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Thought Experiment in Solving Physics Problems: A Study into Candidate Physics Teachers *

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Abstract

The current study is a two-step survey aiming at determining thought experiments designed by students within problem solving behavior and the structure. The first step was carried out with 22 first year and 28 fifth year students studying in the Program of Physics Teaching. A scale made up of 6 open ended questions regarding the motion law was used and the answers given by the students were examined through codes made to allow them to design a thought experiment. In the second step, an unattended observation was made to determine the thought experiment they will show in another test made up of 4 open – ended questions. Following the observation, semi-structured interviews were made with the students. At the end of the data analysis, the structures of the thought experiments were compared and the differences and similarities found were discussed.

Keywords

Thought experiment
Physics education
Problem solving
Motion law

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Introduction

Scientists having no opportunity to realize complicated experiment mechanisms realized their experiments adding a great many innovations to the history of science through experiments. Made in the "mental laboratories", these experiments had a preparation period with the information transformed from the earlier periods and emerged through a group of intellectual activities. As an example, when Newton started to think about gravitation, he benefitted from some existing information about moving objects to a large extent (Bixby, 2002; Grant, 2007). "Thought experiments" where human mind is enough as a mechanism offer us some examples of imagination and creativity. Thought experiments help us decide whether the claims and explanations with regard to logical relations among concepts are valid universally (Schcik, 2003; Clatterbuck, 2013). "Heisenberg's Gama Ray Microscope" and "Einstein's Photon Equation", and "Stevin's Chain", "Maxell's Gin" concerning thermodynamic laws, "Schrodingen's Cat" and "Newton's Bucket" with regard to quantum physics and "Galileo's Free Fall Experiment" regarding thought experiments are all examples offering thinking opportunities over physics laws.

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Thought experiments are the processes of reasoning based upon the results of an experiment realized in a thought (Reiner, Haifa and Gilbert, 2000). According to Gendler (1998), carrying out a thought experiment means producing judgments and comments over what will happen in the case of making the things and events in an imaginative scenario real. Various types of these experiments could be used to support, criticize a theory or to create a new one. It has been observed that creating and using thought experiments help students solve problems. In this way, they would have an opportunity to cooperate with other students in this process and have a talk over the results. That's to say, they would behave just like a scientist in this sense (Reiner, 1998, 2000). Bearing this concept could make the student attain the ability to judge correctly over the applicability of it even in an imaginative case (Schcik, 2003; Clatterbuck, 2013).

Thought experiments could be regarded as arguments with regard to certain hypothetical events or cases and these are in special relation with both a certain "background theory" and earlier experimental observations. It is essential that this special relation between a thought experiment and observatory/theoretical process exhibit at least a few, if not all, of scientific features characterizing the experiments in general. These features could be given in general sense as follows (Irvine, 1991):

1. A thought experiment should have a quality that could test a hypothesis formed as a result of a certain observatory / theoretical process or answer a set of questions obtained in a similar way.
2. Most, if not all, of the hypotheses within a thought experiment should be verified by independent experimental observations. In short, if there is going to have any relation with general scientific research, thought experiment should at least be based upon observable world.
3. Imaginative conditions realized by a thought experiment should be recognized well so that the quality of renewability sought in real experiments could be obtained even in the limits of thought.
4. As in real experiments, dependent and independent variables should be recognized in thought experiments as well; therefore, cause and effect relation could be perceived in a good way.
5. The results of thought experiment should be discussable depending on the theory at the background of the experiment. They should be question whether they support some dimensions of the theory or have a contrast with it so that the consistency of the experiment with its starting point could be discussed.

Brown (1991) put forward a three-classification system with regard to thought experiments as Destructive, Constructive and Platonic. *Destructive Thought Experiment* is a view acting against a theory which is destructed in the end or points out serious problems by mentioning about a mistake in the general structure of this theory. The bases of *Constructive Thought Experiment* depend on the establishment of the fact of thought experiment (in mind). Constructive thought experiment is divided into three sub-groups. *Mediative Thought Experiment;* it is a thought experiment created in the basis of a certain theory. *Conjectural Thought Experiments;* theories are hypothesized in order to explain some thoughts and experimental facts. *Direct Thought Experiments;* these are made up of both mediative and conjectural sub-type elements. However, only one is used by scientists. Thought experiments in this type start with a non-problematic fact (intellectual – experimental) and finishes with a theory. *Platonic Thought Experiment;* it is both a destructive and a constructive thought experiment. This type of thought experiment do not belong to a new experimental formation. In this type of thought experiment, a development with regard to terminating theory where a better theory is obtained out of existing theory is observed (Reiner, 1998; Gilbert and Reiner, 2000, Urbaniak, 2012) (Table 1).

Each thought experiment is made up of six elements (Reiner, 1998). Firstly, a hypothesis or a problem is questioned. Following that, an imaginative world made up of creatures related to each other in an order (out of objects or imaginative formations regarded as an object) must be created. Thirdly, a thought experiment is designed. The fourth stage is carried out by thought experimenter. In fifth stage, a result is produced with regard to thought experiment in line with logical rules. In the sixth and last stage, a decision is reached. These components form the basis of thought experiment typology by coming together in different shapes. The classification made by Brown is given in Table 1.

Table 1. Brown's Classification of Thought Experiments

Class	Sub-class	Purpose	Example
Destructive	-	Determining weaknesses in a theory	Schrodinger's Cat
	Mediative	Deducting out of a theory	Maxwell's Gin
Constructive	Conjectural	Determining a fact and theorize	Newton's Bucket
	Direct	Deduction (deductive)	Stevin's Inclined Plane
Platonic	-	Theory development	Galileo's Free Fall Experiment

In the process of education, when an unsatisfactory student is offered a different concept about the current concept, either an integrity is formed between the old concept and the one or new concept replace the old one. Using thought experiments to support conceptual changes show that they provide positive contributions in the process of training (Gilbert and Reiner, 2000; Ylikoski, 2003; Reiner, Haifa and Gilbert, 2004).

Various types of thought experiments could be used to support, criticize a current theory or to form a new theory. It is known that forming and using experiments help student solve problems. In this way, students could have an opportunity to make a collaboration with other students in this process and talk about the results of one another. In other words, they behave like a scientist in this sense (Reiner, 1998; Ateş, 2008; Kızılkaya and Aşkar; 2009).

The current study aimed at determining the thought experiments designed by students in a problem solving behavior and the structures of these thought experiments. In this way, students will be able learn about the place of thought experiments in making them effective in teaching physics by learning perceptions about physical concepts and transition between these concepts. In addition, students will be encouraged to use thought experiments in supporting conceptual changes and solving physical problems.

Method

The current study is a descriptive survey aiming at determining the structures of thought experiments put forward with regard to motion laws. The study was carried out in the basis of a longitudinal survey and conducted through a focus group interview with each student (Fraenkel and Wallen, 2006).

Population and Sampling

It was made up of first year and fifth year students studying into motion laws in the Department of Physics Education. The sampling of the study was made up of 50 students, 22 first year and 28 fifth year students, studying in the Department of Physics Education of Gazi University, Faculty of Education. The study consisted of two stages. In the first stage, a test made up of 6 open ended questions with a conceptual content was applied to 50 students comprised out of first and fifth year students. In the second stage, 5 students from the first year students and 4 students from the fifty year students having the highest score were chosen in order to make the data richer and more significant. Then, the second test comprised of 4 open ended questions was applied to the students chosen and it was finalized with observations and interviews. First year students just registered and those who were at the position of graduation were not included in the study as thought experiments were aimed at being compared in terms of designs.

Data Collection and Analysis

In the study, the tests Georgiou (2005) used in his research were used. General structure of the tests and the purposes to use them were determined and then two separate tests were formed for the two sessions of the research by choosing items out of the tests.

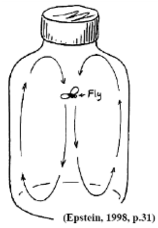
The first test comprised of 6 open ended questions and the students were asked to explain the answers they would give to each question. As these explanations were asked to be within the limits of the determined purpose, each question has guiding sub-items. The first test was applied in 60 minutes and totally correct answer was scored as 2 points, partly correct answer was scored as 1 point and totally incorrect answer was take as 0 point. Item difficulty level was calculated as 0.23 and KR-21 (Kuder-Richardson-21) reliability coefficient was calculated as 0.58. It found that the difficulty level and reliability of the test was consistent with the objective (Tan, Kayabaşı and Erdoğan, 2002; Tekin, 1993, Bademci, 2008). The answers given in the first stage were analyzed depending on the features of a thought experiment, the answers students gave to the questions with an explanation were examined and depending on the scores students obtained in the tests 5 first year students and 5 fifth year students were invited for the application of second stage. The purpose here was to investigate the answers given by students in detail in terms of thought experiments. In addition, the test items to be used in the second stage were determined in the basis of the application here and a four-item second test was prepared with its guiding sub-items. While deciding on the items, the answers students gave to the questions in the first stage were taken into consideration and such issues as the perception styles of students and whether the ability of the students to produce solutions was high were also discussed.

In the second session, the four-item test was handed out to the students and a semi-structured observation was made in the type of structured field study. Following the observation, interviews in the form of a standardized open ended interview were carried out in order to clarify critical points and to learn more about the answers given. In the interviews, an additional question was prepared for each question and were handed out to the students as a printed material. The observation period in the second stage took about 60 minutes and interview took almost 20 minutes, and the data was recorded during the application. The dialogues recorded as a video record and behaviors observed during narration were presented by coding the names of the students as a written text within the flow of observation. These applications were carried out separately for the groups of first year and fifth year students. In the study, first year students were coded as A_1, B_1, C_1, D_1, E_1; and fifth year students were coded as A_5, B_5, C_5, D_5 (Bademci, 2008).

The data of the second session were given as an observation form (Table 2) depending on Brown's (1991) thought experiment classification and Gilbert and Reiner's (2000) thought experiment characteristics and extractions from dialogue texts were given. In the current study, representing a small part of the main study, only one question out of four questions used in both sessions was chosen and the answers given to this question were analyzed. In addition, at the stage of deepening the interviews with regard to the question, it was supported with an additional question giving the conditions of the fish in the aquarium (Bademci, 2008).

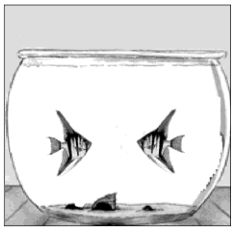
Question

A few flies were trapped in a jar. You placed the jar on a scale (this scale shows the weight values). Which one of the followings are observed?



a) The scale shows the weight heavier when the flies are at the bottom of the jar.
b) The scale shows the weight heavier when the flies are flying.
c) The same values are shown on the scale when the flies are both in the jar and they are flying (Epstein 1998; ext. Georgiou, 2005).

The additional question used to support question through interview (Georgiou, 2005)



a) Compare the movements of the flies in the jar with those of the fish in the aquarium.
b) Will there be a change in the weight of the container while the fish are swimming or when they go up and go down again?
c) How are the weight of flies in the jar and fish in the aquarium transmitted to the bottom?

Findings

In the second part comprised of findings and comments on these findings, the data obtained in the first and second stage were analyzed. In the first test, students were asked to write their answers with an explanation for each question. As for the scoring of the tests, totally correct answer was scored as 2 points, partly correct answer was scored as 1 point and totally incorrect answer was take as 0 point. Item difficulty level was calculated as 0.23 and KR-21 (Kuder-Richardson-21) reliability coefficient was calculated as 0.58. It found that the difficulty level and reliability of the test was consistent with the objective (Tan, Kayabaşı and Erdoğan, 2002; Tekin, 1993, Bademci, 2008).

The observation form was finalized depending on the results obtained in the second stage, the classification of Brown's (1991) thought experiments, the features of thought experiment determined by Gilbert and Reiner (2000) and the structures determined with regard to the use of thought experiments in science education. These observation forms were determined in order to use in the analysis of the qualitative data at the second stage as follows:

- A thought experiment should be constructed within a conditional perspective as in a physical experiment.
- The guiding sub-items of the questions in the test will be the basis of the new components that will appear on its own within the imaginative world of the students, therefore forming thought experiments. The answers given in this sense should be investigated in detail.
- Whether an imaginative fiction emerging in the problem solving behavior is totally new or it is the enriched aspect of a fiction given in the problem should be determined well (Bademci, 2008).

Such applications were realized for first and fifth grade groups and the data obtained were coded in observation forms depending on the criteria given above (Table 2, Table 3).

The Answers Given by First Year Students to the Third Question

The observation form of the features observed in the answers of first year students is as in Table 2.

Table 2. The Features Observed in the Answers of First Year Students Given to Third Question

Features / Students	A_1	B_1	C_1	D_1	E_1
Making up a hypothesis or asking questions	*	*	*	*	*
Creating an imaginative world comprised of objects or cases regarded as objects	*	*	*	*	
Designing a thought experiment	*		*	*	
Conducting a thought experiment	*		*	*	
Making deduction regarding thought experiment within rules of logic	*		*	*	
Deciding with regard to the result	*	*	*	*	

The codes in Table 2 and Table 3, the ideas and approaches put forward by each first year and fifth year student participating in the research were formed benefitting from dialogues while solving the related problem.

When it comes to the dialogues first year students, A_1 asked what would happen to the forces affecting it when you threw a stone to a bucket full of water and the stone fell down to the bottom of the bucked, and B_1 had a similar explanation supporting it as follows:

Extract - 1

"A_1: … there is a reactive force and buoyant force. For example, let's think of the stone suspending in the air. In such a case, there is a buoyant force and it has an mg downward. As the flies fly in the jar, there is a force of friction in the air in this time. When there is the friction force of air with the mg of the fly (pointing upward with his hand) it will stay lighter this time. In this case, the jar is lighter when the fly flies … but when it lands on the ground (the bottom of the jar), there will be no force friction of air. There will only be mg weight on the ground, so to me, it will be heavier when it lands on the ground…"

"B_1: These flies are alive, there should be an entrance of exist for air in the jar. Otherwise, these flies would die. When they die, they will fall on the ground in the jar and this (talking about the scale) will measure the weight as much as the weight of the flies (showing A_1), he tells the truth to me… In other words, there is (drawing on the figure in the question) the resistant force of air and these flies have an mg. Just like we say reactive force or buoyant force in any case; when they (flies) fall on the ground, there won't be a resistant force of air, they will have already died her. We cannot determine anything before they die. As we do not know where resistant force is and what it is, we wait for them to die and then we make our calculations then".

On the other hand, C_1 and D_1 in the same group came to the fore with more different views:

Extract – 2.

"D_1: To me, when the fly is on the ground and staying at a constant position in the air, the value on (the scale) is fixed. A fly flies by striking the air under its wings towards the ground. It will ascend with the force with the push given by air. If it applies a weight to the bottom of the jar as much as its own weight, it will stay suspended in the air. When it is on the ground, it will have only its own mg. If it gives a push toward the bottom as much force as it will compensate in the air, it will stay fixed. In this case, total mass will not change when it is in the air or on the ground. When does it change then? (Raising the hand) If it takes off upward, in other words if it does not stay fixed in the air and it speeds upward; in this case, it will strike more push to the ground than its own weight. So, a push heavier than the weight of the fly itself will be applied to the bottom of the container. In such a case, weight will be higher than the one before relatively. However, while the fly is landing, when it is in the landing position, it will apply less force than its own weight and there will be less total mass than what is normal."

"C_1: (Turning to D_1) The answer of A_1 seems true to me… (fly) turns normally, when it first touches the bottom, it will be a slightly heavier… just like the scale will show 100 kg when you jump on it while you are 70 kg and it turns back to 70 kg again… it will be the same thing when this fly drops on the bottom when it dies. It will be slightly heavier for some time; but it is a change in seconds. Just like the person jumping on the scale … As a result, we say that total weight of the system did not change."

Even though C_1 says he supports the view of A_1, he actually reaches the same result with D_1; since A_1 claims that while the fly is flying, the jar is lighter, when it lands on the bottom of the jar, it will be heavier. C_1 says that the weight will not change but there will be a slight deviation in the indicator. While D_1 is saying that the weight will not change, he indicates that it is a prerequisite for the fly to stay suspended in the air and motionless at the bottom and tells it to C_1 like this:

Extract – 3

"D_1: … for example, you stay on the carpet. Suddenly, you accelerate and the carpet slides backward, right? … or when we think of the carpet as a flat wood (showing the table with his hand), and we place something at the back to measure it. When we accelerate (showing the direction of acceleration way and the motion way of the wood as opposite directions) the wood will strike the scale and it will show us a value. Here (turning back to the question) we take the air instead of the wood, (opening the arms in two sides and pushing them downward) we send the air back… if the motion is with an acceleration it becomes like that … if it stays (in the air), it becomes equal when it is placed (on the bottom)…"

"C_1: I believe that the mass will stay the same and total weight will not change. I say that there will be a change just at the very start.

D_1: I say that there will be a change only in the case of an accelerated motion.

C_1: You explain that acceleration as a motion in a different example. I do it as the change of force when it first strikes…

D_1: I agree with the time when it first strikes (making a sign up and down with his hand); since there is a force applied on the floor while striking, there is an inertia.

The Answers Given by Fifth Year Students to the Third Question

The observation form of the features observed in the answers of fifth year students are as in Table 3.

Table 3. The Features Observed in the Answers of Fifth Year Students Given to the Third Question

Features / Students	A_5	B_5	C_5	D_5
Making up a hypothesis or asking a question	*	*	*	*
Creating an imaginative world out of objects or cases known as objects	*	*	*	*
Designing a thought experiment	*	*	*	
Conducting a thought experiment	*	*	*	
Making a deduction regarding a thought experiment within the rules of logic	*	*	*	
Making a decision with regard to the result	*	*	*	

When we have a look at the dialogues of the fifth year students in general sense, it was observed that only D5 showed little participation and some views considered important in the dialogues of the rest were given as follows:

Extract - 4

"B_5: I thought there is air in the jar, since there is a need for it to fly. Normally, it is believed that flies do not have any weight while flying. But, it should leave the air behind as much as its weight, in other ways it should apply a force as much as its weight so that it could stay in balance.

D_5: You say that the net force affecting on this (fly) is zero. We say that the weight affecting it is downward while the buoyant force is upward. The reactive force should replace the difference of buoyant force so that the weight of fly could go deep.

C_5: It is something like this: How heavy the container full of water would become if we put an orange in it? How much is the buoyant force … I thought that a fly could fly in an airless environment at that time. In that case, I believed that there would be no change in the weight…"

It was observed that students gave short and clear answers, but it was found that in the extract -5 below C5 answered A5 in a different way:

Extract – 5

"A_5: … when the fly moves upward it is not in a balance position … (thinking for some time) while going upward it pushes more air downward. In fact, there is a need for it to push more air than its weigh, isn't there?

C_5: Yes, it changes. But we cannot say it increases or decreases in that case. Every time the fly flaps its wings the air will go up and down like this (moving his hands up and down opening and closing). In other words, while striking the wing downward, the air will go down and one + a will be added in the acceleration, but when it moves its wings upward, the air will move downward. Therefore, the needle on the scale will change, tick, tick… (showing vibrations to the left and right with his finger).

B_5: The fly applies a force itself. Normally, the buoyant force applied by the air isn't enough, the fly creates an additional force by flapping. But we ignore it and say it has no effect.

C_5: … as we are already in the air and our weight is measured without the buoyant force of the air, it is the same for the fly. Similarly, the jar itself is in the air… you measure it without the buoyant force. This reference system is valid for all the objects in it…"

The inadequate data in the observation was supported during the interview with "the fish in the aquarium" question and the view put forward by C5 is interesting:

Extract - 6

"C_5: … actually it is like this example: when you make a container having gas and liquid upside down, the volume of the liquid will not change, and that of the gas will not, either… let's put the pressure aside, it means that total pressure applied to the bottom of the container will not change, and that the weight of the container will not change in either position. So, as the total mass doesn't change with the same logic, it is necessary that the value showed by the needle should not change…"

"D_5: … if the pressure applied to the bottom of the trainer changes, the pressure force will also change. Therefore, weight will change as well."

After deciding that the weight will not change depending on the pressure force, the following was told about whether the weight of the container will change or not while the fish goes up the surface and down the bottom:

Extract - 7

"B_5: … we say that the object staying in balance will also stay in balance because of the difference of the pressure force affecting the underside and upper side of the object. If the pressure force affecting the fish is different, the fish stays in balance and when it is in motion or at the bottom, the difference of pressure force is delivered to the bottom in either case…

"D_5: … wherever you put the fish, it will change the place of water in its own volume. That's to say, water as much as the buoyant force will change its place and it will be equal to the weight of the fish. Therefore, the weight of the fish will be delivered to the bottom of the container with the motion of the liquid and the needle will not change…"

With the analysis of the student extracts, it was found that some ideas near to the correct answer of the question were given. "*There will be a slight (unimportant) difference at the weight of the jar when the flies fly and on the bottom. But in the capped jar, if the flies are flying, the weight of the jar will be the same as the one when they are at the bottom of the jar. Weight depends on the mass inside and it doesn't change; since the weight of is transmitted to the bottom of the jar thanks to air currents. In particular, an upward pull is formed thanks to the wings of the flies. But there must be a reply for this upward pull of the air. The things to pay attention is that the force value that the air will have when it is at the bottom of the jar will be bigger than that of the one at the top, because when the air strikes at the bottom it moves faster and in return "friction" decreases the speed of the air before it strike at the top (there is a friction because there is an air inside as the flies can fly). The difference at the bottom and top forces will be equal to the weight of the flies (we can liken it to the example of "the fish swimming in the aquarium") The Answer: (c)*".

The extracts of both student groups were analyzed depending on Brown's classification for thought experiments(Table 1) and the types of thought experiments formed by the students were given in Table 4.

Table 4. The Types of Thought Experiments Developed by First and Fifth Year Students at the End of the Application

Classes	Students	Features of Thought Exeriments	Type of Thought Experiment
First Year	A1	-Depending on the similarities between habits they gave the examples of “stone in water” and “fly in the air”	Constructive
	B1	-They claimed that the weight of flies must be weighed in order to weigh the weight of the jar	Destructive
	C1	-They think that the mass will remain the same and total weight will be kept . They point out that there will only be a change at the very start.	Constructive
	D1	-They say that the reactive force at the bottom will be caused by the difference between buoyant force and weight itself. As the fly pushes weight during its take off as much as its own weight, the effect of the weihgt that will meet the buoyant force of the air will be transmitted to the bottom. In other words, familiar ”buoyant force of the liquid” is combined with unfamiler “accelerated motion of the fly”.	Yapıcı
	E1	The student with the code of E1 stayed in passive position during the application.	………..
Fifth Classes	A5	- When the fly moves upward, it is actually not a balance position, but it pushes more air downward. Isn’t it necessary that air more than its weight should reach the bottom?	Destructive
	B5	- I thought there was air in the jar, as it needs the air to fly. Normally, it is believed that flies are thought to have no weight while flying. However, it needs to leave the air as much as its weight or it should apply force equal to its weight so that it can fly or stay in balance. -Fly itself applies a force. Normally, the buoyant force applied by air is not enough, it also flaps its wings and applies an additional force; but we can ignore it and say it has no effect. - Because of the difference of the pressure applied the bottom and top parts of the object suspended in the liquid it stays in balance. In the difference pressure force affecting on the fish, it remains in balance and this difference of pressure force must be transferred to the bottom when the fish is in motion or at the bottom.	Platonic
	C5	-While the fly strikes its wing downward, the air will move downward and an additional a will be added to the acceleration, but when goes upward, this time the air will move upward. So the needle will go right and left… -This is a case like this: when you make a container full of liquid and gas upside down, the volume of the liquid will not change, the volume of the gas will not change either, so the pressure of the gas will not change … let’s leave the pressure aside, not changing of the total pressure of the gas affecting the bottom of the container means that the weight of the container will not change in either position. So here is the same logic, as the total mass does not change, the value shown by the needle should not change …”	Platonic
	D5	-Now, you say that the net force affecting the fly is zero. We say the weight affecting it is downward and the buoyant force is upward. The reaction of the buoyant force should replace the difference of the buoyant force so that the weight of the fly could be transferred to the bottom. -Wherever you put the fish, it will change the place of water in the volume as much as its own volume. In other words, water as much as the buoyant force will replace, and it will equal to the weight of the fish. Therefore, the weight of the fish will be transferred to the bottom of the container with the movement of the liquid …”	Platonic

As given in Table 4, the thought experiments developed by both groups of students have constructive and destructive features. In the fifth year students, a “Destructive Thought Experiment” structure determined with certain lines appeared. However, fifth year students designed thought experiments suitable for the features of “Platonic Thought Experiment” containing constructive and destructive thought experiments (Ylikoski, 2003; Clatterbuck, 2013). That’s to say, they destructed imaginative cases where they thought there was a mistake in the content with new scenarios the developed as strong ones, and they put forward the invincibility of their views, producing new theories.

Discussion, Conclusion and Suggestions

In the dialogues Extract – 1, A_1 transferred the example of “the stone in the water “to the example of “the fly in the air”. B_1 expressed with a different approach that the flies must be dead in order to measure the weight. Without taking the correctness of the result they obtained into consideration, A_1 exhibited Constructive and B_1 showed Destructive Thought Experiments as he refused such a measurement that did not suit for his logic. However, the views put forward by A_1 and B_1 did not lead them to the correct answer.

As given in the dialogues of Extract -1 and Extract -2, C_1 and D_1 could reach an agreement at a certain point. When they were asked to repeat their views with the additional question of “the fish in the aquarium”, just D_1 explained it with his drawings. So, drawing the force diagram of an object at the bottom of container full of water, he said that the reactive force at the bottom would happen because of the difference between the buoyant force and weight. He pointed out that as the fly pushes air as much as its weight during its upward movement, the weight effect that will meet the buoyant force of the air will be delivered to the bottom. In other words, it combines known “the buoyant force of the liquid” phenomenon with unknown “accelerated movement of the fly”. In this sense, we can see the tracks of Constructive thought experiment.

In the dialogues of Extract -4 and Extract-5, C_5 expressed as his first opinion that there would be no change in the weight, while he changed his mind in his talk to A_5. In his reply to B_5, we observed the features of Platonic thought experiment combining both Destructive and Constructive structures; since he refuted the view of B_5 with his idea having a strong basis.

In the dialogues of Extract -6 and Extract -7 which were supported with interviews, fifth grade students were successful in transferring the motion of the fish in the water to the motion of the flies in the jar compared to first year students. They first found that the weight of the container must not change and depending on this fact they approached the question with such a different concept as “pressure force difference”. Even though there was not a difference from first year students in terms of the result reached, there became a difference between the tool used, in other words “the motion known beforehand” and the thought experiment used.

It was found that first year students were in an intense effort to make the questions meaningful before they started a thought experiment or designed a simulation compared to fifth year students. While expressing the features that problem solving will make individuals attain in learning based problem, Brown (1998; ext. Taşpınar, 2005, Acar, 2013) pointed out that the evaluations with regard to the essence of the problem would create a structure for thinking. These evaluations focuses on both the concepts taking place in the problem and understanding the complex situations appearing in the problem solving process, and also on forming the standards to compare thoughts. For that reason, as the first year students just completed their education with regard to the laws of motion in these questions, they mostly focused on the concepts. The reason for that could be the fact that they just encountered with these kinds of multi-case questions.

On the other hand, the process of interpreting the concepts in the questions and the case of movements at the beginning was shorter in the observations for fifth year students. Students either answered them in short and clear responses or tried to understand the views of others by asking questions when they were indecisive. Therefore, the interviews made with fifth year students took longer time in order to determine certain structures.

Imaginative surroundings created in the thought experiments designed had a positive difference for first year students compared to fifth grade students. However, fifth year students differed more in terms of being able approach the questions from different topics and various topics. They design thought experiments that were determined with strict lines, taking short time. Depending on the dialogues of both groups, while first year students stayed within the lines of laws of motion in their thought experiments designed with regard to "flies in the jar", fifth year students additionally exhibited some different approaches over pressure, fluid features and even "how the fish in the water can go up and down".

Another important result was over the structures of thought experiments. In both of the groups, thought experiments had constructive and destructive features. Just like scientific experiments, thought experiments could go wrong and could be criticized as well (Schcik, 2003; Çalışkan, 2005; Tüzün, 2010). There could be some suspicions unless they are explained in detail or base upon illogical suppositions. Therefore, first year students achieved more controversial results and a great many situations emerged depending on mutual distrust in their solutions offered. In such a case, a structure of "Destructive Thought Experiment" not offering a new solution in the end but trying to eliminate the opposing view within certain logics. Besides, as first year tried to support each other in verifying a structure they knew well and through different groups by benefitting from what they knew so often, "Constructive Thought Experiments" were also observed. As for fifth year students, a "Constructive Thought Experiment" determined with strict rules emerged. However, fifth year student designed thought experiments suitable for the features of "Platonic Thought Experiment" as well (Clatterbuck, 2013). In other words, they exhibited the invincibility of their views by refuting the imaginative cases which they believed they had some mistakes in the content with the new scenarios they developed as a strong idea (Ylikoski, 2003; Beck, 2006).

Due to the fact that thought experiment are consistent with the nature of physics education, it has a feature supporting the conceptual development of students. In particular, supporting the physics education at the introductory stage with classical thought experiments depending on the structures of thought experiments exhibited by first year students is of great importance as it would provide active participation of the students and make learning permanent (Ylikoski, 2003; Rafal, 2012; Acar, 2013). This research shows that we can determine some thoughts in students in detail by investigating the problem solving deeply

As Ylikoski (2003), Georgiou (2005) and Clatterbuck (2013) pointed out in their studies, the views of the students determined in the thought experiments reveal their perception of concept. In the current study, the behaviors exhibited by the students for the body language, mimics, the explanations on drawings and opposing views were found significant in understanding secret information which they cannot explain verbally or in written form. Therefore, a similar research could be repeated with a common study of Physics Education-Psychology and more detailed information could be obtained over student perception with regard to physical concepts.

This study was designed upon motion laws. In a similar study designed over different issues in physics, thought experiments and the structures of thought experiments developed by students could be investigated.

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