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Analysis of the Thinking Process of Science Teachers: The Light Absorption Thought Experiment

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Abstract

The aim of this research is to investigate the thinking processes of science teachers who are master students in science education regarding the thought experiment designed for the light absorption. For this aim, the phenomenological study method, one of the qualitative research designs, was used. In the study, eight science teachers who were continuing their master were studied by using purposive sampling. Data were collected through interviews on the light absorption thought experiment. Data were collected through face-to-face problem-solving sessions, thinking aloud and backward questioning. From the data, it is seen that the teachers mostly showed secondary effects as establishing a new amount relationship, they carried out thought experiments to conviction, and while they preferred scientific concepts and intuition-based simulations as sources of thinking equally, spatial reasoning-symmetry-compound simulation and experience were preferred equally and less frequently. At the end of the research, it was concluded that the self-efficacy perceptions of the science teachers were high, having a command of the curriculum, having an uneasy mood when solving problems, and having hypothetical thinking skills.

Key words: Light absorption, physics education, thought experiment

INTRODUCTION

Physics helps us understand the universe and how physical phenomena take place. Physics not only helps us understand the universe, but also helps technological growth by emulating nature (Özel, 2004). The importance of understanding and teaching physics concepts is an undeniable fact at both secondary and high school levels. For this reason, the importance given to science literacy and science courses is increasing day by day. Science education in schools seems to play an important role regarding the problem which is the general lack of interest in science (Raes, Schellens & Wever, 2013). For students to adapt to life easily and achieve success, they need to know the world of science well and know how to benefit from this world. In the learning-teaching process, the teacher; It assumes the role of an individual who researches, questions, explains, discusses the source of information, and turns it into a product while taking on the roles of encourager and guiding to student (MoNE, 2018).

Everyone's understanding and interpretation of a topic or a problem occurs at different times and in different ways. There is a collective activity that takes place for everyone to think about. The knowledge we have in this action through the mind emerges through predictions or a

blending of knowledge and predictions. The pictures we see around us or the visualization process we perform in our minds reflect the cognitive process in our mind. In retrospect, it is seen that various ways and methods are used in the interpretation of thinking processes. It is seen that the thought experiments, also known as the laboratory of mind, which is a new approach used in the interpretation of scientific thinking, are used in revealing the individual's thinking processes and interpreting the thinking processes (Acar & Gürel, 2016; Gelen, Duran & Özer 2017; Gilbert & Reiner, 2000). Light is one of the basic parts of science and physics education. It is frequently encountered in daily life, and it is open to interdisciplinary use. In the literature, the subject of light absorption has been tried to be taught with different methods, approaches, and methods. These are named as modeling method (Şahin-Akyüz & Çil, 2013), alternative evaluation approaches (Er & Şaşmaz-Ören, 2015), teaching with educational game (Karamustafaoğlu & Yurtyapan, 2016), the use of concept cartoons (Sayın, 2015), computer supported (Mor, 2016), activity based (Yurumezoglu, Isik, Arikan & Kabay, 2015), metacognitive-based teaching (Güler-Gürsel, 2016), peer teaching (Mazlum & Yiğit, 2017), context-based learning approach (Karslı & Akın-Yanmaz, 2021). However, not enough research on thought experimentation has been found during the learning process.

In the related literature there was not any study that aimed to understand teachers' thought structures with thought experiments. Therefore, in this study, it is important to reveal the mentality of teachers who continue their graduate education in science education in the face of the facts and problems they encounter. In this context, in this study, it was aimed to investigate the thinking processes of science teachers who received postgraduate education to increase their own development in their profession, regarding the thought experiment developed for the absorption of light.

METHOD

In line with the aim of the study, the following research questions are addressed using the phenomenology method.

RQ1. What are the secondary effects of science teachers', who master students in science education, doing a thought experiment designed to absorb light on their thinking processes?

RQ2. What are the aims of science teachers who master students in science education to conduct a thought experiment designed to light absorption?

RQ3. What are the sources of thought of science teachers who master students in science education while conducting a thought experiment designed to light absorption?

The phenomenology method, which is one of the qualitative research methods, was used in this study. Two criteria were determined in line with the purpose of the study. The first of these criteria is to be a science teacher and the second is to continue graduate education. According to the purposeful sampling method, the participants of the study consisted of eight volunteer teachers who were active teaching and postgraduate studies. Demographic information of the participants is given in Table 1.

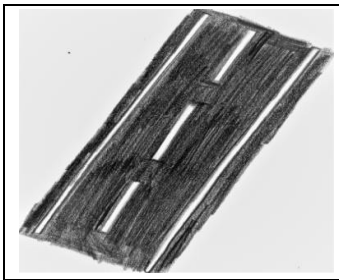
Table 1. Demographic information of the participants

Participants	Gender	Age	Graduated University	Professional Experience
P1	Female	36	19 Mayıs	13
P2	Female	26	Amasya	1
P3	Male	31	AİBU	7
P4	Female	32	Kocaeli	7
P5	Female	33	19 Mayıs	10
P6	Female	28	Gazi	6
P7	Female	30	Gazi	6
P8	Male	36	19 Mayıs	6

In this study, face-to-face problem-solving sessions, thinking aloud and retrospective questioning methods were conducted with the teachers to analyze the thinking processes of the teachers who continue their graduate education in

the field of science education regarding the light absorption thought experiment.

Within the scope of the study, a thought experiment was designed for the absorption of light included in the 7th grade ‘interaction of light with matter' unit of the Turkish Science Curriculum. This experiment is for the acquisition 'He discovers that light can be absorbed by matter as a result of its interaction with matter'. Data were collected from teachers through interviews on this thought experiment. The thought experiment designed to the light absorption, on which the interviews were conducted, is presented in Figure 1.



Imagine walking on a traffic-free asphalt road at noon on a hot summer day. After a while, when you look at the soles of your shoes and see that they are black, what do you think? Please explain.

Figure 1. The thought experiment designed to the light absorption

After each problem-solving session, the researchers revised the transcription process to avoid overlooked words and phrases. After the deciphering process was completed, all the collected data were read repeatedly, and it was tried to become familiar with the data. A research diary was kept at the stage of data collection. The information written in the research diary helped the participants to think in detail about their answers. A diary was also kept while providing data familiarity. The information in the diary was helpful in discovering and analyzing the data. The coding process was carried out by printing out the deciphered data and using colored pencils. Separate coding was done for each participant's deciphering process, and then by comparing them with the codes of the other participants, notes were taken in the diary while deciding the codes according to how often the codes were used. The codes were constantly reviewed and continued until a new code could not be created. After completing the coding process, the category process was carried out from induction to deduction. When the categories reach saturation, the category creation process is completed. The data were analyzed under three main issues in which the research questions would be answered. These main topics are sources of thought, for what purpose they use the sources of their thoughts and how their thoughts are affected in line with the aims. All coding and analyzes made throughout the research were reviewed by the researcher, an expert in this field. The stages of this phenomenological research are demonstrated in Figure 2.

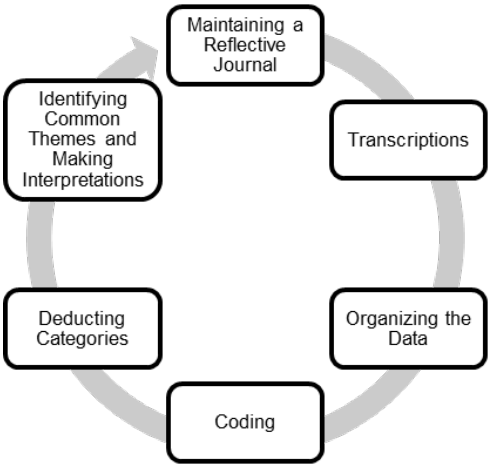


Figure 2. The performed stages of phenomenological research

RESULT AND DISCUSSION

This part of the study consists of three main issues. Results are presented using deductive and inductive techniques together.

1. Secondary Effects of Science Teachers on Light Absorption Thought Experiment

The secondary effect enables us to instantly comprehend the participants' thought patterns or methods of thinking after they have completed the thought experiment. The participant can build a consistent link between the past knowledge and the thought experiment, engage in conflict, or create a new schema by using thought experiments. These findings were categorized into three groups.

Establishing a New Coherence Relationship

The participant conforms between their prior knowledge and the thought experiment while doing the thought experiment. When a participant reads the thought experiment, s/he establishes consistency by applying prior knowledge to solve the difficulty arose.

P3: Now, of course, the asphalt heats up because it receives heat .., the temperature rises and we walk on it … the soles of our shoes become black. What happens to the ground part of the asphalt? It can change the color of our shoes because it gets a little hot, this is the way I reach a conclusion.

Establishing a New Conflict Relationship

It is the situation where the participant experiences a discrepancy between their prior knowledge and the ideas, they put forward during the thought experiment.

P5: … So, is the physical change like normal freezing or mild melting? I used to think my shoes were black, thinking that a meltdown had occurred in the asphalt. As an asphalt structure, hmmm, I don't know if it can become the same as it was in its original state.

Activating a New Schema or Schemas

It is the visualization of new schema or schemas in the mind of the participant who performs the thought experiments by using their prior knowledge. In other words, while the participant finds a solution to the problem, s/he associates some concepts related to the problem and not related to the problem and makes new interpretations.

P2: … But asphalt has to be very hot as such a material? Now I don't know what material asphalt is, but is it something that goes back to its original state when it cools down? The material it is made of is at a very high temperature, which means it is too hot so that it can indulge our shoes. Maybe the weather is very, very hot. I do not know what kind of material the asphalt is. But when we look at the soles of our shoes, if it is black, if it is only caused by this asphalt, if nothing black has been spilled on

the ground, it is because the asphalt melts, that is, it tends to melt slightly, or maybe that black pitch is coming out on its surface due to the heat. It could be because of that. …

Table 2. Secondary effects of science teachers on light absorption thought experiment

	P1	P2	P3	P4	P5	P6	P7	P8
(1)	+		+	+		+	+	+
(2)					+			
(3)		+						

(1- Establishing a New Coherence Relationship, 2- Establishing a New Conflict Relationship,3- Activating a New Schema or Schemas, P- Participant)

2. Thinking purposes of Science Teachers on Light Absorption Thought Experiment

Thinking purposes enable us to understand the purposes for which participants are doing the thought experiment. The results regarding the purpose of the participants to do the thought experiment are categorized into three groups.

Prediction

While offering solutions to the problems, the participants attempt to give possible answers to situations that they have not encountered before, or that they have not made any comments on the event, even if they have encountered it.

P5: I think the asphalt melted so that the bottom of my shoes became black… I used to think that my shoes were black, thinking that there was a meltdown on the asphalt. I do not know if the asphalt structure turned into its original state.

Conviction

Conviction is the participant's supporting the solution to the thought experiment with a formula, a law, or presenting it within the framework of some rules, in the light of scientific knowledge.

P1: ... The asphalt will absorb more light because of the heat and its black color. As it absorbs the light, the heat energy inside will increase. Due to the heat energy, that we call melting or liquefaction, will occur. This shows that the tar liquid, which gives the black color in the asphalt, will stick to the bottom of my shoes.

Explanation

The explanation is that the participants present their thoughts on the thought experiment with an example.

P8: I think it is difficult to find a vehicle on the traffic-free asphalt. Suppose I found … a phase change occurs due to temperature. The pitch material, which is solid before, receives heat and turns into a liquid. What happens as it turns into a liquid state? We get a black appearance on our shoe soles. This is a good possibility, but if your shoe sole is not of good quality, it also melts. I experienced before; I know it melts. Especially if you are someone like me whose shoes melt in the heat of July, I think you wouldn't go that road anyway. I think we would have suffered from a phase change.

Table 3. Thinking purposes of science teachers on light absorption thought experiment

	P1	P2	P3	P4	P5	P6	P7	P8
(1)		+		+	+			
(2)	+		+			+	+	
(3)								+

(1-Prediction, 2- Conviction, 3- Explanation, P- Participant)

3. Thinking Sources Used of Science Teachers on Light Absorption Thought Experiment

The results of the thinking sources used by the participants in the thought experiment are presented under six subheadings in this section.

Spatial Reasoning

It is the participant's ability to offer a solution more easily by adapting the existing situation to herself/himself.

P7: … heat causes solids to melt. I think of asphalt as a kind of solid material here, and it also starts to melt with the temperature. You step with your foot on this surface, if you apply a pressure, so when you look the bottom of your shoes, you can directly see the blackness there...

Symmetry

It is the participant's personal view about the situation in the problem and the development of an opinion in relation to the rules of nature.

P4: Well, when you mentioned the asphalt and noon time, I expect that you could ask me about the mirage incident, but you didn't mean it … Ha, when you say it's an asphalt on the closed road to traffic, isn't it a newly applied asphalt?... Is it a melting due to the heat? I hadn't thought the black color of the asphalt indulge our shoes. I thought that a different black substance stuck to my shoe sole from somewhere. I think that also melted that asphalt floor. Suddenly I realized that the black color on my shoes was the result of the asphalt melted.

Compound Simulation

Since the existing problem situation is interesting to the participant, the participant is directed to some situations and situations that should not be directed in reality.

P3: Now, of course, the asphalt heats up because it receives heat, which means, its temperature increases, and we walk on the asphalt. There is a heat exchange between our shoes and the ground, and because the friction force is also involved, naturally, the bottom of our shoes becomes black due to this energy exchange between them …

Experience

It is the participant's use of their experiences as a source in the thought experiment because they have encountered the problem in the thought experiment before or have experienced a similar situation.

P8: A phase change occurs due to temperature. The pitch material, which is solid before, receives heat and turns into a liquid. What happens as it turns into a liquid state? We get a black color on our shoe soles. This is a good possibility, but if your shoe sole is not of good quality, it also melts. As I experienced it before, I know it melts. Especially if you are someone like me whose shoes melt in the heat of July, I think you wouldn't go that road anyway. I think we would have suffered from a phase change.

Intuition-based Simulation

Since thought experiments are given on situations that can be encountered in daily life, the participant has unconsciously experienced this situation before but presents it without being aware of it.

P2: I imagine, so I say that the asphalt melts again… Maybe that black pitch is coming on the surface of the asphalt because of the heat. It can be because of that. But as I said before, I don't know what material an asphalt structure is like. I attributed the reason to the temperature, frankly, I couldn't think of anything else.

Scientific Concepts

It is the participant's solution to the problem situation in the thought experiment by explaining the concepts through an acquisition s(he) has previously presented to the students in the curriculum, an experiment s(he) has done, or an experiment s(he) has observed, or by using the analogy technique.

P6: As the asphalt is black and the season is summer, dark colors absorb the light on a hot day. So, I can say that it absorbs more, it reflects a little of it. Light colors reflect most of them and absorb a little. Since asphalt is black, it absorbs a large amount of light. That's why it melts because of the heat. As it melts, the soles of our shoes become black.

Table 4. Thinking sources used of science teachers on light absorption thought experiment

	P1	P2	P3	P4	P5	P6	P7	P8
(1)							+	
(2)				+				
(3)			+					
(4)								+
(5)		+			+			
(6)	+					+		

(1-Spatial Reasoning, 2-Symmetry, 3-Compound Simulation, 4-Experience, 5-Intuition-based Simulation, 6-Scientific concepts, P-Participant)

The scope of the tested topic and its contribution to the thought process were stated in Table 5 in the context of these three highlighted issues.

Table 5. The scope of the topic being tested and its contribution to the thought process.

Thought Process		P1	P2	P3	P4	P5	P6	P7	P8
1	(1)	+		+	+		+	+	+
	(2)					+			
	(3)		+						
2	(1)		+		+	+			
	(2)	+		+			+	+	
	(3)								+
3	(1)							+	
	(2)				+				
	(3)			+					
	(4)								+
	(5)		+			+			
	(6)	+					+		

(P- Participant, 1- Secondary Effects, 1.1- Establishing a New Coherence Relationship, 1.2- Establishing a New Conflict Relationship,1.3- Activating a New Schema or Schemas, 2- Thinking Purposes 2.1-Prediction, 2.2- Conviction, 2.3-Explanation, 3- Thinking Sources 3.1-Spatial Reasoning, 3.2-Symmetry, 3.3-Compound Simulation, 3.4-Experience, 3.5-Intuition-based Simulation, 3.6-Scientific Concepts)

Below is a discussion of the above-mentioned results. A combination of mental actions is called imagination. The term "thought experiments" refers to mental experimentation. Thinking while imagining is a cognitive activity that leads to some outcomes dependent on thought processes. Examining the mental processes of teachers is seen as beneficial in terms of education. The subject of “the gravity based on falling objects”, which is the subject of the research, is included in international science teaching programs. For example, while Indonesia is in the 8th grade in the science education curriculum, in the 11th grade in the UK physics curriculum, and in the 12th grade in the physics curriculum of France and Italy, Norway is within the scope of modern physics 1 & 2 courses (TIMSS & PIRLS International Study Center, 2015). In the study, it is aimed to investigate the thinking processes of science teachers who continue their graduate education in the field of science education, when they conduct thought experiments designed to absorb light. Table 2 shows that there is mostly a consistency between the information held by the participants and the information in the problem. Teacher's content knowledge and conceptual background (Johnson & Cotterman, 2015) and pedagogical skills related to innovations (Avidov-Ungar & Forkosh-Baruch, 2018; Zhu, Wang, Cai & Engels, 2013) increase the teacher's dominance of the curriculum. Since the thought experiment used in the study was aimed at an achievement in the Turkish Science Curriculum, the participants, both as teachers continuing their graduate education in the relevant field and as on-the-job teachers, may have easily interpreted the solution suggestions for the problems and established a relationship between them. As can be seen from Table 2, establishing a new conflict relationship, and activating a new schema or schemas took place much less frequently than the effect of establishing a new coherence relationship. According to Daniel (2016) Problem-solving is the application of mental and physical abilities in resolving a tasking situation. Many factors affect the participant while solving the problem. One of them is emotional state. If the participant has a tense or stressful mood in the problem-solving session, he may be directed to establish a conflict relationship between the information he has before and the information in the problem. In activating new schemas, the participant is in the situation of establishing turning to other situations with the existing situation in the problem instead of a new conflict relationship or a new coherence relationship (Clement, 2008). The participant may have encountered the problem in daily life, but because he did not pay attention, he may have wanted to learn the reasons and interpreted it differently.

Certainly, the act of thinking is performed to conclude about any situation. In the study, it was aimed to investigate the thinking processes of science teachers in the process of conducting a thought experiment designed to light absorption. It is understood from Table 3 that the participants are frequently involved in producing a solution by

presenting evidence, which is one of the purposes of performing thought experiments. Presenting evidence while generating solutions to the thought experiment; carried out using a law, a scientific rule, or formula. The main goal is to raise individuals with integrated knowledge, skills and behaviors included in the competencies of the Turkish education system (MoNE, 2018). The eight competencies that science teachers have are the most significant elements in gaining students the eight basic skills specified in the Turkish Qualifications Framework (TQF). The participants in the study produced solutions by presenting evidence to the problems. This situation shows that the participants have full knowledge of the basic competence in science and technology, which is one of the eight competencies, and the knowledge and skills in three dimensions included in item 43 of the Turkish National Education Basic Law (TNEBL) (SPO, 2000). When Table 3 is examined, it is seen that the second frequency is prediction. When the internal information schemes in the long-term memory start to think about a system, they are activated and make predictions on the system (Clement, 2008). The professional experience of the participants ranged from one to thirteen years. Bağçeci and Kinay (2013) revealed that teachers with five years or less of professional experience act more hastily than those with more than twenty years, but those with more than twenty years have more self-confidence. In this context, since the participants of the study are teachers who continue their graduate education, the possibility of their answers being wrong may have caused them to be nervous and may have led them to make guesses instead of answering the problem clearly. From the findings, it is seen that only one participant performed the thought experiment for the purpose of making an explanation. According to Clement (2008), performing thought experiments for the purpose of explanation; Arguing over the situation is simply a way of giving similar or dissimilar examples to the situation, without the purpose of proof. Even though it shows that the general cultural knowledge in item 43 of TNEBL is not at a sufficient level, the fact that the examples given are related to daily life can be interpreted as the ability to learn, which is one of the eight keys of TQF, by making use of natural events.

Our personal differences emerge when we unconsciously use our sources of thought while performing the act of thinking. From the data in Table 4, it was understood that the participants frequently preferred scientific concepts and intuition-based simulation as a source of thought. In the relevant literature, it is stated that people do not only have logical mathematical thinking, but also need to pass their thoughts through the emotional filter (Damasio, 2006; Tuyakova et al. 2022). The fact that the participants prefer scientific concepts as a source of thought may show that they can think hypothetically. Both experiments and intuitions, which are seen as mental activities, are used together to obtain information (Bergson, 2013). The fact that the intuition-based simulation was not used as a source of thought because the participants were directed to scientific thinking rather than their intuition in teaching science indicates that teachers' self-efficacy perceptions are high. According to Table 4, it is seen that the sources of experience, compound simulation, symmetry and spatial reasoning are used equally frequently. While the right hemisphere of the brain uses existing information, the left hemisphere produces information that is not based on a hypothetical basis or draws conclusions, that is, the left hemisphere of brain creates theories by constantly inferring broad meanings (Boydak, 2017). The purpose of reflective thinking is to reveal acquired implicit knowledge. Participants who use their experiences as a resource in the thinking process can show that they can think reflectively because the experiences are used as a resource without awareness. Analytical thinking principles encourage considering different possibilities, and then gradually focuses more on the best of these alternatives (Nuroso, Siswanto & Huda, 2018). Tian et al. (2014) stated that Analytical thinking is the ability to know the details or explain a problem into smaller components and to understand the interrelationships among those components. Accordingly, it can be said that the participants

who use compound simulation as a source of thought have analytical and integrative thinking. If the situation in the problem is too complex for the participant, the participant tries to reach a solution by making spatial changes and making the problem convenient and easy (Lindsay, 1988). Because creative thinking skill is related to problem posing skill (Contreras, 2013; Elgrably & Leikin, 2021; Puspitasari, In'am & Syaifuddin, 2018; Van Harpen & Sriraman, 2013; Wulandari, Sa'dijah, As'ari & Rahardjo, 2018). Accordingly, it can be said that the participants who use spatial reasoning as a source of thinking can think creatively. It can be said that the participants who use symmetry as a source of thought also have vertical thinking competence. This idea is supported by Frank's (2013) statement that vertical thinking tends to be analytical, sequential, and finite process. It uses the negative to block certainty, forces to exclude what is irrelevant and always follows the most likely path.

CONCLUSION

The results obtained in the study Three types of secondary effects arise in the thinking process when science teachers carry out thought experiments designed for light absorption namely establishing new coherence relationships, establishing new conflict relationships, and activating new schemes or schemes. participants were directed to different sources of thought according to the problem, but they more often chose scientific concepts and attention-based stimulation that impacted hypothetical thinking skills and perceptions so as to motivate them through their thinking. These results indicate that this study has achieved its objectives. In conclusion, this study contributes to understanding the mentality of science teachers towards the realities and problems they face.

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