the dark.
3. We see by looking at objects.
4. We are able to see in the dark after our eyes have adjusted to the darkness.

Item 13

In a room perfectly sealed to external light there are some flowers in a vase. When a candle is lit in the room, one can see that the vase is white and that there is a red flower, a yellow flower, a purple flower, a pink flower and some green leaves. What will we see after the candle is extinguished?

A. We can see all the original colours of the objects.
B. We can only see the shape of the objects without any colours.
C. We cannot see anything.
D We can see only the white vase.

The reason I chose my answer is because:

1. Light must be present for objects to be visible.
2. We are able to see colours in the dark after our eyes become adjusted to the darkness.
3. We can see shapes in the dark when our eyes become adjusted to the darkness.
4. Colour is a property of an object, not that of light itself.
5 Bright colours are visible in the dark.

Item 14

SUE

When Sue looks in the mirror she cannot see all of herself. She can only see her head and shoulders. To see more of herself, she should:

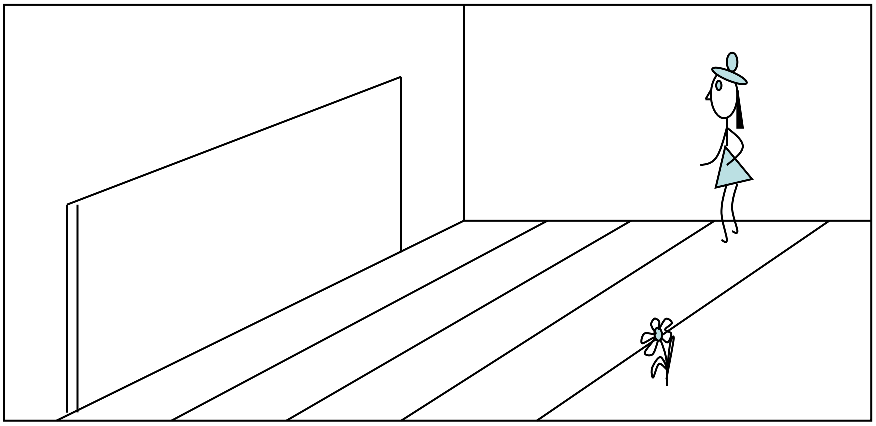
A. move the mirror forward, towards her.
B. move the mirror backwards, away from her.
C. tilt the mirror.
D any of the above would do.

The reason I chose my answer is because:

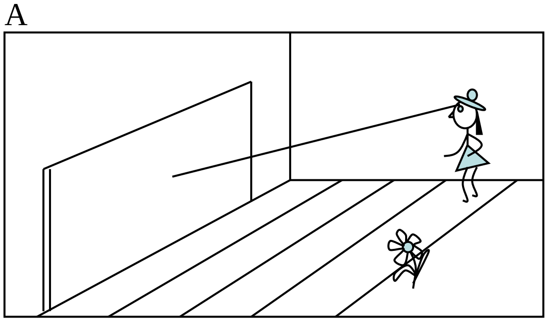
1. Light from more parts of her body is reflected from the surface of the mirror.
2. Her body will become small enough to fit the mirror.
3. Light will travel further and spread out.
4. The mirror will be able to include more of her when the mirror is moved away from her.
5 The mirror will be able to see less of her when the mirror is moved toward her.

Item 15

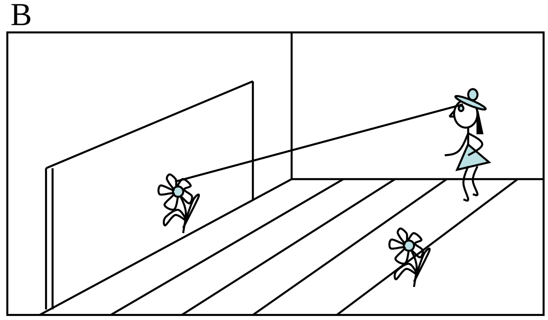
A girl is standing to one side away from a flower and is looking in the mirror. The girl says she can see the flower. Which of the diagrams below shows how she is able to see the flower?



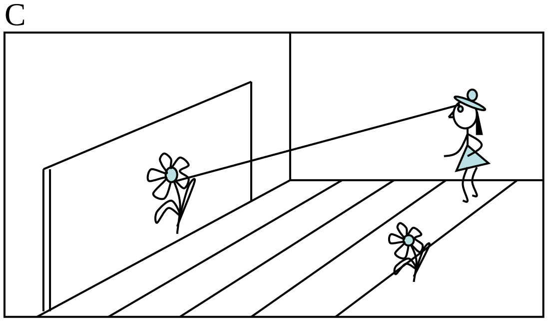
A



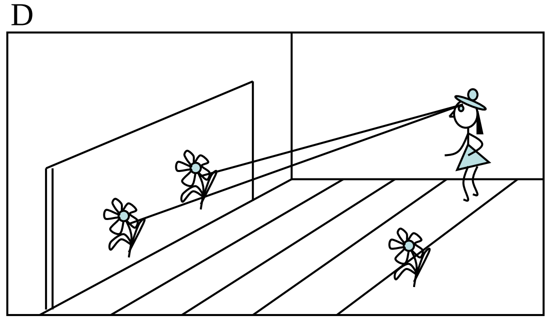
B



C



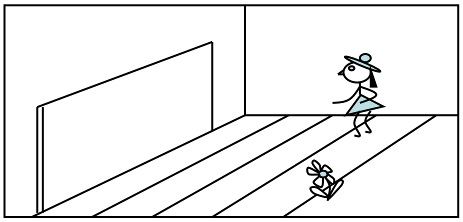
D



The reason I chose my answer is because:

1. The mirror reflects the rays from the flower and so the image of the flower is on the mirror.
2. The mirror reflects the rays from the flower in all directions and so the image of the flower can be in two places at once.
3. The image is located behind the mirror in the extended lines of reflected rays from the mirror to the eyes.
4. The mirror reflects the rays from the flower and so there is no image on the mirror.

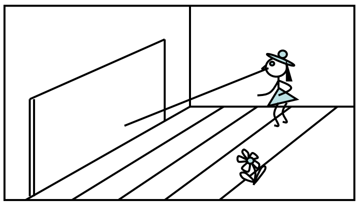
Item 16



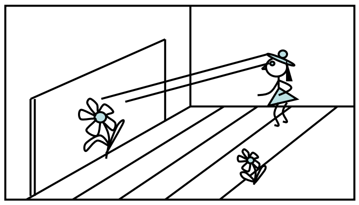
Sue asserts that she can see a flower in the mirror in the picture above although she is not in front of the mirror. Her brother and two friends discuss Sue's statement. They each draw a picture to help support their explanations. You can see their pictures A, B and C below.

Which picture do you think best explains how Sue is able to see the image of the flower?

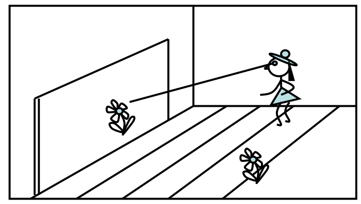
A



B

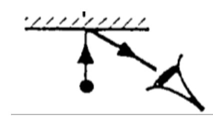


C

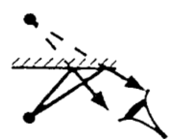


What could be the scientific reason for seeing the flower in the mirror? Consider the diagrams next to each explanation as well. Both should support your argument.

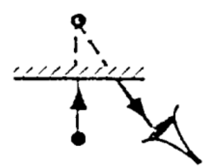
1. Sue sees the flower because the ray is thrown back by the mirror into her eye. So she sees not an image but the reflected flower itself.



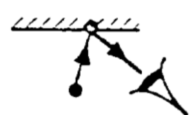
2. Sue sees an enlarged image of the flower because every point of the flower is reflected several times. Since she stands nearer to the mirror than the flower is she sees the image larger than the flower.



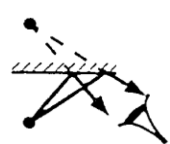
3. Sue sees the image of the flower because her eye is in the straight line of sight to the image in the mirror. The image belongs to a virtual reality behind the mirror.



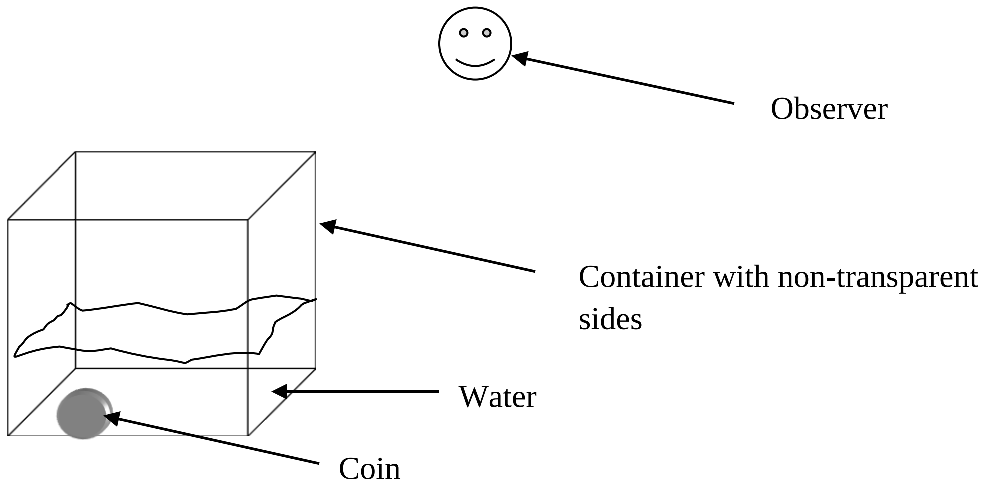
4. Sue sees the image of the flower that lies on the mirror's surface. This image is caused by light rays coming from the flower taking the properties of the flower to the mirror.



5. Sue can see a picture of the flower because bundles of rays are reflected by the mirror but seem to come from the point of intersection of the rays behind the mirror's surface.



Item 17



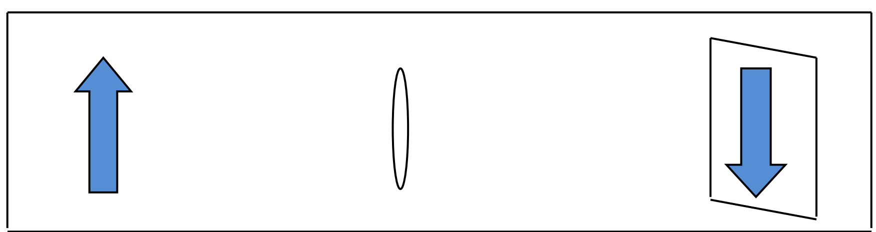
A coin is fixed in position at the bottom of a container with non-transparent sides using some glue. The observer's position does not allow him to see the coin in the container. Water is then poured a little at a time into the container with the observer still in the same position. Suddenly the coin becomes visible to the observer. What has happened?

A. The image of the coin is brought to the surface of the water. Then the observer can see it.
B. The surface of the water reflects the light from the coin like a mirror. Thus, the observer sees the mirror image of the coin.
C. Refraction occurs at the surface of the water so the light is directed to the eyes of the observer.
D. The coin has moved because the water lifts the coin. In a higher position the observer can see the coin.
E. The water makes the coin look bigger. Thus it becomes big enough to get into the sight of the observer.
F. The coin becomes much brighter because of the water. So, the observer can see the glint of the coin.
G. The water improves the contrast between the coin and the container. So, the observer can see it more easily.
H. Light can go into water but it cannot leave the water because water is too thick. So the sight of the coin was captured and it becomes visible.
I. Light is split into different colours under water like in a prism. This is why the observer can now see the colours of the coin.

The reason I chose my answer is because:

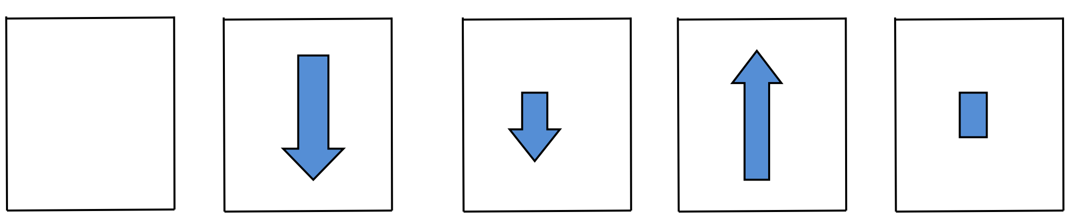
1. The propagation of light is different in air and water. Since the light always chooses the way which takes the shortest time, there will be refraction each time when the ray of light goes from air to water or vice versa..
2. The light that returns from an object forms many images everywhere in the room. If one of the pictures is in a straight line of sight to the observer, he will be able to see this picture.
3. Light can only travel a certain distance. To be able to see an object, it has to be close enough.
4. Sometimes our sight is not strong enough to pierce the air around us (e.g. in the night). The water helps the observer like a lens to strengthen his sight.

Item 18



When an arrow acting as an object is placed before the lens, an image that is upside down appears on the screen. If the lens is removed so that it is no longer between the object and the screen, what would you see on the screen?

A B C D E

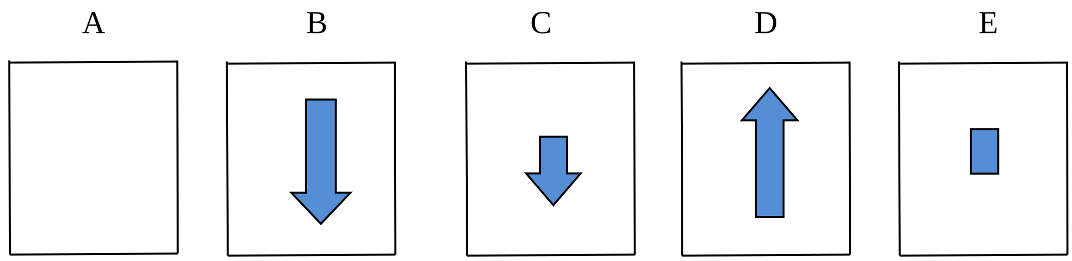


The reason I chose my answer is because:

1. A lens is necessary for the formation of an image.
2. There is something in the way to form the image.
3. The lens only allows light from the object to pass through.
4. Light from the object will carry the shape of the object to the screen.
5. Only some light from the object reaches the screen.

Item 19

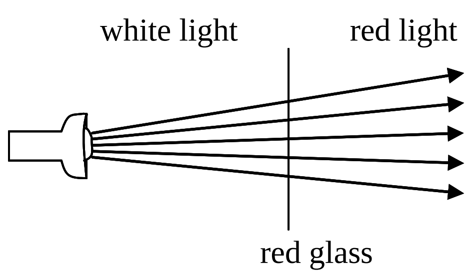
In Item 18, an image appears on the screen. When the top half of the lens is then covered, what would you see on the screen?



The reason I chose my answer is because:

1. Light travels in all directions from all points of the object and strikes every point of the lens.
2. A whole lens is necessary to form an image.
3. Only light from the lower half of the object can pass through the lens.
4. Light from the top of the object is blocked by the card, while light from the lower part of the object passes through the lens.

Item 20



When you shine white light through a piece of red glass, the light looks red on the other side. What does the red glass do to the light?

A. The glass adds red colour to the light.
B. The glass lets all the light through, but it stops all the colours except red.
C. The glass lets red light through, but it stops all the other kinds of light.
D. The glass turns the white light into red light.

The reason I chose my answer is because:

1. The red glass absorbs all the components of white light, except red light.
2. The white light is changed in some way by the red glass.
3. Light passing through the glass is painted red by the glass.
4. The red colour is purely a property of the red glass, not that of light itself.

Item 21

21 A rose that looks red in white light, is placed in yellow sodium light. What colour would it appear?

A. Yellow B. Red C. Orange D. Black E. Blue

The reason I chose my answer is because:

1. The rose has a different colour because it reflects a mixture of colours.
2. No light emerges from the rose when yellow light falls on it.
3. The colour is purely a property of an object, not that of colour of light.
4. The yellow light from sodium light is present around the rose.

Item 22

When we see a blue book:

A. the light helps our eyes to see the blue colour of the book.
B. the book absorbs blue light and reflects the other colours.
C. the book reflects blue light and absorbs other colours.
D. white light is reflected off the surface of the book.

The reason I chose my answer is because:

1. The colour of an object depends on the rays that are reflected from the object to our eyes.
2. The light reflects the blue colour of the book.
3. Our eyes see the blue colour of the book.

Item 23

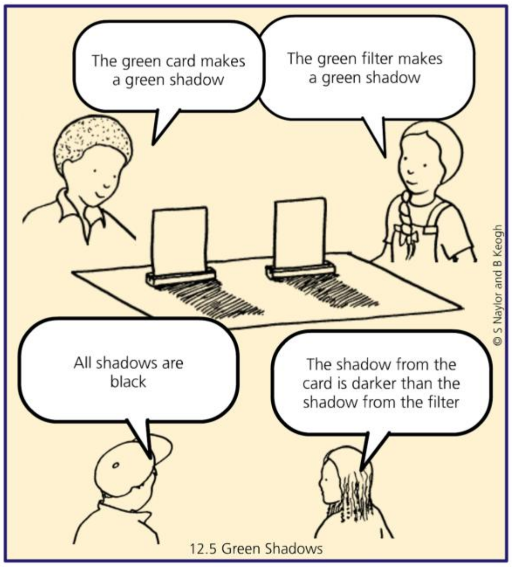
Light from a flashlight falls on a red filter. What colour of light will emerge from the other side of the filter?

A. White B. Red C. Pink D. Blue

The reason I chose my answer is because:

1. White light passing through the filter is ‘painted’ by the filter.
2. White light is absorbed from the filter.
3. White and red colours are mixed and then emitted.
4. Only red light passes through the filter.
5. The red filter absorbs red light from the white light.

Item 24



What do YOU think?

A. The green card makes a green shadow.
B. The green filter makes a green shadow.
C. All shadows are black.
D. The shadow from the card is darker than the shadow of the filter.

The reason I chose my answer is because:

1. A shadow is the absence of light. Where there is no light, there is no colour.
2. A filter allows only light of its own colour to pass through.
3. A card blocks all the light, a filter allows some light to pass through.
4. The rays of the shadow have the same colour as the object which causes the shadow.
5. The card blocks all light except its own colour.
6. Light cannot go through any matter.

Hye-Eun Chu
Alexander Kauertz
A.L. Chandrasegaran
Science and Mathematics Education Centre, Curtin University of Technology, Perth, Australia
May 2006

Appendix H

MISCONCEPTIONS IDENTIFICATION QUESTIONNAIRE

INTERVIEW PROTOCOL

1. Thinking back to your science classes, have you studied the nature of light before? If so:
   a. When? In which class?
   b. What was your experience in the learning about light?
2. Could you briefly describe what light is?
3. Describe and discuss the basic properties of light you expect your students to learn in your class.
4. I want to walk you through some possible scenarios that might happen to you as a science teacher. In each case, a student expresses a misconception about light. For each scenario, I'll first ask you to:

   Describe the currently accepted scientific explanation of the phenomenon that the students do not understand. Explain the science in as much depth as possible, even if you wouldn't expect 3-8 grade students to know that content. As much as possible, please explain the underlying science that shows why the students' explanation is incorrect.

   I'll then ask you how you would address this misconception using best instructional practices. Please describe the classroom instruction, including what the students and teacher are doing, in enough detail so that the listener can envision what is happening. For example, if you refer to a specific lesson, textbook, activity, piece of equipment, or media, assume the listener is not familiar with it and explain how it is used to support student learning. Assume you have access to any equipment that would be available in a reasonably well-funded K-12 school setting so that your proposed instruction is feasible to implement.

   Are those two questions clear? If so, I'll describe the first misconception:

1. In replying to a question about how an eye is able to see an object, your student mentions that the eye emits light in order for people or animals to see an object. In addition, other students in class agree and provide evidence that we use phrases such as 'her eyes shine', 'his face radiates light', 'she casts a glance'
    a. Describe the <u>currently accepted scientific explanation of the phenomenon</u> that the students do not understand.
    b. Explain how you would address this misconception using <u>best instructional practices</u>.

2. In replying to a question on what travels faster between light and an airplane, your student says that it is an airplane.
    a. Describe the <u>currently accepted scientific explanation of the phenomenon</u> that the students do not understand.
    b. Explain how you would address this misconception using <u>best instructional practices</u>.

3. During an experiment with mirrors, one of your students concludes that when light hits the surface of a smooth, flat object like a mirror, light is reflected in all directions.
    a. Describe the <u>currently accepted scientific explanation of the phenomenon</u> that the students do not understand.
    b. Explain how you would address this misconception using <u>best instructional practices</u>.

4. During an activity with a hand lens, one of your students explains that an object (e.g. a butterfly) looks bigger when viewed through the lens because a lens scatters light.
    a. Describe the <u>currently accepted scientific explanation of the phenomenon</u> that the students do not understand.
    b. Explain how you would address this misconception using <u>best instructional practices</u>.

5. During an activity on the formation of shadows, in response to a question about what a shadow is, your student explains that a shadow is a reflection of an object because an object such as a tree casts its shadow.
    a. Describe the <u>currently accepted scientific explanation of the phenomenon</u> that the students do not understand.
    b. Explain how you would address this misconception using <u>best instructional practices</u>.

6. In reply to a question on why an opaque object appears the color it does, a student explains that the ability of an opaque body to reflect one color of light and absorb others is called reflection.
   a. Describe the currently accepted scientific explanation of the phenomenon that the students do not understand.
   b. Explain how you would address this misconception using best instructional practices.

7. In reply to a question why a transparent material appears the color it does, a student explains that the ability of a transparent material to transmit one color of light and absorb others is called transmission.
   a. Describe the currently accepted scientific explanation of the phenomenon that the students do not understand.
   b. Explain how you would address this misconception using best instructional practices.

8. In response to a question asking students to write about what they know about light, a large number of your students repeatedly mention that light is not a form of energy, and that it is just something that is present in order to aid us see objects.
   a. Describe the currently accepted scientific explanation of the phenomenon that the students do not understand.
   b. Explain how you would address this misconception using best instructional practices.

9. In response to a question about listing examples of luminous and illuminated bodies, students working in groups comment as follows: Examples of luminous bodies are desks, chairs and tables, and examples of illuminated bodies are the sun, stars and various artificial light sources.
   a. Describe the currently accepted scientific explanation of the phenomenon that the students do not understand.
   b. Explain how you would address this misconception using best instructional practices.

Appendix I

PERMISSION TO USE THE 24-ITEM MULTIPLE CHOICE TEST ON LIGHT

Z Hye Eun (NSSE) <hyeeun.z@nie.edu.sg> **Fri, May 20, 2011 at 3:17 AM**
To: Simeon Mbewe <smbewe@siu.edu>

Hi Simeon I am attaching the 8items that I have used for the papers.

I am also attaching other questions that I have developed at Curtin University of Technology.
Except the 8items that I have used for the papers, items were not validated.
Please refer our names and my article when you use the items.
Your topic sounds very interesting.
Good luck for your research.
Maybe I can see you next year at NARST if you are attending.
Regards,
Hye-Eun

Hye-Eun Chu, Ed.D. | Assistant Professor | Natural Sciences & Science Education | National Institute of Education
NIE7-03-65, 1 Nanyang Walk, Singapore 637616
Tel: (65) 6790-3853 GMT+8h | Fax: (65) 6896-9414 | Email: hyeeun.z@nie.edu.sg |
Web: http://www.nsse.nie.edu.sg/faculty/hyeeun.htm

An Institute of Nanyang Technological University

From: Simeon Mbewe [mailto:smbewe@siu.edu]
Sent: Tuesday, 17 May, 2011 4:59 AM

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National Institute of Education (Singapore) http://www.nie.edu.sg

2 attachments

LPDI_24items.doc
2485K

English_KoreanQ_Original_LightDI_8items.doc
112K

Appendix J

OPEN ENDED QUESTIONNAIRE DATA SETS

Data set 1

Tchr. No.	**Question and Responses** **Thinking back to your science classes, have you studied the nature of light before?** **If so: a. When? In which class?** **b. What was your experience in the learning about light?**	Analysis	Theme
1.	Studied speed of light, shadows in grade school.		
2.	Elementary school experiences. Later on reviewing subjects I was assigned to teach myself.		
3.	I'm sure I did but I don't remember.		
4.	I do not remember studying light at all.		
5.	Cannot remember.		
6.	While taking my masters classes we briefly talked about light.		
7.	I must have studied light as a kid, but I don't really remember learning it well until I taught it as a teacher.		
8.	I really do not remembering studying light.		
9.	I don't think that I have ever study light unless it was in middle school.		
10.	Junior High School Read about it in the textbook.		
11.	It has been a long time ago. I don't remember very much about it.		
12.	Study light in 5th grade During my time as a student I remember reading and doing an assessment. No experiments		

13.	High School Biology We did an experiment with some light bulbs but do not really remember he experiment.		
14.	In classes I have taken it has been to long ago for me to remember. I am not sure what I studied about light in classes I took.		
15.	I am sure we did, but I don't remember in what class or when.		
16.	I don't recall.		
17.	In high school in earth science and grade school in general science. We read about it in the textbook.		
18.	In second semester physics lab in college. Probably sometime in high school but don't remember.		
19.	I remember covering light....but not into great detail.		
20.	No		
21.	I’m sure I did I'm just not sure when. I do teach 4th grade and it is in our Science book that we cover.		
22.	Yes, but I don't know which classes because it was way back in elementary.		
23.	No		
24.	No! None		
25.	A) Very little. Middle School B) Do not remember anything. It was boring.		
26.	No		
27.	A: Yes. I have studied it in physics class during my college courses, but I also teach a small unit over light in my classes. B: I enjoyed learning about light and its properties. It helped me to further understand and explain observations of the world around me.		
28.	Not that I can remember other than a small amount during this workshop.		

29.	a. I know I have but I can't remember when. It was probably sometime in high school. B. I always find it interesting, but apparently have never really learned exactly how it works.		
30.	Maybe in high school, I do not remember		
31.	Yes I have studied it in general science. I found it very interesting.		
32.	I am sure that I have but I don't' remember which ones and obviously if I don't remember it wasn't very interesting to me.		
33.	I do not recall. Probably very little.		
34.	We studied about the electromagnet spectrum.		
35.	I taught the electromagnetic spectrum last year for an action research lesson.		
36.	Physical Science Jr. High School		
37.	Probably not since High School		
38.	a. never b. I supported a student in general science at the 9th gr. level and gained a minimal amount of knowledge re: light.		
39.	Physics in high school not good		
40.	no.		

Data set 2

Tchr. No.	Question and responses		
	Could you briefly describe what light is?		
1.	what allows us to see		
2.	Light is a source of energy that comes from either natural sources such as the sun, fire, heat, etc. or generated from man-made power and produced using technology that produces and contains heat that is illuminating.		
3.	light allows you to see		
4.	Light is travels in wavelengths.		
5.	light is a group of reflected rays		
6.	It travels in waves.		
7.	Natural light is from the sun here on Earth, but it is also produced by stars. Light is also produced from things like fires and electricity. I know it travels in waves.		
8.	A source of energy that illuminates objects.		
9.	Energy		
10.	Rays that brighten whatever is around the light source.		
11.	Light is the emission of light through a spectrum.		
12.	Light is distributed by waves and when it hits an object it takes on color.		
13.	Light is energy given off from a luminated object.		
14.	A form of energy that moves in waves and it can affect properties		
15.	??????		
16.	I don't know an exact definition.		
17.	no		
18.	Particles traveling in a straight line at a very high speed.		
19.	Light is filtered color shown from bulbs..sun..moon..candles		
20.	The reflection of waves that help the eye identify objects.		
21.	Light is the reflection of energy which illuminates things.		
22.	Photons of energy that travels in waves.		

23.	a source of brightness that illuminates an area		
24.	No.		
25.	Light is a collaboration of the all colors of the spectrum.		
26.	Light is when the colors of a prism hit an object and some colors are absorbed and some are reflected.		
27.	Light is an electromagnetic wave emitted from illuminated objects. It may be reflected or absorbed in the environment.		
28.	illuminating energy		
29.	It is a reflection off an object.		
30.	particle-wave duality some refer to it as matter most refer to it as energy in the form a wave that travels through space light has the ability to cause a force (energy) light has the ability to do work in the form of a photon (like in photosynthesis)		
31.	Light is a form of energy from a source such as the sun. We can see a small range of the electromagnetic spectrum with our eyes. This range is called the visual spectrum.		
32.	The reflection of rays from one object to another.		
33.	Light is....		
34.	Light is a form of energy that travels in waves and does not require a medium. Visible light consists of red, orange, yellow, green, indigo, and violet. Infrared and ultraviolet are invisible forms of light.		
35.	it is electromagnetic waves detected by the human eye		
36.	it is the way all colors are together in a spectrum		
37.	Light is the reflection of energy		
38.	Light is a form of energy,		
39.	reflection of a bright object		
40.	light is the reflection of energy into rays.		

Data set 3

Tchr. No.	Interview Question **Describe and discuss the basic properties of light you expect your students to learn in your class.**		
1.	reflection, refraction, shadows		
2.	I expect my students to know that natural light comes from the stars and the sun or heat sources. I expect them to understand that light travels all around us and is "white" or invisible, but when refracted light contains the entire visible spectrum. I expect my students to understand that color is a product of light being absorbed or reflected by objects. They should understand and apply the concepts of transparency, translucency, and opaqueness. I also expect my students to understand the general concept that we can create heat energy and harness it to be used in light bulbs.		
3.	That it travels in a straight line and must reflect off of objects so we can see.		
4.	We do not study light.		
5.	Currently I only teach health related subjects.		
6.	Radiant energy and how one aspect of it is visible light. This travels in waves. We also talk about transparent, translucent, and opaque objects.		
7.	That light travels in straight lines in waves. We cannot see without light.		
8.	In kindergarten we do not teach about light.		
9.	We study different kinds of energy, which is where we look at light.		
10.	?		
11.	Reflection and refraction. The visible spectrum.		
12.	That light is a wavelength.		
13.	What is light and how does it work?		
14.	We discuss what light energy is, sources of light, and shadows. Also we talk about how light and matter interacts.		
15.	Reflection and Refraction		
16.	We don't teach specifically about light in Kindergarten.		
17.	I don't expect my students to learn about light in my class as I teach music.		

18.	We will use the speed of light for certain formulas so a basic discussion of that will be necessary. Basic properties of light, such as lines, rays, shadows, and reflection. This will be as time allows however.		
19.	What is light? How does the brain process light?		
20.	The reflection of light off objects. The different wave lengths for each color.		
21.	Light travels in a straight path. It shines out in all directions.		
22.	Light is necessary for vision.		
23.	basic light absorption and reflection		
24.	Light travels in waves and is reflected and refracted		
25.	Light can pass through certain objects and is absorbed by others.		
26.	Light is a spectrum of colors. We see a certain color when light hits an object and all of the colors of the spectrum are absorbed except for the color we see.		
27.	I expect my students to understand that light is a electromagnetic wave. It may travel through a vacuum or a fluid as rays. It travels out from a source in all directions, When it strikes an object, it may be reflected or absorbed.		
28.	We don't discuss light much. We do discuss the fact that you need light to see & that your pupils dilate in the dark to let more light in. We also discuss day & night & shadows.		
29.	I would want my students to know that light reflects on different colors differently. The lighter the color the more reflectivity that happens. With a darker color there is less light reflectivity because it is absorbed. I would want my students to know how lights travels, however, I need to be more comfortable with that myself. I would definitely need to study more myself before I taught about light.		
30.	can be separated into wavelengths (visible light) a type of energy		
31.	That light is a source of energy and it travels from a source in a straight line. Light travels in different wave lengths but we see all of the colors at once because light travels extremely fast. The visual spectrum is the part of the electromagnetic spectrum that we can see. When we see an object as being a certain color we are really seeing the light that is reflected from the object.		
32.	What is light? How does light travel? What animals can see in the dark?		
33.	Light helps you see things.		
34.	Light travels in waves. It does not require a medium to travel through.		

	It can be reflected, refracted and absorbed. Components of the electromagnetic spectrum.		
35.	How light diffuses into the color spectrum.		
36.	I can't think right now		
37.	Some things absorb light. Some things reflect light. Some things refract light.		
38.	I don't teach science therefore have no expectations. However, I would like my kids to know that light has effects on life forms, is a form of energy.		
39.	.		
40.	Light is energy and it can be transferred through heat. it can reflect and refract and it has every color in the spectrum (ROY G. BIV)		

Data set 4

Tchr. No.	**Interview Question** **In replying to a question about how an eye is able to see an object, your student mentions that the eye emits light in order for people or animals to see an object. In addition, other students in class agree and provide evidence that we use phrases such as 'her eyes shine', 'his face radiates light', 'she casts a glance' -Describe the currently accepted scientific explanation of the phenomenon that the students do not understand.** **-Explain how you would address this misconception using best instructional practices.**		
1.	The eye absorbs through the cornea and the iris and that transmits to the brain what the object is.		
2.	I would probably ask her to cover her eyes with her fingers held very tightly together, but try to round her hands over her eyes to leave a little room to blink without having her eyelashes touch her hands. I would then ask her to keep her eyes tightly covered, open them, and tell me what she sees. She will probably see dark hands with a small bit of light visible near the cracks between her fingers. I would then ask her if the light seems to come from inside her hands near her eyes or from the outside of her hands. I would then ask all students to participate and pose the same question. I would follow up with questions that confirm that in a totally dark room or closet, there is no light inside whatsoever and invite students to brainstorm together other times when they were in a totally dark place and wished their eyes could emit light, but the only light was in cracks if there was any at all!		

3.	I would tell them that the eye is not a light source so that the statement cannot be true. I could show them the page in our Science textbook that talks about light sources. I would explain that light from a light source bouncing off objects is how animals and humans see, that is why when the lights are turned off or it is nighttime, we can't see.		
4.	The student's misconception is that the eye emits light. I am not for sure how to explain it.		
5.	I do not teach physical science.		
6.	I would have my students sit in a room that has no light so that they can see that their eyes do not emit light no one would be able to see at all. We have to have some light in order to be able to see.		
7.	I would first address the phrases by handing out mirrors and having the kids look for reflections of light in their eyes. I would then have them look for light reflecting off of their neighbor’s eyes. I would then turn off the lights and ask them why they think that there is no light shining out of their eyes. I would probably ask them to try really hard. They would soon see that they cannot produce light themselves. I would then turn the lights back on and have them discuss just where the light reflecting in their eyes is coming from. I would have them try using the mirrors to reflect light on the walls in the room. I would then explain that the shine they see in others eyes, works much like them reflecting light from the mirror to places around the room. Personally, I would tell them how mirrors have been used to signal for miles because the light from the sun is very intense and can be seen a long way off when one knows how to direct the mirror to send a signal to someone else. You know, make connections.		
8.	I don't know.		
9.	Considering I do not much about light, I would need to look do some research in order to answer the question.		
10.	?		
11.	I would show a simulation on how an eye sees light.		
12.	I would probably go to the internet and find a brain pop on how the eye is able to see an object. I would explain that the eye does not emit light the light is allowing them to see.		
13.	Light emits energy and goes on until it hits an object. The eye does not emit light and I would tell them to look at a mirror in a pitch black room and see if they can see their eyes in the dark.		

14.	First, I would tell the student that "her eyes shine" "his face radiates light" are just figures of speech and that it does relate to how people actually see. I have a poster that has a diagram of an eye on it. I would pull it out and show them that iris controls how much light enters the eye. That light doesn't come out of the eye - it is going in the eye		
15.	Your eye does not emit light. I would find an internet site that showed examples of what was taking place.		
16.	I don't know.		
17.	Students do not understand that light is refracted or reflected into the eye. Our eye allows light to come in. We would have to do an experiment with a lens to help show that light passes through but doesn't come from the lens itself.		
18.	First I would show an image of an eye, probably from a trusted educational website such as science spot. I would show the parts of the eye and describe how an outside light source is essential to make the eye see the image. We would also talk a little about metaphors, which should be a term with which they are somewhat familiar. Hopefully I could find an online simulation to demonstrate the process, but I have never looked so I am unsure where.		
19.	An object emits light and goes directly to the brain. The brain then sends the message to the eyes and reflects light back to the object to be seen.		
20.	The student thinks that the eye gives off the light instead of the light bouncing off objects. I would give a demonstration of how light comes from a source.		
21.	The eye is emitting light; it has a reflection of light sent to their eye and that image is then processed by the brain. To address this I would probably refer back to my science book and look at diagrams showing the idea. We could also look up some examples on the internet to help illustrate the idea.		
22.	Light is reflected off of objects and caught by the eye. I would take the students in to the dark room and ask them to identify the color of my shirt. This would prove that the light is not be transmitted from the eyes.		
23.	It is not our eyes that emit light, but we see an object when light is reflected from it. I would address it with an activity in a dark room where a light shines only on an object, not toward a person. Students should be able to see the object even if the light is not coming from their eyes.		
24.	I would show them an example of how the eye works. I don't teach this.		

25.	I would use an explore activity and use the learning cycle process to help the students understand the concepts and misconceptions of light. I would pull information from book and internet sites.		
26.	I would explain that the eye may seem to emit light but really it is reflecting light. We could use a lens and a flashlight to demonstrate how an eye reflects light.		
27.	Light is not emitted from our eyes, but bounces (reflects) from an object that it strikes, or is emitted from a illumiated source. Our eyes simply catch the rays and organize them through a lens into a visible image. to address this, I would simply ask the students to observe the objects they see in the room around them. I would then turn off all of the lights and close the blinds to achieve a dark room. I would then ask the students to observe their surroundings. They should not be able to see the objects. If their eyes were emitting the light, they would still be able to clearly see the objects.		
28.	Light does not shine from our eyes. Light is reflected off of a surface into our eyes. Our nerves send it to our brain & our brain interperets what is seen. We could first turn off all of the lights & close out any outside light. If light was emited from out eyes then we would still be able to see. We could also use an ipad app to see the parts of the eye and how they work. There are also simulations that can be found in the internet that could show them what happens.		
29.	I think we see an object because the light reflects and therefore we see the object's reflection. -I would somehow conduct an experiment that proves how the eye doesn't emit light, but instead the eyes takes in the reflection caused by light.		
30.	We see non illuminating objects when light is reflected off them. It is not true that our eyes radiate light. Students believe that we see objects and colors because they are giving off light; instead of they are reflecting light that is present. Use the moon phases as examples. When we see a half moon, it does not mean that the other half of the moon is not there, but that because of the moon-sun-earth position, the half of the moon that is not illuminated by the sun cannot be seen however looking closely, one can see the shadow of the non-illuminated portion.		
31.	The students are misunderstanding the fact that light is emitted from a light source such as the sun. We see objects because of the way our eyes and mind process light. Demonstrate that a source of light is needed in order to see objects. Put the students in a room that is completely void of light. Set an object in front of the student after the light is turned off. They will not be able to see the object until the light is turned on.		

32.	Our eyes are not the objects that emit the light so that we can see. Light is reflected everywhere that we are looking, unless it is completely dark out or you are in a completely dark room. The reflected light illuminates the images that you are seeing through your eyes.		
33.	The eye is able to take in the reflection of light. I am not sure of what the current accepted scientific explanation is.		
34.	The phenomenon is that if you can't see something, it can't hurt you. False. Ultraviolet rays from the sun can't be seen, but exposure to them over time can cause premature aging of the skin and several forms of skin cancer - thus the need for sunscreen.		
35.	The eye does not transmit light but absorbs and reflects it.		
36.	The eyes catch the rays of light thru the lens and puts it on the retina and then takes it to the brain		
37.	The eye reflects light. To address it you could show a mirror and shine a flashlight in it and show how it reflects.		
38.	I don't know.		
39.	reflection of the light on their faces has a shadow		
40.	I would explain how the eye does not emit light but that it is seeing the reflection of light on an object. I would talk about how we cannot see thinks when light is not present. i would do some experiments and turn the light on and off and see how what they see changes. I would research online and try to find some YouTube videos demonstrating reflection and refraction.		

Data set 5

Tchr. No.	**Question and response**		
	In replying to a question on what travels faster between light and an airplane, your student says that it is an airplane. -Describe the currently accepted scientific explanation of the phenomenon that the students do not understand. -Explain how you would address this misconception using best instructional practices.		
1.	Light travels faster than anything we can see. So we can see an airplane moving therefore light travels faster.		
2.	I would challenge the students to discover how fast the fastest airplane travels and how fast the speed of light really is. I would allow computer lab time to do so, or I would provide access to reference materials that might give them this information. We would then compare the speeds.		
3.	It's not correct. Light travels faster. I would find a Brain POP or simulation that explains this.		
4.	Light travels faster.		
5.	I do not teach physical science.		
6.	Light would travel faster. There is light on an airplane.		
7.	I would have the kids make paper airplanes and then divide them into pairs. Each pair would have one person with a paper airplane and the other would have a flashlight. Then I would give them paper and them record which gets to the wall faster, the paper airplane, or the light from the flashlight.		
8.	Light travels faster than anything else but I don't know why.		
9.	Again I would use the computer. Hopefully find a simulation that would explain.		
10.	?		
11.	I would use the internet to research and show how this differs.		
12.	I believe that light travels faster. I would refer to light speed and how fast it is. Then I would go to the internet to help support this for students.		
13.	I would explain that light travels at a speed far higher than an airplane ever will.		

14.	First I would use the internet and pull up on the smart board the actual speed of light. We would read the information. Then, I would find at what speed an airplane travels. After reading and comparing the information, the students would see that the speed of light is much faster than an airplane.		
15.	Light travels at 186,000 miles/sec obviously the plane it not going to travel that fast. I would find an internet site that showed a simulation of light in motion.		
16.	I don't know.		
17.	Light travels faster than an airplane. I don't know how to address this issue.		
18.	I would first discuss the sun and light and heat we receive from it. The students should be able to discuss sunlight traveling faster than an airplane. We could reference our earth science textbook, or our physics textbook chapters regarding the properties of light and properties of motion.		
19.	Light travels faster than speed. I would show the students a video clip or animation to describe the process.		
20.	The student thinks that an airplane, which is a physical object that they can touch, is faster because they can see it easier. I would explain that light is faster than the eye can process, and the airplane is slower because your eye can keep up with it.		
21.	Light travels at a speed of 186,000 miles per hour I think. To explain this I would again refer to the Science book and look for examples and pictures that I could use to show the student. I would also look for examples on the internet to help them understand.		
22.	We have not yet achieved speeds above the speed of light. I would play a video of lightning and ask if they see the lightning first or hear the sound. Once they have identified that the sound is slower than the light, I would ask them which one is faster sound or an airplane. Then I would take them to an airport and ask them where the airplane sounds like it is, the answer shows that the airplane is traveling slower than sound which is slower than light.		
23.	Light travels faster than an airplane. Show students that without the light they would not be able to see the airplane at all. If they didn't see the light first, they wouldn't see the airplane.		

24.	I don't teach this. We have not had this in our classes here. Id talk about the speed of light and the speed of an airplane and investigate their speeds		
25.	Students can see an airplane move they cannot see light therefore it is very difficult for them to comprehend. I would try to gather some learning cycle lessons and hopefully come up with a good experiment that light does travel faster than an airplane.		
26.	I would explain that the speed of light is much faster than an airplane and explain how long it takes for light to travel through space.		
27.	Light travels faster than anything else known on Earth. In order to address this we would talk about the electromagnetic spectrum and how it is organized. I would show them that if a plane were able to travel at speeds higher than visible light, that it would be too strong for us to see (it would be above the range of sight like uv rays, gamma rays, etc). We can obviously see airplanes; therefore they travel slower than the speed of light.		
28.	Light is considered the fastest thing. You can discuss how fast each travel & discuss why you see lightning before you hear thunder & how you can use it to calculate the distance between you and the lightning. I'm sure there are apps& simulations that could also be used.		
29.	Light definitely travels much faster than an airplane. It is faster than we are able to see, therefore, proving it is faster than a plane. -I would show examples of planes flying through the air versus ways in which light is emitted and received. They will see that you cannot see light travel; you simply see the results of it traveling.		
30.	Light travels faster than sound. Light travels in waves and usually in straight paths unless there in interference. Sound travels in concentric waves and decrease in intensity the further one gets from the source. Therefore light travels faster than sound. In a vacuum, both would travel at the same speed however in the atmosphere, light travels faster than sound. Ask students which occur first when observing an approaching airplane see the airplane or hear the airplane. You can also use the lightning and thunder example, although this is one event, we usually see the lightning before hearing the thunder.		

31.	Nothing travels faster than the speed of light. The teacher could show a video clip of the fastest jet fighter going from one edge of the screen to the other. Ask the students if they saw the jet travel from one side to the other. Then turn the light off and ask them if they could see the light travel from one side of the room to the other. The light is so fast it is either off or on.		
32.	Explain to students that light travels so quickly, that you can even show them how quickly by turning on a light switch. The lights are off, and then all of the sudden, they're on. The speed of light. An airplane simply cannot travel at the speed of light.		
33.	Light is the fastest. Not sure.		
34.	I would explain that light travels at a speed of 186,000 miles per second. I would have them blink their eyes and explain that in that time they could have traveled around the world over 7 times during the time of the blink. We could also do exploratory activities with light in a dark room or gym.		
35.	Because light travels on waves and an airplane has to travel through the air it would be slower.		
36.	Light travels faster than any object		
37.	You couldn't see the airplane if the light hadn't traveled there first.		
38.	I don't know.		
39.	show them with a flashlight and have them move around		
40.	I would talk about the speed of light compared to the speed to air travel. I would use stars as an example. I would talk about how the stars we actually see are no longer really 'there', that they are now black holes. This can help me demonstrate that the speed of light and travel.		

Data set 6

Tchr. No.	Question and responses		
	During an experiment with mirrors, one of your students concludes that when light hits the surface of a smooth, flat object like a mirror, light is reflected in all directions. -Describe the currently accepted scientific explanation of the phenomenon that the students do not understand. -Explain how you would address this misconception using best instructional practices.		
1.	Light is not reflected off the mirror it is refracted which means it is bent.		
2.	Light reflected from a mirror is reflected in only one direction. We would turn off the lights and go to the darkest corner of the room and use a flashlight and mirror to prove this point.		
3.	Again I would show them in our Science textbook where it talks about light reflecting off different surfaces. Flat, smooth surfaces directly reflect light.		
4.	The light will bounce off at a 90 degree angle.		
5.	I do not teach physical science.		
6.	I would recreate this experiment and show students how you could make the light bend in you move the mirror.		
7.	I would give them mirrors and have them reflect light onto the wall. I personally would make targets that they have to try to shine the reflection on. They would see that the light shines in a line.		
8.	I think the light is actually reflected in more of a straight line rather than in all directions.		
9.	Again I would use the internet.		
10.	?		
11.	I would do an experiment.		
12.	When light hits the surface it reflects in one direction. I would find something to demonstrate this with.		
13.	I could explain that it will travels in all directions but only reflect in a certain manner based on the size of the mirror		

14.	First, I would explain that light travels in a straight line as long as nothing gets in its way. Reflection happens when light rays bounce off a surface.		
15.	mirrors use refraction		
16.	I don't know.		
17.	Light is reflected at an angle. I would use mirrors to show them the different reflection patterns seen from a mirror.		
18.	We could experiment using a mirror and different objects, varying the amount of light at different intervals. We could again use Internet animations, if there are any available.		
19.	I would show another object that is not flat...and how light may bounce off of it. Then have the students research differences and why.		
20.	This happens with mirrors, but not with all objects. I would put up a mirror with a black cloth over it and show the difference of how light is bounced off a plain mirror and how it is absorbed with the cloth mirror.		
21.	Light is reflected at the same angle it is shone on the mirror. Once again I would refer to the book or internet.		
22.	Light is deflected at the angle that it strikes an object. I would take a mirror and shine a laser at it. When the laser hits another point and is not reflected in all directions, they will see that the light is reflected at one angle.		
23.	Light is reflected in a projected area and will remain in the same shape. Illustrate this with the use of a mirror and a flashlight but holding the flashlight at different angles and having the students see where the light reflects. Also use different shapes of flashlights to show that even if a light is not as intense, it still hold the same shape that is projected from flashlight.		
24.	Don’t teach this. I would use experimentation with surfaces that are flat and examine the reflectiveness of them.		
25.	I would do a demonstration with mirrors and flashlight.		
26.	When light hits a mirror, light is reflected straight back and at an angle but the mirror itself stops the light from traveling through to the other side. We could practice using mirrors and flashlights.		

27.	I would tell them that on a smooth surface the angle of incidence is equal to the angle of reflection. I would have one student stand to the side of a mirror, looking at the mirror and I would have another student stand in front of the mirror, but out of the line of sight of the first student. The first student would be able to see the image of the student in the mirror, because the rays reflecting from that student bounce off the mirror at the same angle that they struck it, keeping the image visible. If the light rays bounced off in all directions the image would not be clear or visible at all.		
28.	Light will not be reflected in all directions. You can turn off the lights. Have a student hold a flashlight and shine it on a mirror & observe the reflection.		
29.	Light is reflected from the place upon which it hits the surface. -Set up an experiment to show the direction from which light is reflected upon another object.		
30.	I do not know. Something about the image appears behind the mirror and then reflected back to the eye.		
31.	The surface of the mirror is highly reflective and light does travel in all directions but it will only be reflected within the path of the mirror. Use a mirror to reflect light to different positions in the room. The light is not reflected throughout the room but only within the area that directly reflects the light.		
32.	When light from one direction hits a mirror, it is reflected at another angle, depending on what angle it came from when it hit the mirror. This is an experiment that can be practiced.		
33.	Not sure.		
34.	Do a reflection experiment using a mirror and flashlights to test the idea.		
35.	I thought light was reflected off a smooth surface.		
36.	Light is reflected out to the object that is looking at it		
37.	I would give them other smooth flat objects to test this theory with, such as a ceramic tile or a piece of glass. Then they would see that it is not all smooth flat objects but actually the mirror. Then we can discuss what makes a mirror a mirror.		

38.	Light is reflected in all directions due to the smooth surface. A mirror is very reflective in nature as is aluminum.		
39.	get a curved mirror and a flat mirror to show the difference		
40.	I would talk about reflection and refraction. i would talk about roy g. biv.		

Data set 7

Tchr. No.	**Question and responses**		
	During an activity with a hand lens, one of your students explains that an object (e.g. a butterfly) looks bigger when viewed through the lens because a lens scatters light. - Describe the currently accepted scientific explanation of the phenomenon that the students do not understand. -Explain how you would address this misconception using best instructional practices.		
1.	the lens magnifies the object it does not scatter it		
2.	Light bends through prisms such as the hand lens and water. We would explore this with hands-on experiences and note the size of the objects through changing circumstances. For example, we would place a pencil in a cup of water and note that the part of the pencil underwater is larger because of the refracted light traveling through the water.		
3.	I would find a Brain POP or simulation to explain this concept.		
4.	The light is focused into a smaller point.		
5.	I do not teach physical science.		
6.	I don't know		
7.	I would give them a magnifying glass and then review how our eye sees light that is reflected off an object. I would have them scatter some scraps of paper and explain that if the lens scattered light, it would break up the butterfly into pieces, we wouldn't see it as an object.		
8.	I don't know.		
9.	find another hand on experiment to help.		
10.	?		
11.	I would do different activities to show why this happens.		

12.	Students do not understand that the lens is magnifying it.		
13.	I could let them look out of different thicknesses of lenses and let them see how size would change.		
14.	First, I would explain that a lens refract light that passes through them. The lens that they are using is a magnifying glass. The light rays bend they do not scatter.		
15.	The lens absorbs the light. Again, I would use the internet to find experiments or simulations to show what was going on.		
16.	I don't know.		
17.	I don't know		
18.	We would discuss the bending and stretching of light rays through a lens or other similar object. We would then relate this to the changing of an image as seen through a lens, using corrective eyeglass lenses as an example. If a textbook we have available addresses this we would reference this, as well as online resources. If I taught light, I would have these resources ready.		
19.	Not sure		
20.	The student believes the magnifying glass is connected to light. The truth is that the image changes because the shape of the magnifying glass.		
21.	The lens actually focuses all of the light into a smaller space. Again, in the Science book there are illustrations that show the difference between a convex and concave lens and what they look like. After taking this class, I would also like to find some animations or simulations to help the students understand this concept.		
22.	The student is most likely accurate in his or her thought process, but the correct term would be refracts, not scatters. I would show the students a puzzle that is "scattered." You cannot tell what a puzzle is until you put it together, so if the light was scattering then you would not be able to identify the object on the other side.		
23.	I do not know how to explain how a magnifying lens works.		
24.	Id talk about concave and convex qualities and experiment and measure actual sizes of things.		
25.	I would have the class explore the way one item looks under different objects and in different lights.		

26.	The object looks bigger because of the shape of the lens. We could explore objects using a hand lens and explore the shape of the lens as well.		
27.	The light is not scattered, but the rays are bent (refracted) so that the image appears larger. I would have them move the hand lens back and forth and observe how the image changes in size showing that the light rays are bent at different angles depending on the place that they strike the lens (thickness of where they move through the lens)		
28.	The lens does not scatter the light It concentrates it.		
29.	I would advise the students to set up an experiment that would prove their statement. In the meantime, I would look up how magnification works. -I would hear the student's experiment, see if it works, and then have them share it with the class.		
30.	A hand lens is concave which magnifies the object be because it concentrates the light rays giving the appearance of magnification. I do know how to teach this. May place magnifying glass between sun and a piece of paper, observe the light on the paper, is it spread out or not.		
31.	The curve in the mirror is what makes the image appear larger. Have the student do an experiment using convex and concave lens.		
32.	A lens, unless a magnifying glass, will not magnify an image to any extent. A lens is just like looking through a piece of glass.		
33.	Magnifying lens? Gives the appearance of the item being bigger. Not sure.		
34.	I would take hand lens out with students on a sunny day and allow them to explore the behavior of light through the lens. Safety issues addressed.		
35.	The lens magnifies the object not scatters the light		
36.	The lens is convexed which makes the object bigger.		
37.	I have no idea; we didn't learn anything about this.		
38.	The student may be looking through a magnifying lens which would make it larger.		
39.	magnification is explained		
40.	I would have to research this topic further.		

Data set 8

Tchr. No.	Question and responses		
	During an activity on the formation of shadows, in response to a question about what a shadow is, your student explains that a shadow is a reflection of an object because an object such as a tree casts its shadow. -Describe the currently accepted scientific explanation of the phenomenon that the students do not understand. -Explain how you would address this misconception using best instructional practices.		
1.	The shadow is the cast of the object opaque simply means it filters the light going through so an object will send light through normally through its material.		
2.	We would work on the definition of reflection by comparing what an image reflected in a mirror has in common with a shadow. We might use a Venn diagram to show commonalities between the two concepts as we explore them hands-on and to point out the larger differences. We would specifically note that a mirror projects an image forward while a shadow projects the shape of the image behind the original shape.		
3.	I would explain that a shadow is an absence or blocking of light and refer back to the science textbook.		
4.	I am not for sure.		
5.	I do not teach physical science.		
6.	I would explain that not everything has a shadow. You have to have an object between the light source and where it shinning.		
7.	I would have them observe their reflection in a mirror where they could also see their shadow so they could see the difference.		
8.	The light cannot shine through the object and so a shadow is a result of no light passing through.		
9.	Simulation/Internet		
10.	?		
11.	I would show a video about shadows.		

12.	I would explain that it is not a reflection. I would find a discovery video on this.		
13.	An object blocks light and casts a shadow. The shadow's size is based on the size of the object blocking the light.		
14.	I would try to explain that a shadow appears when the light rays cannot travel through. I could pull out a flashlight out of our science tub and try to show them. I would turn the lights off and have a student hold their hand out in front of the wall. The shadow of their hand would appear. Another thing I could use would be the overhead and do the same thing.		
15.	use some sort of light source and place different objects in front of it and look at the shadows also the internet is a great source of examples		
16.	I don't know.		
17.	A shadow is the blocking or lack of light. I would address this issue with a flashlight and have students stand in front of the flashlight noting that the student is blocking the light leaving a shadow.		
18.	Again we would discuss the movement of light particles in a straight line. If there is an object blocking the path of the light, the light will either bend, pass through, or be absorbed. This will then cause a shadow of the object in the area where there is no light on the opposite side. We can use a flashlight and various objects in a dark room to demonstrate this.		
19.	We would create different shadows and have students brainstorm ideas. Then research what they believe.		
20.	The student is under the impression that shadows are created by light when they are a result of a lack of light or an obstruction of light.		
21.	A shadow is caused by the light not being able to penetrate the thing blocking the light and casting a shadow. I would like to find a simulation or animation to help illustrate this.		

22.	A shadow is the absence of light in an area resulting from an object getting in the path of the light. If light can be reflected off of a tree and cast a shadow, then other things like water or balls should be able to do the same thing. I would take them out to a tree and have them stand with their back to the sun and looking at the tree. Then I would tell them to throw a ball off of the tree in to the shadow, or spray the tree with a hose and hit the shadow after bouncing the water off of the tree.		
23.	A shadow is the space that created when an object blocks light.		
24.	I don't teach this but I would use hands on experimentation with trees and shadows.		
25.	I would have my class use flashlights to cast shadows on different things. I would have them draw the shadows the best they can and then we would compare the shadows.		
26.	A shadow is formed when an object absorbs and stops light from passing through an object. We could experiment with different objects and different light sources shining on them.		
27.	Explain that a shadow is the absence of light. Get a flashlight and show them that when you place an object in front of it, there is a shadow formed where the light rays are absorbed by the light. You may also have a fun round of shadow puppets to see how they can manipulate their shadow by changing the shape of their hand.		
28.	A reflection is light bouncing off of something. A shadow does not have light bouncing off of it. You can play with many different objects & a flashlight to see what happens with a shadow.		
29.	I would have them conduct an experiment to try to prove their theory. -I would have them share their findings with the class after I have approved of their investigation.		
30.	I could explain circular reason. An attempt to support a premise by restating the premise in a different way or without added new information. But shadows are cast by non-illuminating objects when light cannot pass through them, the result is the outline of the object or shadow. Use lunar eclipse as an example.		

31.	Shadows are not reflections but are areas in which the light source has been blocked. There wouldn't be shadows in light didn't travel in a straight line. The student could take different objects and a flashlight and experiment with the shadow that is cast when the light source is moved.		
32.	A shadow is not a reflection, but an image that shows what is being blocked from the light.		
33.	The tree is what is blocking the passing of the light.		
34.	I would conduct a lab in a dark room and then discuss the terms reflection, transparent, translucent, and opaque. I would also have a discussion on light sources.		
35.	A shadow is causes by the light being blocked so there is no light which causes it to be black.		
36.	The shadow is the absent of light		
37.	A shadow is created when light is blocked by an object. I would create a lesson using a flashlight and give the students opportunities to test that theory.		
38.	I don't know.		
39.	show them with a flashlight and have them move around		
40.	I would simply explain that a shadow is the absence of light, not a reflection of anything.		

Data set 9

Tchr. No.	Question and responses		
	In reply to a question on why an opaque object appears the color it does, a student explains that the ability of an opaque body to reflect one color of light and absorb others is called reflection. -Describe the currently accepted scientific explanation of the phenomenon that the students do not understand. -Explain how you would address this misconception using best instructional practices.		
1.	Opaque does not mean reflection its color simply allows it to dull some of the color before it even begins to function.		
2.	Again we would explore the definition of reflection using a mirror as a starting point because of its common nature. Kids know that a mirror gives you a reflection. We could note using a Venn diagram the similarities and differences of a reflection that students see in a mirror v. the view of a opaque object. The opaque object would appear only once while the mirror would provide the reflected image and you could also see the original object, etc.		
3.	I would find a Brain POP or simulation to address this concept.		
4.	I am not for sure.		
5.	I do not teach physical science.		
6.	Opaque means light can't pass through it.		
7.	I would probably use a sponge and water to show how a sponge absorbs water and then make the connection that color being absorbed is much like that. It doesn't reflect off like a mirror, but absorbs.		
8.	I don't know.		
9.	Simulation/Internet		
10.	?		
11.	I would do a simulation.		
12.	I would find something on the internet to explain this.		

13.	Opaque objects absorb dark colors which give it a light color.		
14.	First, I would tell the students that things that are opaque does not let any light pass through it.. Opaque objects either reflect or absorb. I could get aluminum foil for an example of an opaque object that reflect and wood for one that absorbs the color.		
15.	opaque objects absorb all colors find an internet simulation or experiment online to show the point		
16.	I don't know.		
17.	I know it's not called reflection but not sure what the process is or how I would explain it.		
18.	We would need to discuss the light spectrum and the colors of light. Then we would discuss the colors of various opaque objects and how the light behaves when it passes through it.		
19.	Not sure		
20.	NA		
21.	I think it is called refraction. Again, my Science book has some good pictures showing the ways that opaque and translucent objects appear to be the color that they are. Also, simulations and animations would be a great help.		
22.	I am not sure what is wrong with this statement.		
23.	I do not know how to explain opaque properties.		
24.	I would do an experiment using transparent opaque and translucent items.		
25.	We would do an learning cycle activity to help the students understand the concept that the reason that objects appear black is because all the colors are absorbed.		
26.	The ability of an opaque body to reflect one color of light and absorb others is called refraction. We could explore various opaque objects by shining light on them and making observations.		
27.	I would use the light sensitivity probe and the Vernier to measure the amount of light reflected by different colors of fabric. It would show that black does not reflect as much light meaning that it absorbs most compared to other colors.		
28.	I don't know.		

29.	Again, I would have the students try it out on their own while I look up the information myself. -I would have them share their findings with the class.		
30.	I do not know. Called reflectivity maybe. A green plant appears green because it reflects the color green and absorbs the others.		
31.	An opaque object blocks out the light it doesn't reflect it. Demonstrate how some objects can be seen through like plastic, glass etc... Then show the students how some objects block the light from passing through like wood, a window shade etc...		
32.	Reflecting and absorbing cannot be grouped all into reflection.		
33.	Not enough content knowledge to explain this.		
34.	I would start with a discovery web quest covering refection, reflectivity and absorption.		
35.	this is not a misconception		
36.	The object absorbs that color and reflects all the other colors		
37.	I have no idea; we didn't learn anything about this.		
38.	An opaque object is not very reflective in nature. It soaks up the energy from the light.		
39.	try it with other colors		
40.	I would have to research this topic further.		

Data set 10

Tchr. No.	Question and responses		
	In reply to a question why a transparent material appears the color it does, a student explains that the ability of a transparent material to transmit one color of light and absorb others is called transmission. -Describe the currently accepted scientific explanation of the phenomenon that the students do not understand. -Explain how you would address this misconception using best instructional practices.		
1.	Transparent material are clear and then when light passes through a colored material it takes on the whatever color it passes through.		
2.	We would discuss the concept of white light having all of the colors of the visible spectrum. We would refract white light through a prism to demonstrate this. After posing the question "Why then can we not see all of these colors without the prism?", students should have better acceptable of the idea that color IS in white light all around us all of the time and that those colors are all absorbed by opaque objects while just the object's own color is reflected.		
3.	I would find a Brain POP or simulation to address this concept.		
4.	I am not for sure.		
5.	I do not teach physical science.		
6.	Transparent means you can see clearly through it.		
7.	I would have to check my own teacher book to refresh my memory on transmitting first.		
8.	I don't know.		
9.	Simulation/Internet		
10.	?		
11.	I would use Workbench to show this.		
12.	I would review transmission.		
13.	Not sure		
14.	Transparent materials let the light rays pass through them. You can see through them. I would use a window as an object that is transparent.		

15.	find an internet site that shows an example of this process		
16.	I don't know.		
17.	I don't know how to answer this question.		
18.	I am not sure how I would describe this. I don't completely understand what concept is addressed here.		
19.	Look up the definition of transition...brainstorm in groups what transmission means.		
20.	NA		
21.	Actually the material is not transmitting the light it is allowing the light to pass through it. The transparent object will absorb all of the colors except for the color it appears to be and that color will be sent to your eye. I would like to find simulations or animations to help the student and also refer back to the book.		
22.	I am not sure what is wrong with this statement.		
23.	I do not know how to explain transparency.		
24.	I would use experimentation with light spectrum and prisms.		
25.	The reason that a transparent material transmits one type of light is because the light is scattered because the object is not translucent. The class would use the learning cycle to assess this to further detail.		
26.	The ability of a transparent material to transmit one color of light and absorb others is called reflection. We would explore various transparent materials with various lights and record our observations.		
27.	I would give them different colors of plastics and have them shine light through it to see if their ideas showed true.		
28.	I don't know.		
29.	Have the student set up the investigation. -share their findings when I have investigated myself and approved.		
30.	I do not know.		
31.	Transparent objects allow some of the light to pass through them. They could do an experiment with different object like plastic, glass,		

	wood, metal and see which ones allow some of the light to pass through them.		
32.	Transparent material lets off one color.		
33.	Not enough content knowledge to explain this.		
34.	I would have my students research the term transmission as it relates to transparent, translucent, and opaque materials and would have them explore questions like, "Why does the ocean appear to be blue?" to help conceptualize the difference between reflection and transmission.		
35.	transparent material let all the light through so it transmits all colors not just one		
36.	I don't know		
37.	I have no idea; we didn't learn anything about this.		
38.	A transparent material shows all the color which travels through.		
39.	.		
40.	I would use a flashlight and different colored lenses. I would show them how a red lens, for example, absorbs all light but red and so on.		

Data set 11

Tchr. No.	**Question and responses**		
	In response to a question asking students to write about what they know about light, a large number of your students repeatedly mention that light is not a form of energy, and that it is just something that is present in order to aid us see objects. -Describe the currently accepted scientific explanation of the phenomenon that the students do not understand. -Explain how you would address this misconception using best instructional practices.		
1.	light is a source of energy that heats the earth through the sun, light bulbs, etc.		
2.	We would demonstrate that light is energy by reminding students of the fact that a fire has light and a fire is absolutely energy. What changes a candle to how wax? Light energy in the form of heat. We would brainstorm all of the ways light energy and heat work in our daily lives.		

3.	Brain POP or simulation needed for me here.		
4.	I am not for sure.		
5.	I do not teach physical science.		
6.	Show them solar panels and how they can make something work. Changing light energy into mechanical energy.		
7.	I would go back and review our lessons on the Sun and how all life depends on the Sun's energy for life.		
8.	I think that light is a form of energy because it can be the cause and fuel for so many changes.		
9.	Simulation/Internet		
10.	?		
11.	Simulation		
12.	Yes light is a form of energy.		
13.	Light gives off heat energy as well. have a student hold their hand close to a lit light bulb. They would be able to feel the heat.		
14.	I would try to explain that light is a form of energy. The Sun is an example of light energy.		
15.	Light is a form of energy. Direct them to simulations that show light as a form of energy.		
16.	I don't know.		
17.	Light is energy. It isn't just present to help us see. But I don't know how to explain it,		
18.	We would discuss solar panels, sunburns, suntans, how hot your car gets in the summer, photosynthesis, etc. These are all things students know that will demonstrate that sun in fact produces energy.		
19.	Not sure of this.		
20.	I would bring in a solar powered object and show them how it is powered only by light.		
21.	Light is definitely a form of energy just like heat is. We could consult the book or look for examples on the internet.		
22.	Light is a form of energy. I would take students to the shop and let them etch wood with a laser.		

23.	Light is a form of energy. The process that turns electricity into a light source (example: electricity traveling from a power source through a circuit to light up a bulb) is a form of energy. Taking electricity and making is useful is energy.		
24.	I would study the energy of the sun and solar energy.		
25.	We would do an experiment showing that light is a form of energy. The get heat from the sun and the sun radiates light therefore light is a form of energy.		
26.	Light is a form of energy. We would explore various kinds of light and discover how light travels in waves.		
27.	I would explain that light is an electromagnetic wave. I would then have them take a white box and a black box and place it on the playground. We would monitor the temperature of each box. I would ask them if light is not energy, how is it that the black box is warmer. They would conclude that light is energy and can be felt as heat. You could also have them monitor the temperature of a light bulb. They get too hot to touch (incandescent)		
28.	Light is a form of energy. You can do many activities with solar energy & heat.		
29.	Explain that light is an energy because it also produces heat. -set up an experiment where they can take the temperature of something after being directly effected by light.		
30.	Light travels in waves and is a part of an energy continuum called the electromagnetic spectrum. It is able to do work or cause a force and can be changed from one form to another. To address the misconception study lasers (light amplification s.... emitting r.......) or light bulbs or photo voltaic cells or solar energy panels or photolysis is photosynthesis.		
31.	Light is a source of energy because it gives off energy. The sun gives off energy that plants use. We can also use the energy of the sun for solar products. Show the students that light produces energy in the form of heat. They can feel of fabric after it has been in the sun or feel the heat produced by a light bulb.		
32.	Light is a form or energy because it cannot be destroyed.		
33.	Work requires energy. Radiation in terms of solar or electrical light emission.		
34.	Allow the students to build incubators using an incandescent light as a heat energy source.		

35.	Light is energy and I would show them the electromagnetic spectrum. I would also remind them that the sun transmits light and to feel the heat from the sun Heat requires energy.		
36.	Light is a form of energy that moves and it is not gained or lost but it changes forms		
37.	We could talk about all the ways light is harvested as energy, such as solar powered lamps. It is an energy just like water and wind. They are all natural resources.		
38.	Light is a form of energy. It can be measured.		
39.	.		
40.	I would talk to the students about how light can be energy and in the form of heat. We could measure that heat with a thermometer probe on the Vernier. I would also bring up solar powered things, such as calculators and how they are converting that light energy to power for the calculator to function.		

Data set 12

Tchr. No.	**Question and responses**		
	In response to a question about listing examples of luminous and illuminated bodies, students working in groups comment as follows: Examples of luminous bodies are desks, chairs and tables, and examples of illuminated bodies are the sun, stars and various artificial light sources. -Describe the currently accepted scientific explanation of the phenomenon that the students do not understand. -Explain how you would address this misconception using best instructional practices.		
1.	Illuminated bodies are naturally lit and luminous are artificially lit.		
2.	We would probably discuss the root word "luminate" and then explore the meanings of the suffix "ous" and the prefix "il". "Ous" is a suffix that would cause the word to mean somethine like "does luminate", while "il" is a negative prefix. Understanding the root word would be an essential precursor to this process.		

3.	They are opposite of what they think. Again, I would discuss light sources and refer to the Science textbook.		
4.	I am not for sure.		
5.	I do not teach physical science.		
6.	I don't know		
7.	Again, I would turn off the lights and let them see that furniture in the classroom does not shine. They are not luminous. I would explain that the sun, stars, and artificial light sources are luminous. that they can see the furniture when I turn the lights back on because of the lights.		
8.	I think these two ideas are reversed. If an object is a source of light, it would be a luminous object. If the object reflects light, it would be a luminated object.		
9.	Simulation/Internet		
10.	?		
11.	Simulation and video		
12.	I would have to go online and research this.		
13.	Luminous bodies reflect light and illuminated objects give off light.		
14.	Luminous bodies let off its own light whereas illuminate bodies reflect light comes from somewhere else. A light bulb would be an example of something that is luminous and the moon would be an example of an illuminate body. The moon reflects the light of the sun.		
15.	Again, I would use the internet to find simulations to show luminous and illuminated bodies.		
16.	I don't know.		
17.	Don't understand the question.		
18.	I don't remember studying this, so I am not sure this would come up.		
19.	Once again...we would look it up on the Internet and see how these bodies work.		
20.	NA		

21.	I think those should be reversed. The sun, stars, etc are luminous and the desks, etc. are illuminated bodies. Luminous would mean they are creating their own light and the other would be they are being lit up by light energy. I would use my Science book and the internet as sources to help explain this to students.		
22.	Luminous bodies give off light, illuminated bodies are reflecting light. I would take students in to the dark room and ask them if the chair is emitting light.		
23.	I do not know how to explain luminous and illuminate bodies.		
24.	I would ask if they emit light and measure candescents		
25.	We would research the questions more in detail. I would then have my students try to come up with a project that would explain this theory.		
26.	Luminous bodies are the sun, stars, and various artificial light sources. Illunimated bodies are objects that are seen when light hits them.		
27.	luminated produces its own light, illuminated reflects light. I would simply shut out the lights and ask them if they see the desk. If it is luminous, it would still be able to be seen because it would produce its own light.		
28.	I don't know.		
29.	Have the students discover with one another their findings. -Create an investigation in which students conduct and share their findings.		
30.	Items are luminous if they can produce their own light (sun, stars, biolumiscence) - chemical reactions must be taking places (exothermic reactions) energy is given off. Items are illuminated if they do not produce their own light. These objects can only be seen when light is reflected from their surface. Address misconception: compare chemical properties of illuminate objects compared to luminate objects is respect to energy.		

31.	Objects that are luminous give off a source of energy or light. Illuminated bodies are objects that we can see because light is reflected from their surface. The moon is a good example. When we see it in the day time we don't see light coming from it, but we can see it at night because it is reflecting the light from the sun. Talk to the students about the phases of the moon and eclipse.		
32.	I think that the vocabulary needs to be clarified and objects that can be illuminated can be lit up by light and look like they are glowing. Objects that are luminous are objects that are already glowing.		
33.	Not enough content knowledge to explain this.		
34.	Vocabulary lesson first of all. Light lab with luminous objects light lamps and illuminated objects lit by the lamp.		
35.	Luminous bodies reflect light and nonluminous bodies absorb light		
36.	They have the answer just the opposite.		
37.	They have it backwards. Luminous bodies give off light, such as the sun, stars and various artificial light sources. Illuminated bodies means those bodies are lit up by other sources. They don't give off light themselves; instead they reflect light from other sources. That would be desks, chairs and tables.		
38.	Luminous: reflects light easily; diamonds; prisms Illuminated items: items that reflect light due to light energy bouncing off other items.		
39.	show them with a flashlight and have them move around the object		
40.	I would explain that anything that can reflect light can be an illuminated body.		

VITA

Graduate School
Southern Illinois University

Simeon Mbewe

smbewe2004@yahoo.co.uk

University of Zambia
Bachelor of Science, Physics Education, April 1988

University of the Witwatersrand
Master of Science in Science Education, April 2001

Special Honors and Awards:
Audrey Tomera Memorial Scholarship, 2012

Dissertation Title:
Middle School Teachers' Familiarity with, Interest in, Performance on, Conceptual and Pedagogical Knowledge of Light

Major Professors: Dr. Frackson Mumba and Dr. Kevin C. Wise

Publications:

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