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This study explored elementary school teachers' familiarity, conceptual knowledge, and interest in learning more about light and its related concepts. This study also sought to establish the relationship between elementary school teachers' familiarity, conceptual knowledge, and interest in learning light concepts. Sixty-six lower and upper elementary school teachers in Midwest of the USA participated in this study. Data were collected using 3 instruments namely Familiarity with Light Concepts Questionnaire, Conceptual Knowledge of Light Test, and Interest in Learning about Light Concepts Questionnaire. Data were analyzed using statistical tests. Most teachers expressed high levels of familiarity with light concepts surveyed. The upper elementary grade teachers expressed more familiarity with advanced light concepts than lower elementary grade teachers. However, most teachers exhibited low conceptual knowledge of light concepts. There was no significant difference in conceptual knowledge of light concepts between lower and upper elementary grade teachers, and between more experienced and less experienced teachers. As such, teachers' self-reported familiarity with light concepts was not consistent with their actual knowledge of the concepts. However, most teachers expressed high interest in learning more about the light concepts. Thus, teachers showed willingness to learn more about light concepts they did not understand. These findings have implications on teacher education, and science teaching and learning.

Keywords: *Light; Teachers; Familiarity; Interest; Knowledge*

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Introduction

Research studies show that elementary teachers have misconceptions about the nature of light and its related concepts (Atwood, Christopher, & McNall, 2005; Bendall, Goldberg, & Galili, 1993; Heywood, 2005; Krall, Christopher, & Atwood, 2009). As such, science educators have raised doubt on whether elementary teachers can effectively teach light and its related concepts (McDermott, 2006). This is a major concern in the USA, where most elementary teacher education programs have less emphasis on science content knowledge (Atwood & Christopher, 2004; McDermott, Heron, Shaffer, & Stetzer, 2006). However, in their role as science instructors, elementary school science teachers must make curriculum and instructional decisions that can promote meaningful learning of light among students. Thus, the success of providing quality instruction on difficult topics like light in elementary schools will largely depend on teachers' conceptual knowledge about light and instructional practice. Similarly, Van Driel, Verloop, and De Vos (1998) stated that science 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 light, most of them mainly focused on identifying misconceptions among teachers (Bendall et al., 1993; Heywood, 2005; Krall et al., 2009) and teachers' pedagogical content knowledge (Van Zee, Hammer, Bell, Roy, & Peter, 2005). For example, Krall et al. (2009) reported that teachers lacked conceptual understanding of light as evidenced by poor performance on the tasks. Similarly, Van Zee et al. (2005) found that teachers did not have sound pedagogical content knowledge for light. None of these studies examined teachers' levels of familiarity with and interest in the topic of light. Yet, research shows that teachers' familiarity with and interest in subject matter have influence on their instructional practice, and subsequently, on student achievement (Cantrell, Young, & Moore, 2003). As such, it is possible to assume that teachers who are not familiar with or less interested in learning more about light are unlikely to teach it well in their science classes, and subsequently, affect student's understanding of light and its related concepts. 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 on a topic or in a course (Ngo, Brown, Sargent, & Dopkins, 2010). Likewise, learners' interests in science have a significant influence on their desire to learn more about its content. As such, teachers' willingness to learn more about light or teach it to their students may largely depend on their interest in the topic. Interest is significant in determining how humans select and persist in processing certain types of information in preference to others (Hidi, 1990). Hidi further argued 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 toward 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 effectively teach science.

In view of the above, more attention to elementary education teachers' levels of familiarity with light, and their interest in learning more about it is warranted as it may contribute to better teaching and learning of light in schools. Likewise, examining teachers' interest in light may serve as a measure of their willingness to learn more about it and its related concepts. Thus, this study goes beyond previous studies on light by exploring elementary school science teachers' familiarity, conceptual knowledge, and interest in learning more about light.

This study focused on light because it is one of the main topics in school science courses, and in the US National Science Education Standards (NSES) (National Research Council [NRC], 1996). The concepts of light assessed in this study are vision (how an eye is able to see), speed of light (light travelling at a greater speed than an airplane), reflection of light, refraction of light, formation of shadows, 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.

These concepts were categorized into basic and advanced concepts based on the NSES (NRC, 1996). According to NSES, basic light concepts are those that elementary school students should understand, explain, and apply that light travels in a straight line until it strikes an object; 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.

Research Questions

(1) To what extent are elementary science teachers familiar with, understand, and interested in learning more about light concepts emphasized in school science curriculum?
(2) Are there differences between and within elementary teacher subgroups' familiarity, conceptual knowledge, and interest in learning more about light?
(3) What is the relationship between elementary science teachers' familiarity, conceptual knowledge, and interest in learning about light concepts?

Significance of the Study

First, this study contributes to existing literature on light by documenting elementary school teachers' levels of familiarity with light concepts, conceptual knowledge of light concepts, and their levels of interest in learning about light and its related concepts. Second, the findings of this study have implications on teacher education, and science teaching and learning in elementary school classrooms. Third, the results of this study are of significance to science teachers, school administrators, science teacher educators, science curriculum designers, professional development (PD) providers, and science education researchers. For example, science teachers would become aware of what needs to be improved with regard to teaching of light and its related concepts in elementary schools. Similarly, school administrators would become aware of how they can support their science teachers to effectively teach the topic of light. Teacher educators may use the findings in developing science methods courses and PD 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 light for elementary school students. Science education researchers may use the findings of this study as the starting points for further research on the topic of light.

Literature Review

Role of Familiarity in Learners' Achievement

The term 'Familiarity' refers to a personal sense of acquaintance with something encountered before (Ngo et al., 2010). In this case, the teachers' personal acquaintance with light concepts is as a result of their encounters with the topic in school and college science courses, as science teachers, and other experiences in society. However, some teachers have familiarity with a multitude of concepts but with limited depth of understanding of the concepts and their connections to broader ideas and principles. Therefore, teachers' familiarity with the light concepts may not be directly associated with their deep understanding of the concepts but merely as knowledge which is associated with facts, memorization, and superficial knowledge. Such knowledge is, however, very important in that it can be considered as teachers' prior knowledge of the scientific concepts being assessed. However, some researchers assert that when learners' 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' (Warren, Ballenger, Ogonowski, Rosebery, & Hudicourt-Barnes, 2001, p. 548). For example, Mullis et al. (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. Similarly, Delen and Bulut (2011) found that students' familiarity with technology helped them to explain math and science achievement gaps between individuals and schools. However, research studies have not reported teachers' familiarity with light and its related concepts. Hence, this study attempted to fill this gap in the literature by exploring elementary science teachers' familiarity with light and its related concepts.

Role of Interest in Science Achievement

The term *Interest* refers to a resulting curiosity in something by an individual due to the interaction of the person with the context and situation (Mitchell, 1993). Osborne, Simon, and Collins (2003) viewed it as a particular type of attitude toward some specific action to be performed toward an object (e.g. attitude toward 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 participants' attitudes to light concepts, and their attitude toward learning more about light concepts.

Some researchers have reported a moderate relationship between learners' attitude toward science and achievement (Shrigley, 1990). On the other hand, some researchers have observed that this correlation is stronger for both high and low ability students (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 toward science (Osborne et al., 2003). Similarly, Lemke (2001) points out that students' interest in, attitudes and motivation toward, science, and willingness to entertain particular conceptual accounts of phenomena depend on their beliefs, acceptable identities, and the consequences for their life outside the classroom. While some may question the value of scientific knowledge, lack of interest in science among learners remains a matter of concern for any society attempting to raise its standards of scientific literacy (Osborne et al., 2003). This becomes especially so with the evidence that students' interest in science declines from the point of entry to secondary school (Breakwell & Beardsell, 1992). 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 knowledge than individuals without interest (Hidi, 1990).

Misconceptions about Light

Several studies have examined teachers' conceptions of light and its related concepts (Atwood et al., 2005; Bendall et al., 1993; Heywood, 2005; Krall et al., 2009). These studies collectively indicate that teachers over a broad range of ages and with diverse educational experiences have many difficulties understanding light and its related concepts. Bendall et al. (1993) used clinical interviews to investigate prospective elementary teachers' verbal and diagrammatic knowledge about various aspects of light, seeing, shadows, and mirror images. They reported that prospective teachers had prior knowledge that emerged from their interpretations of everyday experiences. Bendall et al. proposed conceptual change instructional strategies for instructors of prospective teachers that 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. Similarly, Heywood (2005) reported that primary school trainee teachers experienced significant difficulties in articulating coherent explanations regarding vision process and image formation in a plane mirror. Heywood focused on primary school trainee teachers' conceptualization of the vision process and image formation in a plane mirror. 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. Heywood made no follow-up study to find out teachers' familiarity and interest in light.

Some researchers have organized misconceptions on light into four categories namely 'active' vision model (Selley, 1996); 'holistic' paradigm regarding images and shadows (Rice & Feher, 1987); image projection model (Galili, Bendall & Goldberg, 1993); and heuristic (Feher & Rice, 1988) or hybrid (Galili et al., 1993) or synthetic (Vosniadou, 1994) models. In the 'active' vision model, learners believe that an eye plays an active role in that it produces light in order for humans or animals to see objects. In a 'holistic' paradigm regarding images and shadows, learners often conceptualize that the image is created at the object and travels through space. In the 'image projection' model, learners explain the image formation in plane mirrors in terms of light rays carrying the image. In the 'heuristic' or 'hybrid' or 'synthetic' model, learners often interpret light concepts using a mixture of pre-instruction and post-instruction understandings of the concepts. In this model, there is often a clash between the spontaneous and formal interpretations. For example, learner diagrams and verbal comments would be in conflict, where a learner would make a comment indicating that light rays carry an image, while the diagram indicates the correct position of the image.

In summary studies show that both teachers and students have misconceptions about light and its related concepts. Yet, it is important for teachers to hold sound conceptual knowledge about light concepts in order to promote meaningful learning of this topic among their students. Studies also show a dearth of research on elementary school teachers' levels of familiarity and interest in learning more about light concepts emphasized in school science curriculum. As such, this study extended previous studies on light by exploring lower and upper elementary grade teachers' familiarity, conceptual knowledge, and interest in learning about light and its related concepts.

Methodology

Participants

A total of 66 elementary school teachers participated in this study. These teachers were drawn from 32 elementary schools in Midwest of the USA. Selection of the teachers was based on their willingness and availability to participate in the research study. All the teachers were certified to teach grades 1–8. Their teaching experience ranged from 1 to 27 years. There were 10 males and 56 females. Twenty-seven (27) teachers taught science in lower elementary grades (1–3), while 39 teachers taught science in upper elementary grades (4 and 5). Therefore, in this paper, grades 1–3 teachers will be referred to as lower elementary grade teachers, while grades 4 and 5 teachers will be identified as upper elementary grade teachers. In the USA, elementary pre-service teachers do not specialize in one subject area like secondary school teachers. However, they have concentration areas in which they take more content courses. They are also required to take content courses in core areas such as science, math, social studies, and languages. Although elementary teachers do not specialize in science like secondary school science teachers, we can assume that they learn more about science content as they teach their students. We can also fairly assume that the upper elementary science teachers would learn high level content on light as they teach it in upper elementary grades than lower elementary teachers who teach the basic light concepts to students in lower elementary grades. Based on this assumption, we examined the differences between the lower and upper elementary teachers' familiarity, conceptual knowledge, and interest in light.

Data Collection

Data were collected using three instruments: 23-item Familiarity with Light Questionnaire, 17-item Conceptual Knowledge of Light Test; and 17-item Interest in Light Questionnaire. First, teachers were asked to complete the Familiarity with Light Questionnaire which had sections 1 and 2. In section 1, participants were asked to provide the following demographic information: gender, teaching subjects, and teaching experience. In section 2, participants were asked to rate their familiarity with each of the 17 light concepts by marking 'Concept not familiar to me', 'Concept familiar to me but not understood', or 'Concept familiar to me and I understand its meaning'. Second, teachers completed the Conceptual Knowledge of Light Test. They were asked to define, describe, or explain, in their own words, each of the 17 light concepts listed above. Third, teachers were asked to complete the Interest in Light Questionnaire. They rated their interest in learning more about each of the 17 light concepts by choosing one of the following: 'Not at all interested in learning more', 'Interested in learning more', or 'Very interested in learning more'.

Reliability of the familiarity and interest questionnaires, and conceptual knowledge test, were determined by computing Cronbach's alpha (α) values. Cronbach's alpha values for Familiarity with Light Questionnaire was 0.94, for Interest in Light Questionnaire was 0.98, and for Conceptual Knowledge Test was 0.83. These values are acceptable measures of reliability because they are more than 0.70 the threshold value of acceptability as a measure of reliability (Cohen, 1988). Content and construct validities of the instruments were established with the help of one physics professor and two physics education professors. These professors, independently, checked for the extent to which the items in the instruments were representative of light concepts prescribed in school science curriculum. On the construct validity the experts looked at whether the questions in the instruments were appropriate for the concepts they were aimed to measure, and if they were well constructed for the target audience.

Data Analysis

Participants' responses to items in the familiarity and interest questionnaires were scored and assigned a score. For the familiarity questionnaire, 'concept is not familiar to me' was assigned a score of 1, 'concept is familiar to me but not understood' was assigned a score of 2, and 'concept is familiar to me and I understand its meaning' was assigned a score of 3. Similarly, for the interest 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.

Participants' responses to conceptual knowledge test items were scored by matching participants' responses with the standard definitions, explanations, and descriptions of the concepts. Standard definitions, explanations, and descriptions of the 17 concepts of light were developed by researchers using several research articles (Andersson & Karrqvist, 1983; Bendall et al., 1993; 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 on the nature of light. Table 1 shows the standard descriptions of the light concepts that were used to score participants' responses.

A correct response included a similar 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 standard description, explanation, or definition or derivatives of such ideas and providing an incomplete understanding of the concept; 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. Table 2 shows how elementary teachers' responses were scored.

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. In order to achieve reliability, one physics professor and one physics education professor independently analyzed teachers' responses to items in the Conceptual Knowledge of Light Test using the procedure described above. Then, the two met to compare and discuss their analyses. Some minor differences that emerged in their analyses were resolved through sustained discussions and re-examination of teachers' responses and standard responses. An intercoder agreement coefficient was calculated using Cohen's kappa (1960). This coefficient factors in chance agreement and represents a measure of reliability. The percentage agreement between the two raters for the teachers' responses to conceptual understanding test

Table 1. Standard descriptions of light concepts' survey in this study

Level	Concept	Description
Basic concepts	Reflection of light	The action of light striking a surface and bouncing off
	Formation of shadows	A shadow is formed when an opaque object cuts off the light rays coming from a source of light. A shadow is a dark space behind an object
	Speed of light (light travels at a greater speed than an airplane)	Distance covered by light in a unit time. Speed of light in a vacuum is approximately 300 million meters per second (300,000 kilometers per second)
	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
	Refraction of light	The bending of light rays as they pass through different mediums
	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
	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
Advanced concepts	Crest of waves	A maximum displacement height of a vibrating particle or transverse wave
	Light as a form of energy	Sunlight is the ultimate source of energy on earth; light can also be converted into other forms of energy. The sunlight 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
	Trough of waves	A maximum displacement depth of a vibrating particle or transverse wave
	Wavelength of waves	Distance between corresponding parts of two waves moving in the same direction. For example, the distance from crest to crest or trough to trough
	Amplitude of waves	The height of a crest or depth of a trough of a transverse wave measured from a point of zero displacement
	Electromagnetic spectrum	A collection of electromagnetic waves: gamma rays, X-rays, ultraviolet rays, visible light, infrared rays, microwaves, radio waves
	Color filter	A transparent colored object that transmits its own color of light and absorbs all other colors
	Luminous object	An object that is a source of light energy; a luminous object produces and emits its own light
	Non-luminous object	An object that becomes visible only when it reflects light back to our eyes; it is not a direct source of light
	Light as transverse waves	Light waves, in which the vibrations of the electric and magnetic fields are perpendicular to the direction of propagation of light

Table 2. Example of how teachers' responses were scored

Concept	Standard description/ explanation	Participant responses		
		Correct (2 pts)	Partially correct (1 pt)	Incorrect (0 pt)
Non-luminous object	An object that becomes visible only when it reflects light back to our eyes. It is not a direct source of light	I think this object doesn't produce light on its own but we see it because light bounces from its surface. For example, trees and tables (Teacher # 23)	It is a metal that sometimes reflects light (Teacher # 35) *Partially correct response because the response implies metals only reflect light at certain times*	An object that absorbs all the light (Teacher # 47) *Incorrect response because non-luminous doesn't absorb all the light; otherwise we wouldn't be visible to human eye*
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	Only its color is reflected from its surface. It absorbs other colors in the white light (Teacher # 11)	Only its color reaches our eyes first (Teacher #22) *Partially Correct response because it doesn't talk about other colors being absorbed and only its color is reflected*	All Opaque objects have more than one colors (Teacher # 29) *Incorrect response because not all opaque objects have more than one color*
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	The object absorbs other colors leaving its own color. That is the color we see (Teacher # 52)	Opaque objects can't reflect many colored lights (Teacher # 7) *Partially correct response because opaque objects only reflect their colors*	They reflect all the colored lights. (Teacher # 31) *Incorrect response because an object reflects its color*

items analyses ranged from 85.4 to 92.5 with a corresponding range of kappa values from 0.80 to 0.92. These statistics suggest a high degree of agreement between the two raters in categorizing teachers' responses as correct, partially correct, and incorrect. According to Chiappetta, Fillman, and Sethna (1991), interrater agreement values above 75% indicate excellent percentage agreement, while kappa values below 0.4 indicate a poor interrater coefficient. Then, Mann–Whitney, Wilcoxon, and Kruskal–Wallis tests were performed on the three data sets to test for differences between and within groups, respectively. Pearson correlation coefficients were computed to determine the extent to which teachers' familiarity with, interest in, conceptual knowledge of light were related. These non-parametric tests were used to analyze the data because the number of participants in each subgroup was small (less than 30 threshold for parametric tests); and the data from the two questionnaires were ordinal in nature.

Results

Teachers' Familiarity with Light Concepts

As shown in Table 3, an overall mean of 49.28% of teachers said they were familiar with the light concepts but did not understand their meanings, 38.67% were familiar with the light concepts and understood their meanings, and 12.04% were not familiar with the light concepts.

About 47.4% of the teachers indicated that they were familiar with the 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. Forty-six percent indicated they were familiar with the basic light

Table 3. Percentages of teachers' familiarity with light concepts ($N = 66$)

			Concept is familiar to me	
Level	Concept	Concept is not familiar to me (%)	but not understood (%)	and I understand its meaning (%)
Basic concepts	Reflection of light	1.5	40.9	57.6
	Formation of shadows	3.0	39.4	57.6
	Speed of light (light travels at a greater speed than an airplane)	3.0	42.4	54.5
	Vision (how an eye is able to see objects)	0.0	47.0	53.0
	Refraction of light	1.5	54.5	43.9
	Appearance of colored opaque objects in white light	18.2	51.5	30.3
	Appearance of colored opaque objects in colored lights	16.7	56.1	27.3
	Mean (SD)	6.3 (7.7)	47.4 (6.8)	46.3 (12.9)
Advanced concepts	Crest of waves	12.1	42.4	45.5
	Light as a form of energy	6.1	50.0	43.9
	Trough of waves	15.2	42.4	42.4
	Wavelength of waves	10.6	48.5	40.9
	Amplitude of waves	18.2	48.5	33.3
	Electromagnetic spectrum	15.2	53.0	31.8
	Color filters	13.6	60.6	25.8
	Luminous objects	19.7	56.1	24.2
	Non-luminous objects	24.2	51.5	24.2
	Light as transverse waves	25.8	53.0	21.2
	Mean	16.1 (5.8)	50.6 (5.6)	33.3 (9.3)
	Overall mean	12.0 (8.2)	49.3 (6.1)	38.7 (12.4)

Table 4. Teachers' familiarity with basic and advanced light concepts

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

Note: $N = 66$.
*Significant at $p < .05$.

concepts and understood their meanings, while 33.32% said they were familiar with the advanced light concepts and understood their meanings. The mean percentage (6.27%) of teachers who indicated that they were not familiar with basic light concepts was less than the percentage of teachers (16.04%) who indicated that they were not familiar with advanced light concepts.

As shown in Table 4, the Wilcoxon test confirmed that teachers' rating of familiarity with the basic light concepts was significantly higher than their rating of familiarity with the advanced light concepts, a large effect size according to Cohen (1988). Of the 66 participants, 41 were familiar with the basic concepts, 14 were familiar 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.

Differences Between Teacher Groups on Familiarity with Light Concepts

Table 5 shows that there was no significant difference between lower elementary grade teachers' mean rank and upper elementary grade teachers' mean rank on familiarity with the basic light concepts. However, there were significant differences between teacher groups on familiarity with advanced and all light concepts surveyed.

Table 5. Familiarity with light concepts differences between lower and upper elementary teachers

Group	N	Mean rank	Sum of ranks	U	W	Z	Sig.	Effect size	Concepts
L. elementary	27	29.81	805.00	427.0	805.0	−1.307	.191	−.161	Basic
U. elementary	39	36.05	1,406.00						
L. elementary	27	26.72	721.50	343.5	721.5	−2.401	.016*	−.296	Advanced
U. elementary	39	38.19	1,489.50						
L. elementary	27	27.89	753.00	375.0	753.0	−1.979	.048*	−.244	All
U. elementary	39	37.38	1,458.00						

Note: $N = 66$; L = Lower; U = Upper.
*Significant at $p < .05$.

Table 6. Familiarity with light concepts differences between teaching experience subgroups

Teaching experience (years)	N	Mean rank	χ^2	df	Sig.	Concepts
1–5	29	35.48	0.706	2	.703	Basic
6–10	17	30.65				
11+	20	33.05				
1–5	29	36.90	1.700	2	.428	Advanced
6–10	17	31.68				
11+	20	30.13				
1–5	29	36.74	1.482	2	.477	All
6–10	17	30.79				
11+	20	31.10				

Note: $N = 66$.

These results suggest that lower elementary and upper elementary grade teachers were not different on their ratings of familiarity with basic light concepts. However, upper elementary grade teachers reported more familiarity with advanced light concepts than elementary teachers.

On the other hand, Table 6, the Kruskal–Wallis analysis of variance revealed no significant difference among the three teaching experience groups on familiarity with the basic light concepts, the advanced light concepts, and all the light concepts. These results suggest that in spite of the differences in the number of years of teaching experience, teachers had similar ratings on familiarity with basic and advanced concepts of light.

Differences Within Teacher Groups on Familiarity with Light Concepts

Tables 7 and 8 show statistical differences within teacher groups on familiarity with light concepts.

Table 7. Familiarity with basic and advanced light concepts based on grade taught group

Teacher group	Concept type	Mean	SD	Mean rank	N	Rank	Z	Sig.	Effect size
Lower	Basic	76.90	15.61	13.26	19	Negative	−3.47	.001*	−.668
elementary	Advanced	65.92	20.03	6.00	4	Positive			
					4	Ties			
					27	Total			
Upper	Basic	82.17	13.14	18.48	22	Negative	−2.67	.008*	−.428
elementary	Advanced	76.92	13.84	12.15	10	Positive			
					7	Ties			
					39	Total			

Note: $N = 66$

*Significant at $p < .05$.

Table 8. Familiarity with light concepts within teaching experience groups

Teaching experience (years)	Concept type	Mean	SD	Mean rank	N	Rank	Z	Sig.	Effect size
1–5	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	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+	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			

Note: $N = 66$.
*Significant at $p < .05$.

These results imply that despite their differences in teaching experience, and the grades they taught, teachers were more familiar with the basic than advanced light concepts.

Teachers' Conceptual Knowledge of Light Concepts

As shown in Table 9, 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 knowledge of light concepts assessed in this study. Table 9 also shows that on average, 49.33% of the teachers provided incorrect responses, 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.

Results in Table 9 suggest that most teachers had low conceptual knowledge of most light concepts assessed in this study. In particular, most teachers had a poorer conceptual knowledge of advanced than basic light concepts. As shown in Table 10, a paired samples *t*-test showed that the teachers' score on conceptual knowledge of advanced light concepts was significantly lower than the score on conceptual knowledge of basic light concepts.

Differences Between Teacher Groups' Conceptual Knowledge of Light Concepts

Tables 11 and 12 show that there were no statistical differences in conceptual knowledge of light concepts between lower and upper elementary grade teachers, and between more experienced and less experienced teachers.

Table 9. Percentages of teachers' conceptual understanding of light concepts

Level	Concept	Incorrect %	Partially correct %	Correct %
Basic concepts	Formation of shadows	22.7	10.6	66.7
	Reflection of light	31.8	6.1	62.1
	Refraction of light	54.5	6.1	39.4
	Vision (how an eye is able to see objects)	40.9	48.5	10.6
	Light travels at a greater speed than an airplane	24.2	66.7	9.1
	Appearance of opaque colored objects in white light	81.8	10.6	7.6
	Appearance of colored opaque objects in colored lights.	89.4	7.6	3.0
	Mean (SD)	49.3 (27.1)	22.3 (24.7)	28.4 (27.4)
Advanced concepts	Trough of waves	51.5	1.5	47.0
	Crest of waves	62.1	1.5	36.4
	Luminous objects	33.3	33.3	33.3
	Non-luminous objects	34.8	31.8	33.3
	Wavelength of waves	68.2	4.5	27.3
	Electromagnetic spectrum	74.2	1.5	24.2
	Color filters	83.3	9.1	7.6
	Light as a form of energy	47.0	47.0	6.0
	Amplitude of waves	92.4	6.1	1.5
	Light as transverse waves	97.0	3.0	0.0
	Mean (SD)	64.4 (22.7)	13.9 (16.8)	21.7 (16.6)
	Overall mean	58.2 (25.2)	17.4 (20.2)	24.4 (21.2)

Note: $N = 66$.

Table 10. Teachers' knowledge of basic and advanced light concepts

Concept type	Mean score	SD	*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				

Note: $N = 66$.
*Significant at $p < .05$.

Differences Within Teacher Groups on Knowledge of Light Concepts

Tables 13 and 14 show statistical differences within teacher groups on conceptual knowledge of light. Within each teacher group mean scores on basic concepts were more than the mean scores on advanced concepts.

Table 11. Conceptual knowledge of light concepts between lower and upper elementary teachers

Group	N	Mean score	SD	t	df	Mean difference	Sig.	Effect size (d)	Concepts
Lower elementary	27	41.01	27.13	−.321	37.32[a]	−1.852	.750	−.087	Basic
Upper elementary	39	42.86	15.20						
Lower elementary	27	28.52	25.56	−.516	64	2.877	.607	.127	Advanced
Upper elementary	39	25.64	19.67						
Lower elementary	27	33.67	24.69	0.175	38.84[a]	0.931	.862	.047*	All
Upper elementary	39	32.73	14.77						

Note: $N = 66$.
*Significant at $p < .05$.
[a]The t and df were adjusted because variance were not equal.

Table 12. Conceptual knowledge of light concepts among teaching experience groups

Group	N	Mean score	SD	df	F	Sig.	Concepts
Teaching experience							
1–5	29	37.93	18.12	2	1.215	.303	Basic
6–10	17	47.48	23.41	63			
11+	20	43.57	21.73				
Total	66	42.10	20.74				
1–5	29	25.86	20.05	2	0.689	.506	Advanced
6–10	17	32.06	27.16	63			
11+	20	23.75	20.64				
Total	66	26.81	22.13				
1–5	29	38.83	17.29	2	0.880	.420	All
6–10	17	38.41	22.75	63			
11+	20	31.91	19.00				
Total	66	33.11	19.28				

Note: $N = 66$.

These results suggest that in spite of their differences in teaching experience and the grades they taught, teachers demonstrated low conceptual knowledge of the advanced than basic light concepts.

Table 13. Conceptual knowledge of basic and advanced light concepts within teacher groups

Group	Concept type	Mean score	SD	*N*	*t*	df	Sig.	Effect size
Lower elementary	Basic	41.01	27.13	27	3.620	26	.001*	.697
	Advanced	28.52	25.56	27				
Upper elementary	Basic	42.86	15.20	39	5.173	38	.000*	.828
	Advanced	25.64	19.67	39				

Note: $N = 66$.
*Significant at $p < .05$.

Table 14. Conceptual knowledge of light concepts based on teaching experience

Group	Concept type	Mean score	SD	*N*	*t*	df	Sig.	Effect size
Teaching experience								
1–5	Basic	37.93	18.12	29	3.749	28	.001*	.696
	Advanced	25.86	20.05	29				
6–10	Basic	47.48	23.41	17	2.624	16	.018*	.636
	Advanced	32.06	27.16	17				
11+	Basic	43.57	21.73	20	4.756	19	.000*	.809
	Advanced	23.75	20.64	20				

Note: $N = 66$.
*Significant at $p < .05$.

Teachers' Interest in Light Concepts

As shown in Table 15, overall mean ratings show that 55.8% of teachers indicated 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. About 59% of teachers were interested in learning more about the basic light concepts, 27.3% were very interested in learning more about the basic light concepts, and 13.86% indicated that they were not at all interested in the basic light concepts. Likewise, 53.64% were interested in learning more about the advanced light concepts, 29.56% were very interested in learning more about the advanced light concepts, and 16.84% were not at all interested in learning more about the 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. As shown in Table 16, there was no significant difference between the teachers' ratings on interest in learning more about basic and advanced light concepts. 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

Table 15. Percentages of teachers' interest in light concepts

Level	Concept	Not at all interested in learning more (%)	Interested in learning more (%)	Very interested in learning more (%)
Basic concepts	Refraction of light	12.1	62.1	25.8
	Reflection of light	13.6	60.6	25.8
	Vision (how an eye is able to see objects)	12.1	59.1	28.8
	Formation of shadows	13.6	59.1	27.3
	Why opaque objects appear in the color they do in white light	15.2	57.6	27.3
	Why opaque objects appear in the color they do in colored lights	15.2	57.6	27.3
	Light travels at a greater sped than an airplane	15.2	56.1	28.8
	Mean (SD)	13.9 (1.4)	58.9 (2.0)	27.3 (1.2)
Advanced concepts	Electromagnetic spectrum	10.6	59.1	30.3
	Light as transverse waves	15.2	57.6	27.3
	Color filters	15.2	56.1	28.8
	Wavelength of waves	15.2	56.1	28.8
	Amplitude of waves	16.7	54.5	28.8
	Trough of waves	19.7	54.5	25.8
	Crest of waves	19.7	53.0	27.3
	Luminous objects	18.2	50.0	31.8
	Light as a form of energy	15.2	48.5	36.4
	Non-luminous objects	22.7	47.0	30.3
	Mean	16.8 (3.4)	53.6 (4.0)	29.6 (3.0)
	Overall mean	15.6 (3.1)	55.8 (4.1)	28.6 (2.6)

Note: $N = 66$.

Table 16. Interest in basic and advanced light concepts within whole group

Concept type	Mean	SD	Mean rank	N	Rank	Z	Sig.	Effect size
Basic concepts	71.14	18.88	14.35	17	Negative	−.573	0.566	−.071
Advanced concepts	70.91	20.49	15.92	12	Positive			
				37	Ties			

Note: $N = 66$.

the mean rank of interest in learning more about the advanced light concepts was 15.92. These results suggest that this group of teachers were interested in learning more about both the basic and advanced light concepts.

Table 17. Interest in light concepts between groups of grade taught

Group	N	Mean rank	Sum of ranks	U	W	Z	Sig.	Effect size	Concepts
Lower elementary	27	34.89	942.00	489.0	1,269.0	−0.507	.612	−.062	Basic
Upper elementary	39	32.54	1,269.00						
Lower elementary	27	34.89	942.00	489.0	1,269.0	−0.508	.612	−.063	Advanced
Upper elementary	39	32.54	1,269.00						
Lower elementary	27	34.78	939.00	492.0	1,272.0	−0.461	.645	−.057	All
Upper elementary	39	32.54	1,272.00						

Note: $N = 66$.

Table 18. Differences in interest in light concepts among teaching experience groups

Teaching experience (years)	N	Mean rank	χ^2	df	Sig.	Concepts
1–5	29	34.09	.404	2	.817	Basic
6–10	17	35.00				
11+	20	31.38				
1–5	29	36.21	1.134	2	.567	Advanced
6–10	17	31.91				
11+	20	30.93				
1–5	29	35.47	.683	2	.711	All
6–10	17	33.09				
11+	20	32.18				

Note: $N = 66$.

Table 19. Differences in interest in light concepts within elementary teacher groups

Group	Concept type	Mean	SD	Mean rank	N	Rank	Z	Sig.	Effect size
Lower 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			
Upper elementary	Basic	69.23	18.85	10.54	12	Negative	0.000	1.000	.000
	Advanced	69.92	19.79	12.65	10	Positive			
					17	Ties			
					39	Total			

Note: $N = 66$.

Differences Between Teacher Groups' Interest in Light Concepts

As shown in Tables 17 and 18, there were no significant differences between teacher groups' interest in learning more about light concepts surveyed in this study.

Table 20. Differences in interest in light concepts within teaching experience groups

Teaching experience (years)	Concept type	Mean	SD	Mean rank	N	Rank	Z	Sig.	Effect size
1–5	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	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+	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			

Note: $N = 66$.
*Significant at $p < .05$.

These results imply that in spite of the differences in the grades they taught and teaching experiences, each group of teachers expressed the same level of interest in learning more about light concepts.

Differences Within Teacher Groups' Interest in Learning about Light

As shown in Tables 19 and 20, there were no statistical differences within teacher groups' interest in learning more about light concepts. For example, of the 27 lower elementary teachers, 5 were interested in learning more about basic concepts and 2 were interested in learning more about advanced concepts. There were 20 ties.

Of the 39 upper elementary 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 suggest that each group of teachers expressed the same level of interest in learning more about the basic and advanced light concepts.

Similarly, in Table 20, among teachers who had 1–5 years teaching experience, only 3 teachers were interested in learning more about basic concepts, 7 were interested in learning more about advanced concepts, and there were 19 ties. For the group of teachers who had 6–10 years of teaching experience, only 5 were interested in learning more about basic concepts, 1 was interested in learning more about advanced concepts, and there were 11 ties.

For the group of teachers who had 11+ years of teaching experience, 9 teachers were interested in learning more about basic concepts, 4 were interested

Table 21. Correlation between teachers' familiarity, conceptual understanding, and interest

	Familiarity	Interest
Interest	.001*	
Conceptual understanding	.214	.189

Note: $N = 66$.
*Significant at $p < .05$.

in learning more about advanced concepts, and there were 7 ties. These results suggest that each group of teachers had the same level of interest in learning more about basic and advanced light concepts regardless of their teaching experience.

Relationship Between Teachers' Familiarity, Conceptual Knowledge, and Interest in Light

Before computing the correlation between teachers' familiarity, conceptual understanding and in light the raw scores were converted to *T*-scores in order to provide a metric that is similar to all the scales. Using the Bonferroni approach to control for type I error across the correlations, a *p*-value of less than 0.01 ($0.05/6 = 0.008 \approx 0.01$) was required for significance. Table 21 shows that the correlations between variables were positive but not statistically significant.

Conclusions

(1) Most teachers expressed high levels of familiarity with light concepts assessed in this study. In particular, most teachers indicated they were more familiar with the basic than advanced light concepts. However, comparisons between groups revealed that the upper elementary grade teachers expressed more familiarity with advanced light concepts than lower elementary grade teachers.
(2) Most teachers exhibited low conceptual knowledge of light concepts. There were no statistical differences in conceptual knowledge of light concepts between lower and upper elementary grade teachers, and between more experienced and less experienced teachers.
(3) There were no significant relationships between teachers' familiarity, conceptual knowledge, and interest in light concepts. However, most teachers expressed high interest in learning more about the light concepts surveyed in this study.
(4) Elementary education teachers' self-reported familiarity with light concepts was not consistent with their actual knowledge of the concepts. However, most teachers expressed willingness to address their low conceptual knowledge of light concepts as evidenced by high levels of interest in learning more about light.

Discussion and Recommendations

These findings suggest that elementary education teachers' self-reported knowledge of light concepts was not consistent with their actual knowledge of the concepts. The non-significant correlation between teachers' familiarity with and conceptual knowledge of light concepts is in contrast with the findings on the relationship between learners' familiarity with subject matter knowledge and achievement reported in previous studies (Mullis et al., 1997). Mullis et al. reported that learners who were familiar with the concepts in the official mathematics curriculum guides performed better on achievement tests than those who were not. Similarly, Attwell and Battle (1999) also reported that familiarity with technology was positively associated with learners' performance. On the other hand, teachers' low conceptual knowledge of light concepts assessed in this study is in keeping with the findings reported in previous studies (Atwood et al., 2005; Bendall et al., 1993; Heywood, 2005; Krall et al., 2009). The non-statistical differences in conceptual knowledge of light concepts between lower and upper elementary grade teachers, and between more experienced and less experienced teachers confirmed previous studies. For example, Krall et al. (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 et al., 2005; Bendall et al., 1993).

However, most teachers expressed high levels of interest in learning more about the light concepts assessed in this study. This finding implies that these elementary school teachers were willing to improve their understanding of light concepts emphasized in school science curriculum. To some extent this finding is consistent with Warren et al.'s (2001) assertion that when learners' 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). Similarly, teachers' high level of interest in learning more about the light concepts would be the best stimulus to learning and may lead to intuitive and analytical thinking among them. On the other hand, this group of elementary school teachers' high levels of interest in learning more about the light concepts is in contrast to some studies on teachers' attitude toward physics. For example, Osborne et al. (2003) reported that light was one of the least favorable topics among teachers. Also, the fact that teachers in this study were predominantly females make this finding even more different from those reported in earlier studies. Breakwell and Beardsell (1992) reported that males had more positive attitudes toward science than females. Nevertheless, the high level of interest in learning more about light concepts expressed by the teachers in this study raises a lot of hope that these teachers are willing to address their knowledge deficiencies on the topic of light. These results may not be generalized beyond this group of convenient sample. However, these findings have important implications on teacher education, and teaching and learning of light in schools. For example, elementary education teachers' low conceptual knowledge of light is manifestation of their failure to have constructed correct knowledge about light concepts in their previous experiences such as science courses. There is a great need to recognize that many lower grade teachers have low content knowledge of light. Yet, teachers' sound content knowledge is an essential element for effective science teaching, and student achievement. 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 elementary school teachers are familiar with and interested in learning more about light concepts, they need PD programs that focus on developing teachers' knowledge of light, how children learn about light, and effective pedagogical knowledge for the topic of light in school science classroom. Teachers' high levels of familiarity and interest in learning about light can serve as the starting point for addressing this problem in teacher education. Based on these results and those reported in previous studies, we suggest that innovative teacher PD programs should be designed and implemented to address the gaps in teachers' knowledge of light and its related concepts. Instruction on light should focus on the pedagogy through raising teachers' awareness of the conceptual difficulties in learning rather than the current curriculum focus that seems to privilege knowing over understanding. Such instructional intervention should be based on research-based characteristics of effective PD highlighted in science education literature (Jeanpierre, Oberhauser, & Freeman, 2005): immerse teachers in inquiry, questioning, and experimentation to model inquiry forms of teaching; PD should be intensive and sustained: teachers must engage in concrete teaching tasks that are based on their experiences with students; PD should focus on subject matter knowledge and deepen teachers' content skill; grounded in a common set of PD standards and show teachers how to connect their work to specific standards for student performance. These five characteristics can be addressed through Loucks-Horsley, Hewson, Love, and Stiles's (1998) PD model that has five steps which are developing awareness, building knowledge, translating knowledge into practice, practicing teaching, and reflection.

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