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A Thought Experiment On Gravity Based On Falling Objects: Investigation Of Science Teachers' Thinking Process

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This study aims to analyse the thought processes of science teachers who are master students in scientific education using a thought experiment on gravity based on falling objects. The phenomenological study approach, one of the qualitative research methodologies, was used to achieve this aim. Purposive sampling was used to investigate eight science teachers continuing their master's degrees. Data was collected through interviews and a thought experiment on gravity based on falling objects. The teachers participated in Face-to-face problem-solving sessions, thinking aloud and backward questioning sessions. Results reveal that the teachers mostly showed secondary effects as establishing a new amount of relationship, carrying out thought experiments to predict, and preferring scientific concepts and hypothetical simulations as sources of thinking. Likewise, spatial reasoning-symmetry-compound simulation and experience were equally and less frequently preferred. Results also show that science teachers had strong self-efficacy judgments, a mastery of the curriculum, an unpleasant attitude when dealing with difficulties, and hypothetical thinking skills.

KEYWORDS: Gravity Based on Falling Objects, 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 knowing and teaching the principles of physics at both secondary and high school levels

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cannot be overstated. As a result, science literacy and science education are becoming more and more important. School-based science education appears to play a significant role in addressing such a common problem as a lack of interest in science (Raes et al., 2014). To quickly adapt to life and achieve success, students must understand the world of science and how to benefit from it. In the learning-teaching process, the teacher adopts the position of an individual who studies, questions, explains, discusses and transforms the information source into a product, and encourages and directs it at the same time (MoNE, 2018). The way people understand and interpret a topic, or a situation differs in different periods and ways. There is a collective activity that takes place for everyone to think about. Predictions or a mixture of information arise through the mind as the knowledge we have in this action. The images we see around us, or the visualization exercises we do in our minds represent our mental processes. In retrospect, various methodologies and approaches are used to interpret thought processes.

Review Of Thought Experiments

The idea was first suggested in thought experiments by Danish physicist Hans Christian Örsted in the 19th century. The impact of thought experiments on hypotheses and conjectures was explained by Örsted. A historical thought experiment, however, was neither discussed nor examined by him (Witt-Hansen, 1976). Ernst Mach is generally acknowledged to be the first scientist to use thought experiments in the literature review. Mach actually created the systematic explanation of the thought experiment notion. Ernst Mach highlighted the evolution of thought experiments and their significance for the development of the mind (Gendler, 1998). The use of thought experiments is debatable from a philosophical and scientific perspective. There is not a precise definition of the idea of thought experiments in the literature review. For this reason, thought experiments have several meanings and explanations. Sorensen (1992) and Wilkes (1988) noticed thought experiments as a source of scientific information. In order to stimulate thought, experiments with open-ended consequences are used (Bunzl, 1996). According to James Robert Brown (1991), thought experiments are difficult to define. Thought experiments are mental exercises that can be imagined. They are based solely on hypotheses; no conclusions can be drawn from calculations alone. However, upon closer inspection, it becomes clear that they are thought experiments. According to Gilbert and Reiner (2000), thought experiments are complementary to genuine experiments. Thought experiments and actual experiments have a lot in common. The student must take some sort of active role in his own learning process to achieve permanent learning. Kuhn (1963) asserts that the basic strategy for teaching science and giving it meaning is to get rid of all unnecessary details. Scientific findings that are independent of context, or issues with theories and laws, suggest that these should be taken into consideration. As was previously established, no scientific material is used in thought experiments. It is the process of mentally understanding all scientific knowledge. It can be shown that thought experiments, also known as the laboratory of the mind, are used to explain and analyse the thinking processes, a new technique used in the interpretation of scientific thought (Acar & Gürel, 2016; Gelen et al., 2017; Gilbert & Reiner, 2000).

The Current Study

Gravity is one of the main parts of science and physics education. It's a common occurrence in daily life, and suitable for multidisciplinary applications. Before starting education, people can see the sky with their naked eyes and continue to live with second-hand information about events occurring in the sky, adding meaning to them using their interpretations. Unfortunately, misunderstandings arise from tactics that are regularly seen in daily life and extremely difficult to correct (Yürük et al., 2000). If teachers, who are crucial aspects of education, have such errors, this information, contrary to scientific facts, is transferred from generation to generation and continues in this way. In a study of Israeli children aged 9–17 years, Bar et al. (1997) discovered that the source of gravity is frequently a magnetic force that requires a medium—air—to be carried from the ground to the item. According to Watts (1982), gravity is "selective" for 12-year-old British children because it does not apply to bodies at rest or objects thrown into the air. Palmer (2001) found that 11- to 16-year-old Australian students believe that gravity is a phenomenon that occurs exclusively on the Earth. Vosdianou (1994) observed that Greek kids do not regard the earth as a planet until the end of primary school, but rather as a physical entity with its laws, and Baldy and Aubert (2005) found that this differentiation remains among 15-year-old students. When traditional teaching methods are applied, students' concepts are resistant and change little with age.

In this context, this study aims to evaluate the thinking processes of science teachers who receive postgraduate education to advance their professional development, in relation to a thought experiment devised for gravity based on falling objects.

Research Questions

The research problems of this study were determined as follows, based on the mentioned aim:

RQ_1. What are the secondary effects on the thinking processes of science teachers who are master students in science education and who conduct a thought experiment designed to explain gravity based on falling objects?

RQ_2. What are the aims of science teachers who are master students in science education to conduct a thought experiment designed to explain gravity based on falling objects?

RQ_3. What are the sources of thought of science teachers who are master students in science education while conducting a thought experiment designed to explain the gravity based on falling objects?

Research Model

Participants in the phenomenology approach have first-hand knowledge of the phenomenon which is working in all of its aspects Creswell (2012) . According to Nitsche (2020), phenomenology, this method of teaching has become more popular recently. The fields of education commonly use two types of phenomenological approaches: descriptive and interpretive. In this study, the descriptive phenomenology approach, one of the qualitative research methodologies, was preferred.

Research Participants

Two criteria were established in accordance with the purpose of the research: you must be a science teacher, and you must continue your education after graduation. According to the purposeful sampling method, the participants consisted of eight volunteer teachers who were actively teaching and continuing their education. Table 1 shows the demographic characteristics of the participants.

Table 1

Demographic Characteristics of the Participants.

Participants	Gender	Age	Graduated University	Professional Experience
P1	Female	36	Ondokuz Mayis	13
P2	Female	26	Amasya	1
P3	Male	31	AiBU	7
P4	Female	32	Kocaeli	7
P5	Female	33	Ondokuz Mayıs	10

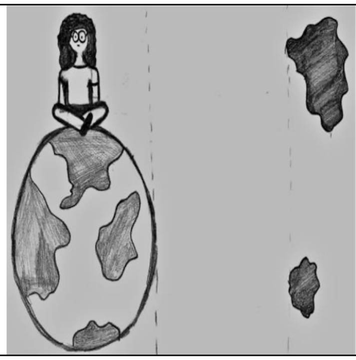
Continued on next page

Table 1 continued

P6	Female	28	Gazi	6
P7	Female	30	Gazi	6
P8	Male	36	Ondokuz Mayıs	6

Thought Experiment

The thought experiment on gravity which was used in this study is illustrated in Figure 1.



Assume the Earth does not spin. Assume you're seated on the Earth, and you have glasses that allow you to see a long distance. You checked your watch when you saw that two meteorites, one bigger than the other, were travelling towards the Earth side by side. Which meteorite will arrive on the Earth first?

Figure 1. The Thought Experiment Designed to The Gravity Based on Celestial Bodies.

Data Collection

In this study, face-to-face problem-solving sessions, thinking aloud, and retrospective questioning methods were conducted with the teachers to analyse their thinking processes regarding the thought experiment on gravity based on falling objects. Within the scope of the research, a thought experiment was created for the unit of 'gravity based on falling objects' in the 7^{th} grade Turkish Science Curriculum. This experiment is for the acquisition 'S/he discovers that gravity can be explained on the falling objects.' Data were collected from teachers through interviews on this thought experiment.

Data Analysis

The researchers changed the transcribing procedure after each problem-solving session to avoid missing words and phrases. After decoding, the entire obtained material was read several times to gain familiarity. A research diary was kept during the data-collecting phase. The material recorded in the research diary helped the participants delve deeper into their responses. A diary was also kept while familiarizing the data. The data was discovered and analysed with the help of the information in the diary. The coding was done by printing out the decrypted data and colouring it with coloured pencils. Separate coding was done for each participant's decoding procedure, and then the notes were collected in the diary while choosing the codes based on how often they were utilized by comparing them to the codes of the other participants. The codes were examined regularly and continued until new codes could not be established. The category process was carried out from induction to the deduction phase after the coding phase was completed. When the categories reach saturation, the category creation process is completed. The data were analysed under three main issues to answer the research questions. These main topics are the 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 analyses made throughout the research were reviewed by the researcher, an expert in this field. Figure 2 illustrates the steps of this phenomenological investigation.

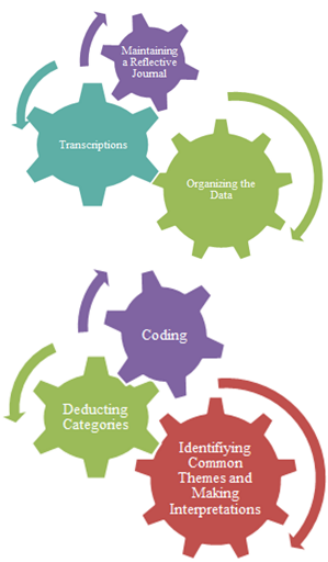


Figure 2. The Steps of This Phenomenological Investigation.

Findings Of The Study

Within the scope of the study, there are three main problems in this part of the research. The results are presented using a combination of deductive and inductive methodologies and data is presented in Table 2.

Secondary Effects of Science Teachers on The Gravity 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 that arose.

P4: *...Both will be subjected to the same gravitational forces exerted by the Earth. As a result, they both arrive in the world at the same time. Or, in the case of a falling object, does the heavier one fall faster? However, because it is in space, there is no friction force. The smaller item falls faster after entering the Earth's atmosphere because it exerts more frictional force on the bigger object and less on the smaller object. If we include friction, we can see that the smaller meteor would drop more quickly. However, whether we consider an item in celestial bodies or on the Earth, we may believe that if we drop two huge bottles of water, one 5 litres and one 1 litre, from the fifth floor, we think as if the heavier one will fall faster. However, when the friction of the environment is taken into account, the smaller one would fall quicker because the smaller atmosphere will not block it, but the larger one will. Then I choose tiny meteor."*

Establishing a New Conflict Relationship

It is a circumstance in which the participants notice a discrepancy between their prior knowledge and the thoughts they present during the thinking experiment.

P1: If we assume that the force of the Earth would remain the same, the smaller one should become a meteorite in a shorter time... Right now, I'm considering abandoning *my first response. In reality, there exist gravitational forces between the masses… Hmm, is it different when it comes to space? Stuffy atmosphere… The smaller one is quicker, but it asks for our time rather than our speed. Would it have been different if the question had been about speed? The result would be different because kinetic energy increases as mass increases. However, when it comes to duration, I believe the smaller meteor will become a meteorite in a shorter time. But what if you're a meteorite? Their scenario prior to entering the environment, perhaps their initial scenario, as I previously stated. However, I can predict that the speed of the smaller meteor will drop after it enters the atmosphere since it will be subjected to less air resistance.*

Activating a New Schema or Schemas

It is the visualization of new schema or schemas in the mind of the participant doing thought experiments based on prior knowledge. In other words, while looking for a solution to the problem, s/he associates some concepts related to and not related to the problem and produces new interpretations.

P2: They reached the atmosphere and began to burn since one is bigger than the other. Because it is larger around it, the larger one must burn more due to friction. Exactly, there should be more friction in the atmosphere, not combustion. Hmmm, that the effect of combustion is accelerated by friction. I'm thinking… It needs to burn when it hits the atmosphere regardless, or at least some of it does at first, but not all of it burns, and the rest falls as meteorites. I think about the moment when it burned in the atmosphere. Is it accelerating? If I assume there is no acceleration, the one with higher mass should fall faster and arrive sooner. But if I look at the friction, the larger mass must be subjected to higher friction because the area is bigger. However, gravity forces the greater mass to drop first. When I consider it, the one with the greater bulk falls first. I discover two solutions here if I start from this point. If they have the same mass, and one has a greater area, we may assume the same. The bigger one will most certainly fall sooner, or if we consider that it accelerates more, the one with the greater mass will descend faster.

Table 2

Secondary Effects of Science Teachers on Gravity Thought Experiment.

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

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

Thinking Process of Science Teachers on The Gravity Thought Experiment

Researchers can understand why people do the thought experiment by looking at their thinking purposes. The results describing the participants' purpose for participating in the thought experiment are categorized into three groups and data is presented in Table 3.

Prediction

While offering solutions to the challenges, the participants attempt to provide viable solutions to circumstances that they have never experienced before or for which they have not made any remarks, even if they have.

P3: … I believe it to be the larger one, but I'm not certain. Because the big one has lots of energy, I reasoned. The only response I can provide is that because kinetic energy is dependent on both mass and velocity, but is larger in one, it will be prone to more friction. Its speed will also slow down. I couldn't offer a whole healthy response because I'm now confused. Therefore, one of them has more bulk, and the other has less.

Conviction

In the gravity of scientific knowledge, conviction is the participant's support for the answer to the thought experiment with a formula, a law or presenting it inside the framework of specific norms.

P6: The one has a huge mass since the gravitational force is proportional to the mass, i.e., the larger the mass, the higher the gravitational force. As a result, the bigger one has more mass, i.e., the bigger one has a mass. Because greater gravity is given to a larger mass, it arrives more quickly. As a result, it arrives faster because it will be subjected to increased gravitational force.

Explanation

The answer is that the participants use an example to communicate their ideas on the thought experiment.

P8: … When you observe them side by side, you can tell that the speed of one meteorite is different from the speed of the other. Since that implies, they didn't become side by side before, and if their speeds are the same from the start, which I don't believe they are, the mass will not influence the speed with which they approach the earth because there is no air there. There is no friction because there is no air. Because there is no friction, both are affected by the same gravitational force. We were doing this *in the experimental environment as follows. When we left a little mass and a large mass in a closed container, their fall speed and duration were the same, but when we left them in an atmosphere containing air, things changed. Of course, because there isn't any air here, which one will turn into a meteorite first? But, as I already stated, they weren't initially adjacent to each other when we saw them side by side. Someone is almost certainly faster than the other… Let's pretend the large asteroid is moving quickly. If the huge meteor is moving quickly, it suggests the smaller meteor is moving quickly as well. And the huge meteor will very certainly surpass the little one. As a result, it will arrive sooner. On the contrary, if the tiny meteor is quick, the small meteor will arrive first and crash. As a result, I don't believe there is a clear answer to this question.*

Table 3

Thinking Process of Science Teachers on Gravity Thought Experiment.

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

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

Thinking Sources Used by Science Teachers on The Gravity Thought Experiment

This section presents the findings of the thinking sources employed by the thought experiment participants under six subheadings and data is presented in Table 4.

Spatial Reasoning

It is the ability of the person to produce a solution more easily by changing the existing circumstance according to herself/himself.

P2: It's been a while since I've sat on the earth, and we're doing so right now, but I couldn't visualize it… It needs to burn when it hits the atmosphere regardless, or at least some of it does at first, but not all of it burns, and the rest falls as meteorites. I think about the moment when it burned in the atmosphere. Is it accelerating? If I assume there is no acceleration, the one with higher mass should fall faster and arrive sooner. But if I look at the friction, because the area is bigger, the larger mass must be subjected to higher friction. However, gravity forces the greater mass to drop first.

Symmetry

It is the formation of an opinion following the norms of nature and the participant's perception of the situation in the problem.

P8: There is no friction because there is no air. Because there is no friction, both are affected by the same gravitational force. We were doing this in the experimental environment as follows. When we left a little mass and a large mass in a closed container, their fall speed and duration were the same, but when we left them in an atmosphere containing air, things changed. Of course, because there isn't any air here, which one will turn into a meteorite first? But, as I already stated, they weren't initially adjacent to each other when we saw them side by side. Someone is almost certainly faster than the other… Let's pretend the large asteroid is moving quickly. If the huge meteor is moving quickly, it suggests the smaller meteor is moving quickly as well. And the huge meteor will very certainly surpass the little one. As a result, it will arrive sooner. On the contrary, if the tiny meteor is quick, the small meteor will arrive first and crash. As a result, I don't believe there is a clear answer to this question.

Compound Simulation

As the participant deals with the current difficulty scenario, s/he is directed to various circumstances and situations that should not be directed in reality.

P4: …Both will be subjected to the same gravitational forces exerted by the earth. As a result, they both arrive in the world at the same moment. Or, in the case of a falling object, does the heavier one fall faster? However, because it is in space, there is no friction force. The smaller item falls faster after entering the earth's atmosphere because it exerts more frictional force on the bigger object and less on the smaller object. If we include friction, we can see that the smaller meteor would drop quicker… However, when the friction of the environment is taken into account, the smaller one would fall quicker because the smaller atmosphere will not block it, but the larger one will. Then I chose a tiny meteor.

Experience

It is the participant's use of their own experiences as a source in the thought experiment since they have already faced the problem or have experienced a circumstance comparable to the one in the thought experiment.

P1: … There was a paper experiment, for example, when we put the normal A4 paper on the ground, and at the same time we dropped the crumpled paper from the same height, the one with the smaller surface area would fall faster. Meteorites are subjected to the Earth's gravity field. The force exerted by the earth will be the same. According to this reasoning, the smaller one should become a meteorite in a shorter *time.*

Hypothetical Simulation

Because thought experiments are based on real-life scenarios, the participant has instinctively experienced the circumstance previously but presents it without realizing it.

P7: … Which would come first, the extremely huge or a rather smaller one? I believe the smaller one would have come sooner. If you're wondering the reason, it's because it's smaller in mass, or because it appeared to move more quickly. The smaller one appeared to be approaching me quicker, but the large meteorite fragmentation and other factors were blocking it.

Scientific Concepts

It is the participant's answer to the issue scenario in the thought experiment by explaining the ideas through an acquisition previously taught to the students in the curriculum, an experiment done or seen, or by employing the analogy approach.

P6: …The one has a huge mass since the gravitational force is proportional to the mass, i.e., the larger the mass, the higher the gravitational force. As a result, the bigger one has more mass, i.e., the bigger one has a mass. Because greater gravity is given to a larger mass, it arrives more quickly. As a result, it arrives faster because it will be subjected to increased gravitational force.

Table 4

Thinking Sources Used by Science Teachers on Gravity Thought Experiment.

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

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

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

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)			x	x	x	x	x	
	(2)	x	x						
	(3)								x
2	(1)	x	x	x				x	x
	(2)				x	x	x		
	(3)								
3	(1)	x	x					x	
	(2)								
	(3)				x				
	(4)								x
	(5)			x				x	
	(6)					x	x		

(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-Hypothetical Simulation, 3.6-Scientific Concepts, P- Participant)

Discussion Of Results

Below is a discussion of the above-mentioned findings. 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 "gravity based on falling objects", which is the subject of the research, is included in international science teaching programs. For example, according to the study on 15-year-old students' perceptions of falling corpses (Baldy & Aubert, 2005), students at this age use a variety of explanatory systems to explain the phenomena, depending on where it happens. The idea that objects fall due to gravity only applies to events that happen on the Earth. Since there is no atmosphere on the moon or in space, objects float because they are in a vacuum. According to Galili (2001), the ″too-complex″ view of current physics, ″deprives us of a golden chance to assist students to get a greater comprehension of the ideas of gravity and weight.″ According to Vosdianou (1994) and Bar et al. (1997), ninth graders, do not comprehend. Einstein's theory provides a geometric explanation for objects falling independently of gravity. Students should be able to see that bodies ″simply″ have the effect of ″deforming″ the space-time that surrounds them and that this deformation affects their course as they pass near one other.

The study aims to examine the thinking processes of science teachers who continue their graduate education in the field of science education when they conduct thought experiments designed to explain gravity based on falling objects. Table 1 shows that the information held by the participants and the information in the problem are generally consistent. The teacher's subject knowledge (Johnson & Cotterman, 2015), conceptual background, and pedagogical abilities associated with innovations (Avidov-Ungar & Forkosh-Baruch, 2018; Zhu et al., 2013) contribute to the teacher's curricular domination. Since the thought experiment used in the study was aimed at 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 shown in 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 process of using mental and physical talents to solve a problem. Several factors have an impact on the participant's ability to solve the problem. Emotional condition is one of them. If the participant is in a tense or anxious mood during the problem-solving session, S/he may be told to create a conflict between the knowledge s/he already knows and the information in the problem. When activating new schemas, the participant has to turn to other scenarios related to the current situation in the problem, instead of developing a new conflict connection or a new coherence relationship (Clement, 2008). The person may have come with the problem in daily life, but s/he may have tried to discover the reasons and interpreted it differently because s/he did not pay attention. The process of thinking is used to reach a conclusion in any scenario. The study aims to investigate the thinking processes of science teachers in the process of conducting a thought experiment designed to gravity based on falling objects.

When Table 3 is examined, it is seen that the highest frequency is prediction. Internal information systems in long-term memory are triggered when they begin to think and make predictions about a system (Clement, 2008). The participants' professional experience ranged from one to thirteen years. According to Bağçeci and Kinay (2013), teachers with five years or less of professional experience act more hastily than teachers with more than twenty years, while those with more than twenty years have more self-confidence. Since the participants are teachers continuing their education, the potential of their responses being incorrect may have worried them and made them guess instead of solving the problem completely. It is understood from Table 3 that the participants rank second in solving by presenting evidence, which is one of the aims of thought experiments. Using a law, a scientific rule or a formula provides evidence while creating answers to the thought experiment. The major purpose is to raise individuals who are integrated with the knowledge, abilities and behaviours that are part of the competencies of the Turkish education system. 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 came up with answers to the problems by offering evidence. This circumstance demonstrates that the participants are fully aware of the fundamental competency in science and technology, which is one of the eight competencies, as well as the knowledge and abilities in three dimensions outlined in the Turkish National Education Basic Law item 43 (SPO, 2000). When Table 3 is examined, it is seen that the second frequency is prediction. Only one person did the thought experiment to explain according to the findings. According to Clement (2008), performing thought experiments for the aim of explanation; and arguing about the circumstance is merely a means of offering comparable or different instances to the scenario, without the objective of evidence. Even though it shows that the general cultural knowledge item 43 in 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 using natural events.

Our personal differences emerge when we unconsciously use our thought resources while executing the thinking process. According to the data in Table 4, the participants generally chose scientific concepts and hypothetical simulation as a source of thought. According to the literature, people should not only think logically and mathematically but also process their views via an emotional filter (Damasio, 2006). The fact that participants prefer scientific concepts as a source of cognition may be an indicator of their hypothetical thinking abilities. Experiments and intuitions, considered mental activities, are combined to gather information (Bergson, 2013). Since the participants tend to think more scientifically than intuition in science teaching, hypothetical simulation was not used as a source of thought. This shows that teachers' self-efficacy perceptions are high. Table 4 shows that experience, compound simulation, symmetry, and spatial reasoning resources are all used in equal amounts. While the right hemisphere of the brain benefits from current data, the left hemisphere generates data that isn't based on speculation or inference. In other words, the left hemisphere of the brain constantly generates hypotheses by continually 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 before focusing on the best of these options (Nuroso et al., 2018). According to Tian et al. (2014), analytical thinking is the capacity to know the details or break down an issue into smaller components and grasp the interrelationships between them. As a result, it can be thought that people who use composite simulation as a source of cognition exhibit analytical and integrative thinking. If the scenario of the problem is too complex for the participant, s/he will try to solve it by making spatial changes and making the problem more comfortable and easier to solve (Lindsay, 1988) because the problem-posing skill is related to creative thinking ability (Contreras, 2013; Puspitasari et al., 2018; Van Harpen & Sriraman, 2013; Wulandari et al., 2018). As a result, people who use spatial reasoning as a source of thought can think creatively. It can be said that the participants who use symmetry as a source of ideas can think vertically. According to Frank (2013), vertical thinking is an analytical, sequential, and limited process. It uses the negative to avoid certainty, forces irrelevant information to be excluded, and always chooses the most likely path.

Conclusions

The results obtained in response to the research questions on the gravity thought experiment are given in the order in which they were received.

Secondary Effects of Science Teachers

When science teachers conducted thought experiments based on falling objects, three types of secondary effects arose in the thinking processes. These are establishing a new coherence relationship, establishing a new conflict relationship, and activating a new schema or schemas. It was determined that the participants had a grasp of the science curriculum, field expertise, and conceptual infrastructure since they created a new quantity connection. The participants' uncomfortable or anxious moods were attributed to the establishment of a new conflict relationship. It was observed that the participants became aware of their surroundings as they activated new schemes and schemes.

Thinking Process of Science Teachers

It was discovered that science professors frequently conduct thought experiments to make predictions. According to the findings, the participants were in an uneasy mood when they made predictions based on thought experiment solutions, they had basic competency in science and technology from presenting conviction, and the ability to learn in TQF was achieved through nature because of their explanations.

Thinking Sources Used by Science Teachers

According to the findings, although the participants valued scientific concepts and hypothetical simulation the most, they turned to different thinking sources according to their difficulty levels. They chose spatial reasoning, symmetry, complex simulation, and experience as sources equally often. It was observed that the hypothetical thinking skills and self-efficacy perceptions of the participants were high. It has been observed that analytical thinking and integrative thinking skills are high when they use the experiences; their creative thinking skills are high when they use compound simulations; when they use symmetry and hypothetical simulations, they are able to filter their emotions through their minds.

Finally, physics courses are challenging in every country, including ours Faisal and Martin (2019) . Thought experiments are used to explain the results of physical theories and to bridge abstract concepts (Uyar & Karamustafaoğlu, 2022; Velentzas & Halkia, 2013).

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