ORIGINAL ARTICLE

A Qualitative Investigation of Pre-Service Science Teachers' Conceptual Understanding of the Concept of Light

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Abstract: In science education and concept teaching, the ways individuals perceive concepts and the processes of establishing relationships between concepts are of great importance for meaningful learning. Conceptual deficiencies in both students and pre-service teachers can lead to problems in teaching processes and students' learning. Therefore, it is important to determine the current knowledge levels of pre-service teachers regarding the concept of light, which is one of the fundamental concepts of science. The aim of this research is to qualitatively investigate the conceptual understanding of second-year science education students regarding the concept of light. The case study method, one of the qualitative research methods, was used in the research. The study group consisted of 45 pre-service teachers studying in the 2nd grade of the Science Education Program at a state university. Participants were selected using the convenience sampling method in terms of accessibility and practicality. As a data collection tool, three open-ended questions were used to determine the knowledge levels of the pre-service teachers regarding the concept of light. As a result of the research, it was determined that pre-service teachers had difficulty explaining the dual nature of light and mostly focused on the physical properties of light. It was found that pre-service teachers struggled to use scientific knowledge when explaining the concept of light and preferred to use affective expressions frequently used in their daily lives when providing explanations.

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Introduction

CONCEPTS interact with individuals' feelings, thoughts, and behaviors and gain meaning as a result of experiences. Concepts are created by people. They are structures that form the basis of knowledge, enabling the understanding and interpretation of the world, and establishing and maintaining interpersonal communication. Education is concerned with individuals developing existing concepts and acquiring new concepts (Ülgen, 2006). The processes of forming and making sense of these concepts play a fundamental role in science education (Rodrigues & Mattos, 2010).

Contemporary science education aims for individuals to make sense of their environment, develop concepts by relating them to their experiences, acquire skills in structuring and organizing knowledge, and find opportunities to apply and evaluate their thoughts (Brown, 2025; Harlen, 1985). The goal in science lessons is not only to provide students with theoretical knowledge but also to develop skills that enable them to produce logical and constructive solutions to problems they may encounter in daily life (Coştu et al., 2007a). Science concepts directly linked to daily life cover topics that almost everyone may encounter directly or indirectly (Demirci & Ahçı, 2016). Therefore, relating knowledge to daily life in science education, and especially in concept teaching processes, is of great importance for both teachers and researchers (Coştu et al., 2007a). Considering the complexity of students' concept-making processes and the difficulties that may arise during the teaching process, it is natural for them to have various misconceptions related to concepts both before entering the classroom and after the lessons (Coştu et al., 2007b). This situation is a common problem in science classes, especially due to the abstract nature of concepts. Students bring with them intuition, ideas, preconceptions, and life experiences that are often considered scientifically inconsistent and incomplete. Such inconsistencies and deficiencies lead to difficulties that complicate the achievement of targeted learning objectives in science classes (Aydoğan et al., 2003).

One of the concepts taught in science classes and frequently encountered in daily life is the concept of light. Considering the widespread use of the concept of light in daily life and its interaction with other disciplines, the correct perception and meaningful structuring of this concept in the mind is of great importance (Ayvacı & Altınok, 2019). Sub-concepts such as the propagation of light, shadow formation, reflection, and light sources frequently lead to misconceptions among students (Çepni et al., 2006; Durkaya & Aydoslu, 2021; Eaton, 1984; Kaewkhonget al., 2010; Yeşilyurt et al., 2005). Such misunderstandings are not limited to students but can also be similarly observed in pre-service teachers (Demirci & Ahçı, 2016; Djanette & Fouad, 2014; Kara et al., 2008; Kaya, 2010; Uzoğlu et al., 2013;

Wahyuni et al., 2019). If teachers and pre-service teachers possess scientifically incorrect conceptual understandings or incomplete knowledge regarding science topics, they will be inadequate in addressing the misconceptions or knowledge gaps that students bring to the classroom. Therefore, determining the conceptual levels, knowledge deficiencies, and cognitive levels of both students and pre-service teachers regarding the fundamental concepts of science is of great importance (Demirci, 2007).

Aim of the Research

The aim of this research is to qualitatively examine the conceptual understanding of the concept of light among pre-service science teachers studying in the second year of the science education program. In this context, by analyzing the responses given by the pre-service teachers to questions related to the concept of light, an attempt will be made to reveal their conceptual explanations, potential misconceptions, and knowledge levels regarding the concept of light.

Significance of the Research

The ways individuals perceive concepts and the relationships they establish between concepts are important for meaningful learning. Both student characteristics and teacher characteristics significantly affect concept teaching. In the correct learning of concepts, the existing knowledge levels of teachers regarding the concepts are as important as students' prior knowledge, misconceptions, and incorrect/incomplete information. Deficiencies in the conceptual level of teachers and pre-service teachers can lead to these deficiencies being reflected in their students. Therefore, it is important to determine the current knowledge levels of pre-service teachers regarding the fundamental concepts related to science that they will encounter both during their academic lives and professional careers. This study aims to reveal the knowledge levels of pre-service teachers by examining their current conceptual understanding of the concept of light.

Research Problem

This study will examine the level of conceptual understanding of the concept of light among pre-service science teachers studying in the 2nd grade of the science education program. In this context, the research sought an answer to the problem: 'How does pre-service teachers' scientific understanding of the concept of 'light' affect their future teaching performance?'

Methodology

Research Design

The case study method, one of the qualitative research methods, was used in the study. In this method, the phenomena and events examined are evaluated within their own context. The meanings people attribute to these phenomena and events are interpreted in depth (Creswell, 2013). In the study, the knowledge levels of pre-service teachers regarding the concept of light were determined and investigated as the case. The case study approach was deemed appropriate for this research because it is an approach where the researcher examines a real-life, current, and bounded situation or multiple bounded situations within a specific time frame in detail and depth using data collection sources such as document review, observation, and interviews.

Study Group

The study group consists of 45 pre-service science teachers attending the 2nd grade of the Science Education Program at the Faculty of Education of a state university. The participants were determined using the convenience sampling method, one of the sampling types, because they were close and easily accessible, and to provide practicality to the study (Creswell, 2013).

Data Collection Instrument

Open-ended questions were utilized as the data collection instrument. Three open-ended questions were asked to determine the knowledge levels of the pre-service teachers regarding the concept of "light". After the open-ended questions were prepared, expert opinions were first sought from three education specialists in the field of science. Following the revisions suggested by the experts, the questions were finalized and administered to the participants. Participants were given 20 minutes to answer all the questions.

Data Analysis

The written responses obtained were analyzed using the NVIVO qualitative analysis software. The research findings were transferred to the relevant program, and the resulting data were grouped under common categories and codes.

Table 1. Categories and Codes Formed Regarding the Definition of the Concept of Light.

Category	Code	Example Phrases	f
Light and science	Energy and energy source	Ex16:'...is a useful energy source.' Ex20:'…useful form of energy.'	6
	Physical definition / scientific knowledge	Ex21:'...It has a specific wavelength and frequency.' Ex44:'...It is formed by the aggregation of photons.'	9
	Optics science	Ex1:'...is a substance studied under the name of optics.' Ex7:'Optics studies light.'	2
Physical properties of light	Propagation in vacuum	Ex12:'It is a substance that propagates in a vacuum.' Ex31:'Light that can propagate in a vacuum...'	5
	Photons / wave property	Ex6:'...is a wave function.' Ex21:'Light consists of photons.'	6
	Speed	Ex4:'It propagates faster than sound.'	3
	Reflection - refraction	Ex7:'Light reflects, refracts, and propagates.' Ex22:'...by the refraction of rays occurs as a result of reflection.'	5
Source of light	Lighting devices	Ex28: '...emitted from lighting devices...' Ex38: '...lighting' provided by devices...'	8
	Natural sources	Ex10: 'From the Sun and the Moon coming...'	14
Function of light	Perception / Sensation	Ex18: '...by the receptors in our eyes perceived...'	2
	Illumination	Ex3:'It illuminates the surroundings.' Ex14:'Light is an energy that provides illumination.'	19
	Enabling sight	Ex2:'...enables us to see objects.' Ex3:'It helps us see objects.'	10
	Enabling color discrimination	Ex24:'...enables us to see and distinguish colors.' Ex34: '...to see colors useful for...'	6

Findings

The findings obtained within the scope of the study were categorized and coded considering the research questions. In the study, pre-service teachers were first asked the question, 'What is Light?' With this question, the aim was to examine the opinions of the participating pre-service teachers regarding the definitions of the concept of light. While some pre-service teachers provided more than one opinion in response to the question, 2 pre-service teachers provided no opinion at all. The findings obtained from the responses of the pre-service teachers are presented in **Table 1**.

When Table 1 is examined, it is seen that pre-service teachers' opinions regarding the definition of light are divided into four categories: Light and science (f = 15), physical properties of light (f = 19), source of light (f = 22), and function of light (f = 37). The prominent categories when examining the opinions of pre-service teachers are the function of light (f = 37) and the source of light (f = 22).

When Table 1 is examined, it is seen that pre-service teachers listed the most answers for the definition of light under the category function of light (f = 37). Four codes were reached in the function of light category. These codes consist of: perception / sensation (f = 2), illumination (f = 19), enabling sight (f = 10), and enabling color distinction (f = 6). The two codes

Table 2. Categories and Codes Developed Regarding the Structure of Light.

Category	Code	Example Phrases	f
Scientific concepts	Photoelectric effect	Ex36: '...electrons were used in the experiment; there was a photoelectric effect.'	1
	Frequencies and wavelengths	Ex21: 'A specific wavelength and has a frequency.'	1
	Abstract definitions	Ex2: 'It is visible but cannot be held.' Ex35: 'In the structure of light, there is a unit useful for illumination exists.'	7
Physical properties of light	Propagation in vacuum	Ex18: 'Movement in vacuum' can do.'	1
	Wave-particle structure	Ex3: 'It has a wave-particle structure.' Ex6: 'A wave-particle structure' it has.'	10
	Linear propagation	Ex8: '...moves linearly.' Ex23: '...very much along a straight lineable to move fast...'	4
	Colors – White light	Ex6: 'White light separates into colors within itself.' Ex11: '...consists of many colors.'	6
	Particle structure - photons	Ex33: 'It consists of photons.' Ex40: 'Particle structure of light exists.'	10
	Reflection -Refraction -Propagation	Ex 21: 'Light can be refracted in certain media.' S32: 'Reflection, Refraction, Propagation'	7
Source of light	Relationship between electricity and circuits	Ex 16: 'Light operates by means of electricity.' Ex 29: '…it has an electrical structure.'	4
	Formation by the transformation of gases	Ex 30:'It forms by the transformation of helium into hydrogen.' Ex 38:'…in a lighter, there is gas and it creates light.'	2
	Formation from light rays	Ex 25:'We obtain light with light rays.' Ex 27:'There are light beams.'	4

most frequently mentioned by pre-service teachers are seen to be illumination (f = 19) and enabling sight (f = 10).

In **Table 1**, the category source of light (f = 22), which is the other category most frequently associated with the opinions of pre-service teachers, includes two codes: Lighting devices (f = 8) and natural sources (f = 14).

In the category physical properties of light (f = 19), four codes were reached: propagation in vacuum (f = 5), photons / wave property (f = 6), speed (f = 3), and reflection - refraction (f = 5).

Looking at the category light and science (f = 17) in Table 1, the codes reached are type of energy and energy source (f = 6), physical definition / scientific knowledge (f = 9), and optics science (f = 2).

As the second question within the scope of the study, pre-service teachers were asked: 'How would you explain the structure of light?' While some pre-service teachers provided more than one opinion for this question, 6 pre-service teachers did not respond at all. The findings obtained from the answers of the pre-service teachers are presented in **Table 2**.

When **Table 2** is examined, it is seen that the opinions of pre-service teachers are divided into three categories: Scientific concepts (f = 9), physical properties of light (f = 38), and source of light (f = 10). The prominent category resulting from the examination of pre-service teachers' opinions was the physical properties of light (f = 38).

Table 3. Categories and Codes Developed Regarding the Speed of Light.

Category	Code	Example Statements	f
Explanation with examples from daily life	The Switch is pressed, the example of a lamp lighting	Ex 6: 'When we press a button, the lamp immediately lights up.' Ex 13:'When we press the switch, the light immediately turns on.'	10
	The Example of sunlight	Ex 32: 'Sunlight.' Ex 44: 'Like the sun's rays reaching the Earth…'	2
	The Example of lightning – thunder"	Ex 10: 'When lightning strikes, light comes first, then sound.' Ex 23: 'When lightning strikes, light is seen first, then sound is heard.'	17
Scientific expression of light speed	Expressing the speed of light as immeasurable or unknowable	Ex 19: 'The speed of light cannot be reached.' Ex 31: '…but the speed of light, I believe is immeasurable.'	3
	Expressing the speed of light with numerical expressions	Ex 18: '…approximately per second at a speed of 300,000 km…' Ex 11: 'at a speed of 3x108c..' Ex 21 'at a speed of 3x10-8m/s.'	8
Comparison of light with sound	The statement that light is faster than sound	Ex 1: 'Light is faster than sound.' Ex 17: 'Light travels even faster than sound travels.'	15
	The statement that sound is faster than light	Ex 33: 'Sound is faster than light.'	1

When **Table 2** is examined, it is seen that pre-service teachers listed the most answers for the structure of light under the category physical properties of light (f = 38). Six codes were reached in the physical properties of light category. These codes consist of: propagation in vacuum (f = 1), wave-particle structure (f = 10), linear propagation (f = 4), colors – white light (f = 6), particle structure - photons (f = 10), and reflection-refraction-propagation (f = 7). The three codes most frequently mentioned by pre-service teachers are seen to be particle structure - photons (f = 10), wave-particle structure (f = 10), and reflection-refraction-propagation (f = 7).

According to the table, the category source of light (f = 10), which is the other category most frequently associated with the opinions of pre-service teachers, includes three codes: relationship between electricity and circuit (f = 4), formation from light rays (f = 4), and formation by the conversion of gases (f = 2).

In the category scientific concepts (f = 9), three codes were reached: photoelectric effect (f = 1), frequency and wavelengths (f = 1) (f = 6), and abstract definitions (f = 7).

Finally, within the scope of the study, pre-service teachers were asked the question: 'How fast do you think light travels? Can you explain your answer with an example?' While some pre-service teachers provided more than one opinion for this question, 5 pre-service teachers did not provide any opinion on the subject. The findings obtained from the answers of the pre-service teachers are presented in **Table 3**.

When **Table 3** is examined, it is seen that the pre-service teachers' views regarding the speed of light are grouped under the categories of explanation with examples from daily life (f = 29), scientific expression of the light speed (f = 11), and comparison of light with sound. Looking at the category of subject areas with the highest frequency, the explanation with examples from daily life (f = 29) is observed to consist of the codes: The switch is pressed, the example of a lamp lighting (f = 10), the example of sunlight (f = 2), and the example of lightning-thunder (f = 17). It is understood that the highest association within this category was made with the lightning-thunder example code (f = 17).

According to the table, the comparison of light with sound (f = 16), which is another category where pre-service teachers most frequently associated their views, includes two codes: the statement that light is faster than sound (f = 15) and the statement that sound is faster than light (f = 1).

According to the table, the category least associated with the pre-service teachers' views was the scientific expression of the light speed (f = 11). Two codes were created for this category: expressing the speed of light as immeasurable or unknowable (f = 3) and expressing the speed of light with numerical expressions (f = 15).

Conclusion

This study qualitatively examined the conceptual understandings of the concept of light among pre-service science teachers studying in the 2nd grade of science education, and attempted to determine the knowledge levels of the teacher candidates. This section of the research presents the results of the findings obtained from the collected data.

The findings obtained from the pre-service teachers' answers to the question, 'What is light?', show that they defined light both as a scientific phenomenon and using examples from their daily lives. In the statements included in the 'light and science' category, it was highlighted that light is an energy source or type, has a specific wavelength and frequency, or is related to the science of optics. Within the scope of 'physical properties of light', the ability of light to propagate in a vacuum, its wave or photon structure, its speed, and its reflection-refraction behaviors were prominent. In the 'source of light' category, pre-service teachers were observed to provide examples of both natural (sun, moon) and artificial (bulbs, lighting tools) sources. The 'function of light' category focused on light's effect on illumination, vision, and distinguishing colors. These results indicate that pre-service teachers utilize both scientific knowledge and experiential knowledge when defining the concept of light, but that scientifically grounded definitions remain limited.

When examining the findings obtained from the pre-service teachers' answers to the question, 'How would you explain the structure of light?', it was observed that advanced physical concepts such as light frequency, wavelength, and the photoelectric effect were included to a limited extent under the heading of 'scientific concepts'. Furthermore, pre-service teachers defined light as an abstract concept that cannot be touched but can be perceived. In the 'physical properties of light' category, it was stated that light possesses both wave and particle structure, propagates linearly, exhibits reflection and refraction in various media, and consists of many colors. This situation indicates that pre-service teachers are familiar with some optical concepts. Although some scientifically based explanations regarding the 'source of light' were included, such as the conversion processes of electricity and gases, conceptual errors were also identified (for example, helium converting to hydrogen). This situation suggests that pre-service teachers struggle to correctly interpret some fundamental concepts related to the structure of light.

When examining the findings obtained from the pre-service teachers' answers to the question, 'How fast do you think light travels? Can you explain your answer with an example?', it is observed that in the 'explanation with examples from daily life' category, pre-service teachers attempted to explain that light is fast using examples such as the phenomenon of lightning and thunder, the lamp turning on when the switch is pressed, and the arrival of sunlight. Within the scope of the 'scientific expression of the light speed', it was determined that some pre-service teachers attempted to express the speed of light using numerical data, while others defined the speed of light as immeasurable. Errors were observed in the numerical data provided regarding the speed of light. This situation reveals deficiencies both in understanding quantitative magnitudes and in interpreting physical concepts. It was also observed that correct answers were given through different forms of numerical values (3×10^8 m/s, 300,000,000 m/s). Using different notations indicates that pre-service teachers can convert information appropriately to the context. In the 'comparison of light with sound' category, most pre-service teachers correctly stated that light is faster than sound, although erroneous statements were occasionally observed. Generally, it was determined that pre-service teachers utilized concrete daily experiences when explaining the speed of light, but they possessed deficiencies and conceptual errors regarding scientific knowledge.

Discussion and Recommendations

Individuals focus more on the interesting and prominent features of events rather than abstract or theoretical explanations of scientific phenomena (Cansüngü-Koray & Bal, 2002). When examining the responses given by pre-service teachers to the question 'What is light?', it was observed that a significant portion defined light based on its characteristics of 'illumination' and 'enabling sight'. This situation indicates that the pre-service teachers considered the functional and concrete aspects of light. Even as students' academic levels increase, they tend toward alternative concepts rather than scientific concepts when defining the concept of light (Ayvacı & Candaş, 2018). In our study, the fact that pre-service teachers provided physical explanations such as 'type of energy', 'wave structure', and 'composed of photons' in limited numbers can be interpreted as an indicator that they can only superficially explain the scientific dimension of the concept of light.

Individuals who frequently encounter scientific concepts in daily life and solve scientific problems using everyday language have difficulty learning the scientific counterpart of the concept or relating it to different situations and applying it (Ayvacı & Candaş, 2018). In the responses given to the question 'How do you explain the structure of light?', the frequency of using scientific concepts such as 'wavy dotted structure', 'particulate structure', and 'composition of colors' stands out. This situation indicates that some pre-service teachers know both the wave and particle properties of light. However, it was observed that these expressions were often conceptually incorrect. Responses appealing more to sensory perception than physical explanation, such as 'Light cannot be held but is visible to the eye', were also encountered. These results suggest that pre-service teachers associate the concept of light, which they frequently encounter and use in daily life, with the misconceptions they hold. This situation can be interpreted as the reason why pre-service teachers struggle to express the concept of light using scientific language.

Among the answers given to the question 'How fast do you think light travels?', concrete examples from daily life such as the 'lightning-thunder example', 'a lamp turning on', and 'sunlight' were observed to be prevalent. Şahin et al., (2008) state in their study that students' constant encounters with items like lamps and flashlights in daily life cause them to directly associate the concept of light with illumination and lead to the formation of incomplete or incorrect knowledge regarding the concept of light. Similarly, in our study, pre-service teachers made inferences about the speed of light based on such examples, but only a limited number of pre-service teachers were able to express the speed of light using numerical values or scientific explanations. Students using different numerical expressions when stating the numerical data of a concept means that they memorized this information and later forgot it (Cansüngü-Koray & Bal, 2002). Therefore, it can be said that pre-service teachers can intuitively make sense of the speed of light but struggle to express it scientifically.

As a result of our study, it was determined that the knowledge levels of pre-service teachers studying in the 2nd year of science education regarding their conceptual understanding of the 'Light' concept remained superficial, they struggled to explain the dual nature of light, and they mostly focused on the physical properties of light. Furthermore, it was found that pre-service teachers had difficulty using scientific knowledge and preferred to use affective expressions frequently employed in their daily lives when providing explanations. These findings indicate that pre-service teachers are insufficient in grasping abstract concepts like light and making sense of them at a scientific level. This situation will directly reflect on the professional lives of the pre-service teachers. Science education is an interdisciplinary course that includes numerous abstract concepts, such as light, which are frequently used in daily life. Based on this, it is first thought that techniques such as visualization, animation, and simulation should be used more frequently in the teaching of abstract concepts, in addition to experimental applications. With such methods, it may become easier for pre-service teachers to understand abstract concepts more deeply and structure them in their minds. Pre-service teachers encounter many concepts, such as the concept of light, which they frequently encounter in daily life, not only in science courses during their education but also in many areas of art, technology, and daily life. It is also believed that having the scientific content of the basic materials and resources used in the teaching of such interdisciplinary concepts prepared by scientific experts will contribute to the multifaceted understanding of these concepts. Determining and developing the knowledge levels, cognitive structures, or expression skills of pre-service teachers regarding fundamental and abstract scientific concepts like light throughout their educational lives is also crucial for their success in their professional careers. In addition, the early identification and remediation of students' misconceptions, knowledge gaps, and incorrect learning at every stage of instruction is important for concept teaching. In this context, conducting case studies focused on abstract concepts and their instruction, and examining them in depth, is highly important for science education and concept teaching.

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