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Identifying Prospective Primary School Teachers' Ontologically Categorized Misconceptions on the Topic of "Force and Motion"

Ayşegül Kınık TOPALSAN[1], Hale BAYRAM[2]

[1] Assist. Prof. Dr., Istanbul Aydin University, Istanbul-TURKEY,ORCID ID: 0000-0003-0947-5355
[2] Prof. Dr. Marmara University, Istanbul-TURKEY, ORCID ID: 0000-0003-2899-0934

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ABSTRACT

This research aims to reveal the misconceptions of prospective primary school teachers on the fundamental physics concepts such as force, frictional force, work, conservation of energy, mechanical energy, kinetic energy, potential energy, energy stored in springs on the topic of "Force and Motion" and to assess the misconceptions based on ontological view. In order to reveal the prospective primary school teachers' misconceptions, a two-tired "Concept Test on the Topic of Force and Motion" has been developed and used which consists of 17 items. The Cronbach's alpha value of the concept test was found to be 0.71. The study group of the research was 35 prospective primary school teachers at a foundation university (30 female and 5 male students) who were sophomore at primary school teacher education program. This research is characterized as a descriptive study. In the study, the misconceptions were assessed according to ontological categories, thus the reasons that lead these misconceptions were revealed based on ontology. Knowing the causes of misconceptions is very important for science education. Misconceptions can only be removed by planning and applying enough teaching methods focusing on causes of students' misconception. Therefore, identifying students' misconceptions based on ontological categories are very important because they facilitate revealing the causes of misconceptions. In the research, students' misconceptions related to the topic of force and motion were identified and discussed according to ontological categories. Analysis of concept test items revealed that the teacher candidates had 301 misconceptions that can be placed to upper categories, and 150 misconceptions that can be placed to the lateral categories and suggestions were provided based on the results of study.

Keywords: Ontology, force and motion, misconception

INTRODUCTION

Misconceptions have been defined as the concepts that are incompletely or erroneously structured by the students rather than those considered to be scientifically correct

Corresponding author e-mail: aysegulkinik@aydin.edu.tr

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and intended to be learned by the students in a meaningful way at the end of the teaching process (Nakhleh, 1992). Misconceptions have been approached from the philosophical perspective in 2000's and some definitions have been made based on philosophy. Chi and Roscoe (2002), who defined the misconceptions based on ontology, has pointed out that there has been an ontological category in which each object and idea belongs and the concepts have all the characteristics of their ontological categories, and misconceptions have been the result of mis-categorizations made by the individuals. In other words, since the individuals do not know the characteristics of the concepts exactly, individuals place the concepts into ontological categories that they do not belong to.

Ontology is defined as "knowledge of existence" in the dictionary. Gruber has described ontology as "the definitive definition of the conceptualization", as it is widely accepted now (Gruber, 1993). Possibly, one of the simplest definitions of ontology can be a "controllable dictionary". The ontology deals with the entities and the basic categories of the entities (Chi, 2005). The ontologies are tools for describing the knowledge and they allow us to present knowledge in a clear and meaningful way, together with well-defined semantic structures. The attribute is the characteristic that an entity may potentially possess because of belonging to that ontological category (Chi, 1997). For example, the matter category has ontological attributes such as volume, mass, and colour whereas the event category has ontological attributes such as having a beginning and end. The concepts are placed into the ontological categories based on their ontological attributes. There are three basic ontological categories: matter, process, and mental states. When the students place a concept to the category of the matter wrongfully instead of the category of the process, they make a misconception. Therefore, determination of the ontological categories that the concepts are placed in is very important in terms of ensuring these concepts are placed in the correct categories by using various teaching methods and techniques, or identifying the origin of the misconception to avoid it, if they are placed in the wrong categories.

In science, the correct structuring of many abstract concepts is achieved by placing concepts in the correct ontological categories. Many factors influence the categorization process of the knowledge in individual's mind. The past experiences of individual play a decisive role in this process (Duit & Treagust, 1995). With this aspect, the concepts can sometimes be perceived differently by the individual's mind other than its scientific situations and can be placed in different categories. The conceptual formations categorized in this way make it difficult for the individual to establish the relationships between the concepts and to make sense of the new situations. The difficulties in understanding physics topics, which consist of abstract facts and conceptual relations, can be given as an example to the students' process of "making and categorizing" (Legendre, 1997). When the students do not make sense of a basic concept of the physics and place it in a category of their minds, they often have difficulty in understanding the top level and more complex concepts and achieving a permanent learning. Therefore, the students need to be able to build a bridge between the intuitional thoughts about the events they face in their lives and the issues and concepts of physics (Ayvacı & Devecioğlu, 2002, Devecioğlu & Akdeniz, 2006). In order to establish these links in a meaningful way, it is crucial to determine the misconceptions of the students at first and then these misconceptions should be removed (Ayvaci & Devecioğlu, 2002, Yagbasan & Gulcicek, 2003, Turgut, Gurbuz, Turgut G. & Acisli, 2011).

In the process of removing misconceptions during planning the teaching process, the determination of the categories that lead misconception due to misplacing in the category, the students' self-testing of their conceptualization, their gaining about awareness of the misconceptions, and the acquisition of the high-level thinking skills required to remove these misconceptions should be the first step in placing the concepts in the correct categories. The second step is the use of methods and techniques in the teaching process to ensure placement in the correct ontological categories. The previous studies are limited to the identification of misconceptions or the effects of various methods on the removing of misconceptions. There are only a few studies examining the misconceptions regarding ontological perspective (Soman, 2000; Özalp, 2008; Özalp & Kahveci, 2011). This research is very important in terms of ontological assessment of the concepts related to "Force and Motion". In this study, it is tried to identify the students' misconceptions about the basic concepts of physics on the topic of "Force and Motion" at 7th grade such as force, friction force, work, conservation of the energy, mechanical energy, kinetic energy, potential energy, the energy stored in springs etc. from the ontological point of view. The misconceptions of the students on the certain issues were assessed ontologically and tried to be categorized. Then, the reasons for these misconceptions were tried to be revealed based on the characteristics of these categories. Knowing the causes of misconceptions is very important for science teachers and science educators. Misconceptions can only be avoided and removed by focusing on their causes, and preparing teaching materials, teaching methods considering students' misconceptions that can prevent their occurrence. This situation constitutes the main purpose and the problem of this study.

Ontology and Ontological Attribute

Ontology is the science of entity. It deals with the entities and the basic categories of the entities. In other words, the ontology corresponds to the categorical structure of the reality. Since Aristotle's period, it has been assumed that everything belongs to basically different categories (Chi, 2005; Chi & Slotta, 1993). These categories are called ontological categories. According to this view, all entities in the world can be placed into three basic ontological categories. These categories are "matter", "process", and "mental states" (Chi, Slot & Leeuw, 1994; Johnston & Southerland, 2000). The reality of ontological categories can be identified by their ontological properties (Chi & Hausmann, 2003).

The ontological attribute is a property that an entity may potentially possess because of belonging to an ontological category (Chi, 1997; Chi, 1994). In other words, it is a characteristic feature specific to the members of an ontological category(Chi & Slotta, 1993; Chi & Hausmann, 2003; Chi, 1997). In other words, member is a concept that can be given as an example for an ontological category. For example, the table and chair are members of the matter category, or the electricity, heat, the concepts of chemical bonds are members of the process category. Ontological attributes are the most basic characteristics of that category (Chi & Slotta, 1993). For example, the 'matter' category has some ontological attributes such as volume, mass, and colour (Chi & Hausmann, 2003; Chi, 1992; Chi, Slotta & Leeuw, 1994). The attributes such as volume, mass, and colour are the main characteristic features that the members of the "matter" category can have (Chi & Hausmann, 2003). For example, if we consider the colour attribute, a squirrel has the attribute of colour, which means it can have a colour. On the other hand, the concept of war, which is a member of the 'event' sub-category, does not have an attribute of colour. However, the members in this category have other ontological attributes such as occurring at a certain time, starting, and ending (Chi, 1992; Chi, Leeuw & La Vancher, 1994). The matter and the event categories are different ontological categories, therefore the ontological attributes of these two categories are also different (Chi, 1992).

The ontological attribute is different from defining attributes and characteristic features. The ontological attribute is a property that an entity may potentially possess. However, the defining attributes are those an entity must have, and a characteristic feature is the one that an entity most frequently has. For example, if a jug is taken into consideration, the fact that the jug has a spout that is its defining attribute. Usually being made of glass is a characteristic feature of it. But being fragile is an ontological attribute of it. Therefore, the ontological attributes are distinct from other properties (Chi et al., 1994). The ontological attribute is a feature that covers that category members, although it is not a feature that a category member must have. It can be stated as: A squirrel has a characteristic colour, which means it can have a colour, but a squirrel cannot be blue but it has the potential to be in another colour (Chi & Hausmann, 2003).

Ontological knowledge is our daily knowledge of the kinds of things that exist in the world and how these things are related to each other (Sera, Gathje & Del Castillo Pintado, 1999). In psychology literature, ontological knowledge was first examined by Keil (1979). Keil suggests that there is a solid hierarchy among the ontological categories in his study. Based on Keil's study, Chi (1992) says that the ontology divides our knowledge into different conceptual categories. Chi (1992) mentioned of three basic ontological categories; matter, event and abstract concepts in his study. However, he has stated that other categories may have been possible. Chi and Slotta (1993) have named the ontological categories as matter, process, and mental states in their studies.

Ontological Categories

All entities in the world can be placed into three basic ontological categories. These categories are "matter", "process", and "mental states" (Figure 1) (Chi et al., 1994; Johnston & Southerland, 2000). Each ontological category has subcategories. As well as all ontological categories are different from each other, subcategories are also different from each other because each category is different ontologically. For example, the subcategories of the "matter" category are ontologically different from the subcategories of the "process" category (Chi et al., 1994).

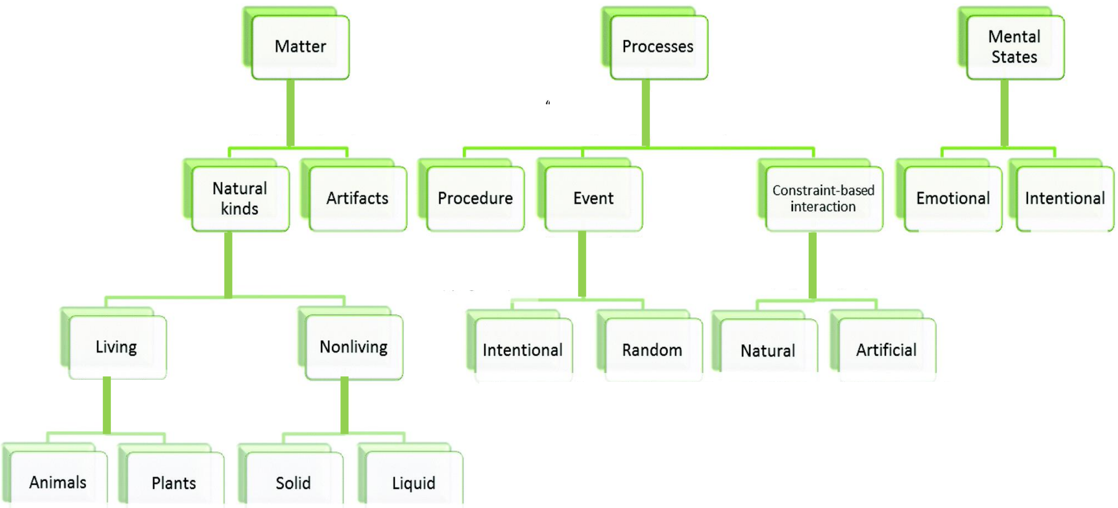

Figure 1. Three ontological categories and subcategories of the entities in the world

Matter Category

The matter is the combination of what is felt by the senses, such as seeing, touching, and can be physically interacted. This category includes concrete objects. There are some ontological attributes for the entities which have the characteristics of matter and belong to matter category. The objects in the matter category have ontological attributes such as mass, volume, storability, and accumulation. Since the students also interact more easily with these attributes. This category is the one that they most easily conceptualize (Johnston & Southerland, 2000).

Natural species (cat, chamomile, water, chrome etc.), and artificial objects (lamp, table etc.) are included in this category. Although both the lamp and water are in the matter category, they have different attributes. For example, while "the lamp is broken" statement is meaningful, "the water is broken" sounds unfamiliar. Therefore, the matter category has been divided into subcategories (Chi, 1997). These subcategories are "natural kinds" and "artefacts".

Process Category

The concepts in the process category are those that express “what happens” rather than “what something is”. A physical property of a process cannot be identified. The process category is divided into three subcategories. These subcategories are the "procedure", "event" and "constraint-based interactions" categories. The most important of them is the constraint-based interactions category. Many scientific concepts are in the constraint-based interactions category (Chi et al., 1994). Such concepts are frequently encountered in physics and biology (Chi, 1997). Concepts such as heat, light, force, current, electricity, natural selection, and diffusion are examples of the concepts in the constraint-based interactions category. Given examples can be further detailed with the example of gravity. The gravitational force is the interaction between two mass particles. The formation of this force does not require any other means except for the existence of two masses. The electric current is the result of the motion of electrically charged particles under the influence of an electric field. The interaction between the electric field (the potential difference between two points in the space) and the charged particle is the reason here. The same examples can be given for concepts such as heat and light (Reiner et al., 2000).

Mental States Category

Mental states cover the abstract concepts conceptualized with our perceptions of the external world (love, hate, and desire). For example, the "acceleration" in the sentence of the "as the force acting on the fixed mass increases, the acceleration also wants to increase" is a mental-based concept. However, the "acceleration" in the sentence of the "as the force acting on the fixed mass increases, the acceleration also wants to increase" expressed as a process-based concept.

Concepts and Ontological Causes of Misconceptions

According to Chi (1992), all concepts and ideas belong to an ontological category. The term concept refers to an example of a category. For example, the concept of "cat" belongs to the category of "animals", the concept of "storm" belongs to the category of "process" or the concept of "thought" is an example of the category of "mental states". A concept has many perceptible and conceptual features; a concept also belongs to certain categories. For example, a robin has a red breast, and this is its perceptible feature. That, it lives in the temperate climates is its conceptual attribute and it belongs to the category of "birds" (Chi, 2007). That is, the concepts are interpreted and understood with the content of the included categories. When a concept is assigned to a category, it takes all the features of that category. From this perspective, it can be deduced that misconceptions occur as a result of incorrect categorization of the concepts. In other words, a misconception occurs as a result of incorrect ontological categorization (Chi & Roscoe, 2002; Johnston & Southerland, 2000). This mis-categorization is not hierarchical but lateral (Chi & Roscoe, 2002).

For example, let's assume that a student gets the electricity concept into the matter category instead of the process category. It is possible to say that this student has the idea that the electricity is stored in the battery because of the storability of the concepts in the matter category. And, the students with this idea, also think of electric current a real current passing through a wire. In other words, they think that the electric current flows through a wire just like the fluids flow through a pipe (Chi & Roscoe, 2002). One of the misconceptions noted in the literature review is the confusion of dissolution with melting (Smith & Nakleh, 2011). Both concepts here are included in the event category, which is one of the subcategories of the process category ontologically. However, the event category also has subcategories.

Another example that can be given to misconceptions is the idea that the bubbles come out when the lids of the fizzy drinks opened are the result of a chemical reaction. In fact, when the bottle is opened, the gas dissolved in the water comes out, so it is a physical event. However, the students think that a chemical reaction occurs during this event and mis-categorize the concept by assigning it to the chemical event category instead of assigning it to the physical event category. Therefore, such a misconception happens due to mis-categorization. Likewise, some students think that hydrogen and oxygen are produced when water evaporates. Here again, the evaporation event is assigned to the chemical event category, by thinking that a chemical reaction takes place, which must be assigned to the physical event category. And therefore, it results in a misconception.

An Ontological Perspective on Some Misconceptions in Science

As mentioned earlier, misconceptions are led by ontologically incorrect categorized concepts. When the literature is reviewed, it is seen that mostly the misconceptions about the concepts of heat and electric current related to physics have been examined from the ontological perspective. In the field of physics, students have some alternative and misleading concepts. The concepts such as heat, light, current, and force can be given as examples of these misconceptions. The students usually place these concepts in the matter category instead of placing them into constraint-based interactions category in the process category. For example, they consider the concept of power as a kind of force that gives strength to the body and since they accept that this power can be used by the body, and they express this concept with the features of matter category (usability, consumption, etc.). Therefore, the concept is placed in the matter category. Likewise, they consider the concept of gravitation to be something within the earth, rather than an interaction between the earth and objects (Chi & Slotta, 1993). The concept of heat in physics is one of the concepts that are difficult to learn by the students. Because the concept is ontologically incorrect categorized in the event category which is one of the subcategories of the process category. While teaching the concept of heat to the class, the teachers express the flow of heat from one place to another. For a physicist, it is an exchange of energy and it is in the process category. However, stating "flow of heat" in the class can be understood differently by students. The flow characteristic is a property of liquid substances such as water. Therefore, the students can place the heat concept, which is in the process category, into the matter category. This incorrect categorization leads to misconceptions about the fact that heat has matter properties (Johnston & Southerland, 2000). Likewise, the concept of electric current, which is one of the concepts of physics, can be taken into the matter category by the students. If the used expressions while teaching electric current is perceived by the students like the flow of the water, they will place this concept in the matter category. If the students place new knowledge about the electric current in the liquid subcategory, this concept will have an attribute like volume and will also have the other ontological attributes belonging to the matter category. It also explains the reasons for the misconceptions about the electrical current in students (Chi & Slotta, 1993; Chi et al., 1994). There are some concepts that belong to the constraint-based interactions category in biology as well as in physics. For example, mutation and genetics in the topic of evolution belong to this category (Chi & Slotta, 1993). The misconceptions of students related to biology are based on the matter (i.e., a concept that belongs to constraint-based interactions category is placed in the matter category). For example, many concepts can be used to the category of the item in biology-related primary school textbooks to describe the human body systems. Therefore, it is natural to create misconceptions about the subject. Although such misconceptions are matter-based, some misconceptions can also be mental-based. In other words, students may use opinions based on their own ideas while explaining a concept (Chi et al., 1994). The chemical bond can be given as an example from chemistry such as the concept of electric current in physics. The concept of chemical bonding is an attraction force between particles. Because it is a kind of force, it should be included in the "process" category. However, some students think that this concept is in the "matter" category. While some of the students materialize it based on the word "bond", some of them attribute matter properties to the concept of the chemical bond based on the expression of "breakage of the bonds". Thus, the students make such a mistake by assigning the concept of chemical bond which is in the process category, to the matter category. As a counterexample to the misconception of the chemical bond concept, the concept of "gas" can be given which is one of the three phases of the matter.

In some studies, it has been seen that some students think the gasses do not have a mass (Stepans, 2003). The gas concept belongs to the ontological category of matter. If the students think that the gasses do not have mass, they may also think that the gas concept is not a matter. This can be shown as another misconception about the gas concept. The most common misconceptions of the students about particles of the matter are the misconceptions related to the assignment of macroscopic properties to particles. For example, some students think that the particles will also melt when the matter melts (Boz, 2006). The ontological explanation of this misconception can be made as follows: It can be said that macroscopic matter and microscopic particle categories exist in the subcategories of the inanimate category which is one of the subcategories of matter category.

When atoms, molecules, or ions exist in the microscopic particle group, the matters visible to the naked eye are included in the macroscopic matter category. The phenomena of state change such as melting or such as freezing, condensation, and evaporation are the ontological characteristics of macroscopic matters. Basically, macroscopic matter and microscopic particles can be thought of as systems with independent properties. The macroscopic matter is composed of microscopic particles. However, it can be said that the total is bigger and have a different quantity than coming together of the separate items. For example, the colour of the matter is not simply the colour of the particles that composed. Similarly, if students think that the particles will melt when ice melts, they assign particles to macroscopic matter category and thus they lead such a misconception. The misconceptions that a particle will heat up (Boz, 2006; Lee et al., 1993) or evaporate (Griffths & Preston, 1992; Kokotas, Vlachos & Koulaidis, 1998) when a matter is heated, and the particles will get frost or will have lower temperature when it is cooled (Lee et al., 1993) stems from the fact that the particles in the microscopic particle category are assigned to the macroscopic matter category. As evidence that students have assigned atoms and molecules to the macroscopic matter category rather than microscopic particle category, it can be shown that they have the idea that the particles can be seen by using a microscope, or that they may regard tiny fragments of the matter that can be seen with naked eye. The misconceptions that gold atoms are as hard and bright as gold (Stepans, 2003) or that the sulphur atoms share the physical properties of sulphur (Othman, Treagust & Chandrasgaron, 2007) again stem from this reason. So, brightness is not the attribute of the atom as a microscopic particle, but it is an ontological attribute of gold which is a macroscopic matter. The atoms of gold do not have this ontological attribute.

Since the students think of atoms as macroscopic matters, it leads these misconceptions. Some students think that the water droplets are particles of the water (Nakhleh, Samarapungavan & Sağlam, 2005). Since water particles (molecules) are thought of as water droplets, rather than as microscopic particles, they assign it to the macroscopic matter category which leads a misconception. Some of the students think that water molecules are as big as bacteria or cells (Lee et al., 1993). This misconception is also due to the same reason. The students think that a molecule is a small thing. However, since they do not know that the molecules have a microscopic structure, they assign macroscopic matter attributes to them.

Therefore, they assign the water molecule, which is in the microscopic particle category, into the macroscopic matter category. Some students have come up with the idea that the shape of the liquid molecules change depending on their container based on the expression that "the liquids get the shape of their container" (Griffihts & Preston, 1992). Here again, the students assign macroscopic properties to matters in the microscopic particle category such as atoms and molecules and classify them into macroscopic matters. Therefore, such a misconception arises. Thinking the atoms as alive can be given as another example of the students' misconceptions. (Griffihts & Preston, 1992; Pideci, 2002; Tezcan & Salmaz, 2005). At the school, the students learn that atoms move. Since atoms move, they take the concept of atom to the "living beings" category. Therefore, they lead to a misconception by taking it into the category of "living beings" rather than into the ontological category of the "non-living things". In any form, students have misconceptions about these sciences. These misconceptions derive from an earlier categorizing of these scientific concepts into a category that they do not belong to (Chi & Roscoe, 2002). There are limited studies in which the assessment is based on the ontological categories. The studies, particularly in the field of physics, are very rare. In their study, Lee and Law (2001) conducted a test on the concepts of "electricity" and used semi-structured interview forms to further deepen the misconceptions they identified, and they assessed the results only from the ontological perspective. In their research, Slotta and Chi (2006) give suggestions on how the new physics instructors can come up with a misconception that has become permanent by an ontology training. As can be seen, there has been no study in the field of physics in which the ontological categories have been used as a theoretical framework, two-tiered questions have been prepared, and therefore the ontological foundation of the students' misconceptions have been identified on this topic.

Purpose

In this study, it is tried to identify the students' misconceptions about the basic concepts of physics on the topic of "Force and Motion" at 7th grade such as force, friction force, work, conservation of the energy, mechanical energy, kinetic energy, potential energy, the energy stored in springs etc. from the ontological point of view. The misconceptions of the students on the certain issues assessed and categorized based on the ontological view of Chi (1992). There are few studies on ontological aspects of misconceptions about force, friction force, work, conservation of energy, mechanical energy, kinetic energy, potential energy, the energy stored in springs, etc. within the scope of "Force and Motion" topic at the course of “Science and Technology”. No detailed research has been found in the literature search. Since it will be potentially the first study in this field, it is thought that the study will be forefront in the international literature.

METHODS

The study is a survey research at a descriptive level trying to reveal the current situation. The research made for determining specific characteristics of a group by collecting data is called as survey research (Büyüköztürk et al., 2012). This study aims to identify the certain misconceptions about the basic concepts of physics on the topic of "Force and Motion" such as force, friction force, work, conservation of the energy, mechanical energy, kinetic energy, potential energy, the energy stored in springs due to misplacement to the wrong ontological categories. All stages of the implementation process were carried out by the researchers. The subjects were selected for the implementation of the study, and the "Concept Test on the Topic of Force and Motion" was prepared based on ontological attributes.

a) The Study Group

The study group was 35 prospective primary school teachers (30 female and 5 male students) who were second-grade students at primary school teacher education program at a foundation University in Istanbul in the 2013-2014 academic year.

b) Data Collection Tools

"The Concept Test on the Topic of Force and Motion", which aims to define ontological bases of the teacher candidates' misconceptions on certain concepts in the topic of "Force and Motion", was prepared by the researchers as a two-tier test, and its validity and reliability studies was carried out. The steps recommended by Karataş, Köse, and Coştu (2003) were followed during the development of the two-tier misconception diagnostic test on Force and Motion. First, the content was determined. The objectives were identified for the subject of "Force and Motion" were examined in determining the content. As a result of this study, it was decided that the focus of the test should be on "force, friction force, work, energy conservation, mechanical energy, kinetic energy, potential energy, energy stored by springs". In the second step, a comprehensive concept map was prepared showing all concepts and their relations with each other. At this stage, the concept map which is included in the 7th grade science and technology course program developed with determined objectives. In the third step of the test, the relationship was examined between concept maps and knowledge propositions. This relationship serves as a control mechanism for the internal consistency of the test to be prepared. The acquisitions determined in the first stage and the concept maps prepared in the second stage were examined during the preparation of the "Force and Motion" unit misconceptions test and it has been seen that the concepts in concept map overlap with the objectives. Therefore, no additions were made on the concept map and objectives. As a fourth step, the "Concept Test of Force and Motion Unit" was examined by two science and technology teachers whose professional experience was between ten and fifteen years, and five faculty members working in the departments of science and physics teaching of state and foundation universities. In accordance with the expert opinions, any corrections were made in the objectives and concept maps. So, the preparation of the test was started. In this context, Force and Motion units' misconceptions determined by national and international researchers and the most common misconceptions identified as a result of this review. Also, the misconceptions of pre-service teachers were revealed. Test items according to the concept map prepared by the researcher and student gains were started to be created to reveal common misconceptions in students. "Force and Motion Unit Concept Test" were included test items used in the literature and test items created by the researcher. For each multiple-choice question for concept test, two or five answer options have been written, one of them is the correct answer. The second part of the questions were selected from the misconceptions in the literature. In addition, "I think" option was written for each question. Thus, the students could convey their different opinions. Total of 20 test items were created in this way. In addition, ontological analysis was performed for each test item. In next stage, the reasons for choosing the answer option in the related question were collected for each question after the implementation of the prepared test. Three or four of the most preferred selection reasons were written as the second part of the problem. And "I think" option was written for each question. In addition, a table of statements were created to show which objectives and which concepts in the concept map contain. After that, a two-tier statement table for test items was created. In this way, objectives of the test items and concepts in the concept map were been determined. The prepared test was once again made available to the experts. The final version of the test on the "Topic of Force and Motion" consists of 17 questions. Seven of the items were taken from the test developed by Ulu (2011) and the remaining ten questions were prepared by the researcher by searching the literature. The existing misconceptions in the national and international studies about the concepts of force, friction force, work, energy conservation, mechanical energy, kinetic energy, potential energy, the energy stored in springs were researched for the questions prepared by the researcher. The questions were arranged to reveal these misconceptions and the other misconceptions that may arise from them. The questions were prepared based on the ontological categories. As shown in Figure 2 and Figure 3, how each question were prepared based on these categories was summarized clearly.

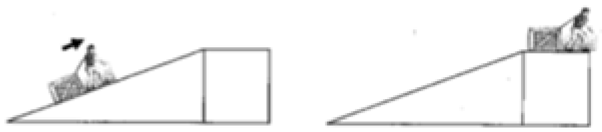

Figure 1 Figure 2

600N worker brings a 500N box to the top of an inclined plane as shown in Figure 1. What can be said about the energies of the worker and the box with the position in Figure 2? (The frictions are neglected).

A)Neither the worker nor the box has energy.
B)Just the worker has energy. The box does not have energy.
C) Both the worker and the box have energy and they are equal.
D)Both the worker and the box have energy and the energy of the worker is greater than the box.

Which one of the followings is the reason for your answer for this question?

A)The energy is just related to motion. The objects without motion do not have energy.

B)The energy is just related to the living beings. Therefore, non-living things do not have energy.
C)The objects have the gravitational potential energy based on their position and the gravitational potential energy is just dependent on the height of the object.
D)The objects have the gravitational potential energy based on their position and this energy is dependent on the weight and the height of the object.
E)I think, ……………………………………

Figure 2. Sample question from the concept test on the topic of force and motion.

In this question, the attention was drawn to the concept of potential energy within the topic of "Force and Motion". The required values were questioned to calculate the potential energy of the objects. In this question, while some of the students were related the energy only to the vitality, some of them were related the variables that affect potential energy only to the height. The misconceptions in this question were frequently seen also in the literature. This question was designed to identify misconceptions arising from incorrect placements in the procedure category, one of the subcategories of the process category.

The correct answer to the first and second part of the question is option "D". Choosing the option "A" as the answer in the first part and choosing the option "A" in the second part as the reason for the answer given in the first part is because they only associate the potential energy concept with only motion. Therefore, it shows the existence of the misconception arising from placing in the intentional-event category.

Choosing the option "B" as the answer in the first part and choosing the option "B" in the second part as the reason for the answer given in the first part is because they only associate the potential energy concept with only vitality. Therefore, it shows the existence of the misconception arising from placing in the natural kinds and non-living things category in the matter category.

Finally, choosing the option "C" as the answer in the first part, and choosing the option "C" in the second part as the reason for the answer given in the first part is because they associate the variables influencing the potential energy concept with only height. Therefore, it shows the existence of the misconception arising from placing in the category of the procedure category.

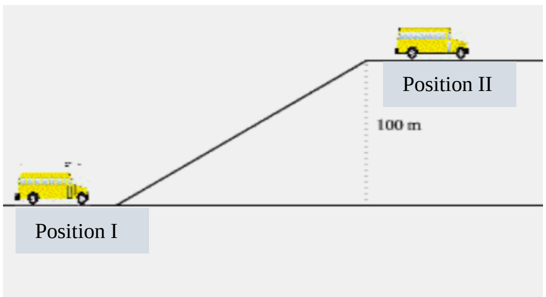

Figure 3. Sample question from the concept test on the topic of force and motion.

According to the picture above, the vehicle reaches the position II from position I after a certain time. The car is stopped in position II. Accordingly, which of the following judgments about the mechanical energy of the vehicle is correct? (Neglect the friction)
A) Mechanical energy does not change.
B) Mechanical energy is reduced.
C) Mechanical energy increases.

Which one of the followings is the reason for your answer to this question?

A) Mechanical energy does not change, only the total energy of the car in “position I” turns into potential energy in “position II”.
B) Mechanical energy decreases because the speed is reduced when climbing. In this case, the kinetic energy is reduced.
C) Mechanical energy increases, because “location II” is higher than the ground. Therefore, the potential energy increases.
D)I think, ………………………………………

In this question, the attention was drawn to the concept of mechanical energy within the topic of “Force and Motion”. The required conditions are questioned to change the mechanical energy of the vehicle. Whether or not the mechanical energy changes are questioned, if there is no friction on the ground. The misconceptions in this question were frequently seen also in the literature. This question was designed to identify misconceptions arising from incorrect placements in the intentional event category, one of the subcategories of the process category.

The correct answer to the first and second part of the question is option "A". Choosing the option "B" as the answer in the first part and choosing the option "B" in the second part as the reason for the answer given in the first part is because they only associate the mechanical energy concept with only motion. Therefore, it shows the existence of the misconceptions arising from incorrect placements in the procedure category, one of the subcategories of the process category.

Choosing the option "C" as the answer in the first part and choosing the option "C" in the second part as the reason for the answer given in the first part is because they only associate the mechanical energy with only potential energy. Therefore, it shows the existence of the misconceptions arising from incorrect placements in the procedure category, one of the subcategories of the process category.

Two-Tiered Concept Test on the Topic of Force and Motion

Analysis of the two-tier multiple-choice diagnostic tests is usually performed by tabulating the answers by the students for the first step of each question and the percentage of the chosen reasons for these answers.

In this way, tabulated student answers is examined in terms of the combination of the content options in the first stage and the reason options in the second stage,. Thus, a second table can be obtained consisting of the correct answers given by the students in the content stage and the correct answers given to both stages. If the correct options are marked in both stages of the test, 1 (one) point is given, and the students are given 0 (zero) points if they mark a wrong option in any or both stages in the test (Karataş, Köse, & Coştu, 2003).

In this case, the maximum score that can be taken from the test consisting of 17 questions is 17, whereas the minimum score is 0. From this point on, the low score taken by the student indicates that the student has a higher level of having misconceptions. Whereas the high score taken by the student indicates that the level of having misconceptions is at low. In the pilot study conducted by applying to 125 prospective primary school teachers at the second-grade in the 2012-2013 academic year, the difficulty indices and distinctiveness indices of the questions of “Concept Test on the Topic of Force and Motion” were determined through calculating KR-20 and Cronbach's Alpha coefficients. The difficulty indices of the questions ranged between 0.44 and 0.67, and the distinctiveness indices ranged between 0.45 and 0.70. According to these results, it was decided that there was no question to be excluded from the test or there was no need to correct the test. Then, in order to determine the reliability of the “Concept Test on the Topic of Force and Motion”, which consists of 17questions, the Cronbach's Alpha coefficient was calculated and found to be 0.72.

Table 1. *Item analysis for the Cronbach's alpha coefficient of the concept test on the topic of force and motion*

Question Number	Average when the Question is Taken out	Question-Test Correlation	Cronbach Alpha Value when the Question is Taken out
1	7.2415	0.432	0.702
2	7.3025	0.356	0.700
3	7.2584	0.214	-0.720
4	8.2536	0.445	0.706
5	7.3853	0.291	0.709
6	7.2569	0.380	0.708
7	7.1546	0.372	0.704
8	7.2856	0.413	0.712
9	8.0402	0.415	0.730
10	7.2531	0.244	0.710
11	7.3670	0.291	0.709
12	8.0204	0.430	0.704
13	8.0965	0.373	0.708
14	7.2752	0.198	0.700
15	7.3021	0.371	0.702
16	7.3028	0.432	0.714
17	7.3945	0.368	0.730

When the values in Table 1 were examined, it has been decided that there was no need to take out any question from the test.

After all this, the development of a valid and reliable measurement instrument with 17 questions was completed which can be used to determine whether there is a difference in the level of conceptual learning of students for the topic of Force and Motion.

In this study, Cronbach's Alpha value was found to be 0.71 and KR-20 coefficient was found to be 0.70 for the “Concept Test on the Topic of Force and Motion”.

c) Data Analysis

In this part, students' answers to each question in the test were determined as a percentage of complete comprehension, misconception, and not understanding and the results were presented in tables. In the tables, the misconceptions were separately analysed one by one by according to their ontological categories. Since there are many analyses in the findings section, the detailed explanations were made by selecting two sample questions from the questions of the concept test, the identified misconceptions were presented ontologically and the findings were presented collectively.

Analyses for the Sample Question from "Concept Test on the Topic of Force and Motion"

In this question, the attention was tried to be drawn to the concept of "work" made in scientific terms within the topic of "Force and Motion". It was tried to search whether the students evaluate all the activities they do in daily life as a work. It was also tried to reveal whether they can completely make the difference between the work done in scientific terms and the concept of work they use in daily life. The students' level of understanding about the work in the scientific terms were classified according to the evaluation criteria, and their misconceptions about this concept were examined from an ontological perspective and the origins of these misconceptions were determined based on ontology.

Table 2. *The students' levels of understanding for the first sample question from concept test on the topic of force and motion*

Comprehension	f	%
Full Comprehension	2	5.71
Misconception	33	94.29
Not understanding	0	0

Table 2 reveals that 5.71% of the students were fully and correctly understood the concept given about the energy, and 94.29% of the students seemed to have misconceptions about this concept. Another study during the analysis of the first sample question from the "Concept Test on the Topic of Force and Motion" was to determine the misconceptions that students have. Table 3 shows the students' misconceptions about the "First Sample Question" from "Concept Test on the Topic of Force and Motion".

Table 3. *The misconceptions in the students' answers for the first sample question from concept test on the topic of force and motion*

Misconception	f	%
The energy is just related to motion. The objects without motion do not have energy.	6	17.14
The objects have the gravitational potential energy based on their position and the gravitational potential energy is just dependent on the height of the object.	6	17.14
The box gains an energy due to the force applied by the worker so there is no energy its final state.	9	25.71
The energy is just related to the living beings. Therefore, non-living things do not have energy.	10	28.57
There is a lot of friction in the box, so its energy is much less than the worker.	2	5.71

When Table 3 was examined, it was seen that the misconception that the students have the most in the test was "The box gains an energy due to the force applied by the worker so there is no energy its final state". The rate of this misconception was determined to be 28.57%

The second misconception that commonly hold by most of the students was the expression "The box gains an energy due to the force applied by the worker so there is no energy its final state". The rate of this misconception was determined to be 25.71%.

The third misconceptions that commonly hold by most of the students was the expression "The objects have the gravitational potential energy based on their position and the gravitational potential energy is just dependent on the height of the object" and "The energy is just related to motion. The objects without motion do not have energy”. The rate of this misconception was determined to be 17.14%.

Finally, it was seen that the students have misconceptions about the expression “There is a lot of friction in the box, so its energy is much less than the worker." The rate of this misconception was found to be 5.71%.

Given these misconceptions, it was seen that the students confuse the variables of energy. In addition, they associate energy only with vitality and movement. They believe that non-moving and non-living objects have no energy. The memorized knowledge of the students who have preliminary knowledge on the subject was noticed once again in their misconceptions.

The final study during the analysis of the first sample question from the “Concept Test on the Topic of Force and Motion” was examining the misconceptions identified by concept test from the ontological perspective. Figure 4 shows the ontological analysis of the students' misconceptions on the “Concept Test on the Topic of Force and Motion”.

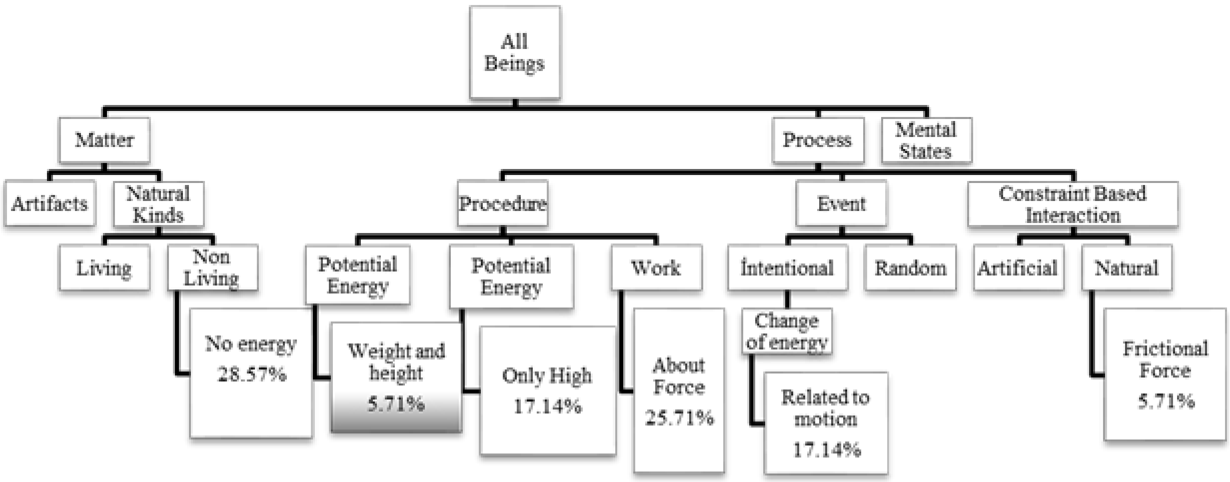

Figure 4. The ontological analysis of the students' misconceptions on the first sample question from the concept test on the topic of force and motion

When Figure 4 was examined, the variables of energy is questioned by the “First Sample Question from Concept Test” on the “Topic of Force and Motion”. It was seen that the students placed the questioned concept in the procedure category, which was one of the subcategories of the process category, however, some students were seemed to be able to place correctly. The percentage of these students was 5.71%.

In this question, five ontological origins were identified for the misconception on the variables of energy, work and relations with each other. The first of these misconceptions originates from placing the energy into the procedure category, which is one of the subcategories of the process category. The students created two different lateral categories under the procedure category. In the first lateral category, the students placed it in the procedure category because they believe that the objects have the gravitational potential energy based on their position and the gravitational potential energy is just dependent on the height of the object. This case was found to be 17.14% in the test. In the second lateral category, the students placed it in the procedure category because they believe that the box gains an energy due to the force applied by the worker so there is no energy in its final state. Students think that, the object cannot gain energy without force. This case was determined to be 25.71% in the test.

The second of these misconceptions originates from placing the energy into the non-living-natural kinds category, which is one of the subcategories of the matter category. Students had a different meaning to energy in this misconception. They believed in that non-living things do not have energy. Only living things had energy. This case was determined to be 28.57% in the test.

The third of these misconceptions originates from placing the energy into the intentional event category, which is one of the subcategories of the process category. Energy has a different meaning in this misconception. The energy is just related to motion. Students installed a different meaning to process. This case was found to be 17.14% in the test.

The last case of these misconceptions originates from placing the energy into the natural constraint-based interaction category, which is one of the subcategories of the process category. The students defined lots of friction in the box, so its energy is much less than the worker. The rate of this case was determined to be 5.71% in the test.

Analyses for the Second Sample Question from Concept Test on the Topic of Force and Motion

In this question, the attention was drawn to the concept of mechanical energy within the topic of "Force and Motion". The questions of in which conditions the mechanical energy of the objects will change and if there is no friction in the environment, whether the total energy, namely the mechanical energy, will change according to the law of conservation of energy are questioned. It was tried to reveal whether the students know this concept and confuse it with the other types of energy. The students' level of understanding about the mechanical energy of the objects were classified according to the evaluation criteria, and their misconceptions about this concept was examined from an ontological perspective and the origins of these misconceptions were determined based on ontology.

Table 4. *The students' levels of understanding for the second sample question from concept test on the topic of force and motion*

Comprehension	f	%
Full Comprehension	5	14.29
Misconception	25	71.43
Not understanding	5	14.29

Table 4 reveals that 14.29% of the students fully and correctly understood the concepts given about the amount of the mechanical energy of the objects and the change of mechanical energy, and 71.43% of the students seemed to have misconceptions about this concept. The other study during the analysis of the second sample question from the "Concept Test on the Topic of Force and Motion" is to determine the misconceptions hold by the students. Table 5 shows the students' misconceptions about the "Second Sample Question" from "Concept Test on the Topic of Force and Motion".

Table 5. *The misconceptions in the students' answers for the second sample question from concept test on the topic of force and motion*

Misconception	f	%
When the kinetic energy changes, the mechanical energy also changes.	9	25.71
When the potential energy changes, the mechanical energy also changes.	8	22.86
The mechanical energy is not dependent on the kinetic and the potential energy. It is a constant energy.	6	17.14
The mechanical energy is only related to the mechanical structure of the car. The mechanical energy of the car is therefore reduced.	2	5.71

When Table 5 was examined, it is seen that the misconception that the students had the most in the test was "When the kinetic energy changes, the mechanical energy also changes". The rate of this case was determined to be 25.71%. The students' misconception with the second greatest percentage was "When the potential energy changes, the mechanical energy also changes". The rate of this case was 22.86%. Another misconception was "The mechanical energy is not dependent on the kinetic and the potential energy. It is a constant energy." The rate of this case was 17.14%. And, since some of the students think that "The mechanical energy is only related to the mechanical structure of the car. The mechanical energy of the car is therefore reduced". They come up with a different misconception. The rate of this case was determined to be 5.71%.

When the misconceptions of the students were examined, it shows the level of lack of the students had in the preliminary knowledge about mechanical energy. They attributed a different meaning to the mechanic energy by classifying it in energy types and thus they had misconceptions. Moreover, some students attributed a totally different meaning by thinking of the mechanical structure of the car. And, due to the lack of preliminary knowledge on energy, there was a misconception that the mechanical energy will also change during any change of energy.

The final study during the analysis of the second sample question from the “Concept Test on the Topic of Force and Motion” was examining the misconceptions from the ontological perspective. Figure 5 shows the ontological examination of students' misconceptions in the “Concept Test on the Topic of Force and Motion”.

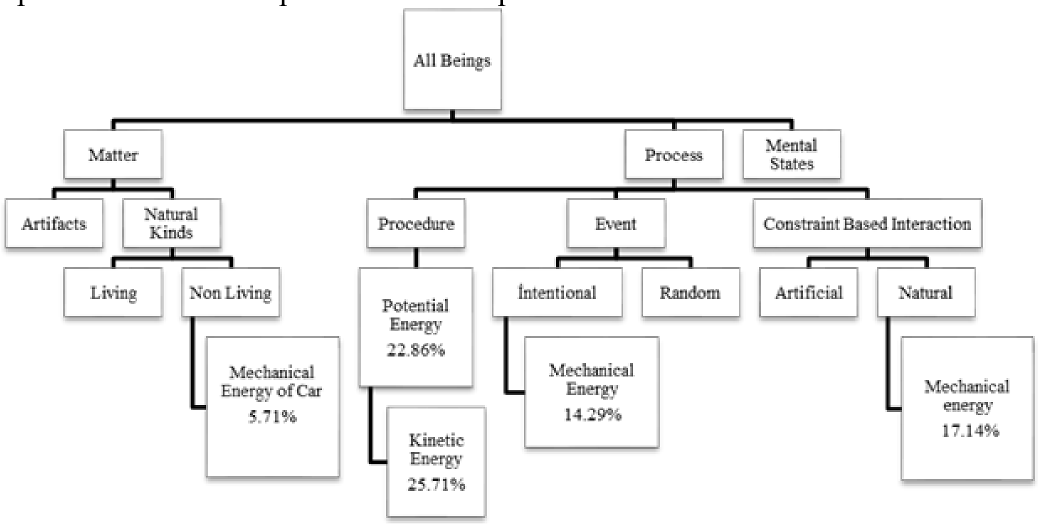

Figure 5. The ontological analysis of the students' misconceptions on the second sample question from concept test on the topic of force and motion

When Figure 5 was examined, the students who correctly answered the second sample question in “Concept Test on the Topic of Force and Motion” was seen to place the concept of the total mechanical energy change due to their motion and position in the intentional-event category, which was one of the subcategories of the process category by determining what the mechanical energy was and the states affecting the mechanical energy exactly. The rate of these students was found to be 14.29%.

In this question, three ontological origins was identified for the misconception on the concept of the total change of mechanical energy due to the motion and position of the objects. The first of these misconceptions originates from placing the concept laterally into the procedure category which is a subcategory of process category by associating the mechanical energy change with the changes of potential and kinetic energy instead of placing the concept that the mechanical energy exchange must not change due to the energy transformation, which is in the intentional-event category under the process category. Two different lateral categories were found in this category. The first of the lateral categories was the misconception that the change in the potential energy will cause a change in the mechanical energy. The proportion of these students was found to be 22.86%. The second of the lateral categories was the misconception that the change in the kinetic energy will cause a change in the mechanical energy. The rate of these students was 25.71%. The reason for these two misconceptions was that the students perceive the change in mechanical energy as the kinetic or potential energy.

The second of these misconceptions originates from placing the concept into the natural species-non-living thing category which was a subcategory of matter category by associating the mechanical energy with the structure of the car which was a non-living thing, instead of placing the concept that the mechanical energy exchange must not change due to the energy transformation into the intentional-event category. The rate of these students was found to be 5.71%.

The last case of these misconceptions originates from placing the concept wrongfully into the natural category which is one of the subcategories of the constrained-based interaction category, a subcategory of the process category. The students attributed a different meaning to the mechanical energy and they come up with an energy type which exists in nature and it was not dependent on the other energy types. According to them, the mechanical energy is constant, and it is not dependent on kinetic or potential energy. The rate of these students was 17.14%.

FINDINGS

Distribution of the Students' Misconceptions by Upper and Lateral Categories

Table 6 shows the number of the misconceptions by upper and lateral categories.

As seen in Table 6, the students used to have 301 misconceptions due to misplacing into the upper categories and 150 misconceptions due to misplacing into the lateral categories. Examples of these misconceptions were shown in Table 3 and Table 5. The numbers of misconceptions shown in Table 6 were the total result obtained by the responses of 35 students for each of the 17 questions in the test. The assessment of these misconceptions based on their categories was presented in detail in Table 7.

Table 6. *Distribution of the students' misconceptions by upper and lateral categories*

Question	Number of Misconception Upper Ontological Category	 Lateral Ontological Category	Total
Question 1	2	18	20
Question 2	8	11	19
Question 3	0	20	20
Question 4	33	0	33
Question 5	32	0	32
Question 6	1	28	29
Question 7	29	0	29
Question 8	30	0	30
Question 9	15	0	15
Question 10	32	0	32
Question 11	33	0	33
Question 12	25	0	25
Question 13	7	24	31
Question 14	23	2	25
Question 15	18	10	28
Question 16	0	25	25
Question 17	13	12	25
Total	301	150	451

According to Table 7, the students had 179 misconceptions in the procedure category. The percentage of the misconceptions eliminated in the procedure category was seen to be 76.30%. Considering the intentional-event category, there can be seen that 128 misconceptions placed in this category. Considering the constraint-based interaction category, there can be seen that 53 misconceptions placed in this category. There seem 69 misconceptions in the random-event category. There seem 13 misconceptions in the constraint-based interaction-artefact category. The last category to be identified was the matter-natural species-non-living-beings category. 3 misconceptions identified in this category. Examples of these misconceptions in the specified category were shown in Figure 4 and Figure 5. The numbers of misconceptions in the specified category shown in Table 7 were the total result obtained by the responses of 35 students for each of the 17 questions in the test.

If the identified categories considered, there can be seen that the most misconceptions seem to be in the procedure category. Intentional-event category seems to be the second category to host misconceptions. The least misconception was seen in the matter category.

Table 7. *The change of the students' misconceptions by the identified categories*

Question	Identified Categories					
	Procedure	**Intentional-Event**	**Constrained-based Interaction Natural**	**Random-Event**	**Constrained-based Interaction Artefact**	**Matter-Natural Species-Non-living Things**
1	2	18	-	-	-	-
2	11	8	-	-	-	-
3	-	-	20	-	-	-
4	15	-	-	18	-	-
5	30	-	-	-	2	-
6	-	23	-	-	-	1
7	12	-	-	17	-	-
8	-	30	-	-	-	-
9	-	-	5	10	-	-
10	-	-	5	24	3	-
11	32	-	-	-	-	-
12	17	-	6	-	-	2
13	24	-	7	-	-	-
14	23	2	-	-	-	-
15	-	10	10	-	8	-
16	-	25	-	-	-	-
17	13	12	-	-	-	-
Total	179	128	53	69	13	3

DISCUSSION and CONCLUSION

In this study, the misconceptions were mostly seen in two basic ontological categories (matter, process). These misconceptions occurred within the basic categories themselves. So, the misconceptions established not because of incorrectly categorization between these two basic categories. However, they established due to incorrectly categorization between their own subcategories. The misconceptions identified in the research examined and explained from the ontological perspective. Because the origins of these misconceptions can be found when these misconceptions are revealed with the help of ontological view. In other words, since the ontological categories between which the misconceptions are determined, it facilitates explaining the reasons for the occurrence of the misconceptions. Finding the causes of the misconceptions provides benefits for both the teachers and the students. The teachers, who know the causes of the misconceptions revealed ontologically, can plan their teaching properly and thus enable the students to learn better.

In this study, 301 misconceptions which is the total result obtained by the responses of 35 students for each of the 17 questions in the test determined to be arisen from misplacing into the upper categories and 150 misconceptions which is the total result obtained by the responses of 35 students for each of the 17 questions in the test determined to be arisen from misplacing into the lateral categories. When the students' misconceptions are examined, it can be said that many of these misconceptions originate from placing the concepts into wrong ontological subcategories of the process category such as operation, intentional-event, constraint-based interaction-natural, constraint-based interaction-artificial, and random-event categories. The misconceptions with the highest percentage are caused by misplacing of the concepts into the operation and intentional-event categories which are subcategories of the process category laterally. In their work, Slotta and Chi (2006) discussed how physicists will avoid the strong and permanent misconceptions by an ontology training and they addressed in which categories the basic topics of the physics can be observed intensely. When their study on electricity is examined, the identified misconceptions gathered under the process category. They state that the concept was placed into subcategories of the process category in different ways because of the teachers' concrete examples. This case falls in parallel with this study. The students in the experimental group generally placed their misconceptions on the basic concepts of the physics which were questioned before teaching in the subcategories of the process category. Acar (2010) also studied electromagnetic induction which is a topic of physics in his master's thesis and tried to categorize the conceptual semantics ontologically. It seems that all the misconceptions found in his study gathered under the process category.

The misconceptions in examples 3 and Table 5 that identified in the study also examined in a different way besides the upper and lateral ontological categories. In this turn, the misconceptions that identified in this analysis assessed by naming the categories. According to this analysis, the students had 179 misconceptions in the procedure category. Considering the intentional-event category, it can be seen that 128 misconceptions placed in this category. Considering the constraint-based interaction category, it can be seen that 53 misconceptions placed in this category. 69 misconceptions identified in the random-event category. There seem 13 misconceptions in the constraint-based interaction-artefact category. The last category to be identified was the matter-natural species-non-living-beings category. 3 misconceptions identified in this category. If the identified categories considered, there can be seen that the most misconceptions seem to be in the procedure category. Intentional-event category seems to be the second category to host misconceptions. The least misconception was seen in the matter category.

When the characteristics of the misconceptions formed under the matter category were examined, it was noticed that the students attribute measurable features such as mass, volume, etc. to the concepts of physics. There can be said that this is due to the examples that are given in the class to facilitate clarity of the topic. The students may attribute different meanings to the concepts while the teachers are trying to explain the issue and make it concrete. But since it is easy to correct the misconceptions created in this category, the teachers can make ontological corrections in a short time. The point to be noted here is the misconceptions that are under the process category. For example, when ontological characteristics of the misconceptions under the procedure category, which hosts the most misconceptions, are examined, a distress that the students experience in the classroom environment seems to be a reason. Mathematical and operational skills are used at a high level, especially in physics subjects. Therefore, when these skills are not fully acquired by the student, if the new concepts taught contain an operational feature, the emergence of a misconception becomes an inevitable condition. Because the students attribute meanings to the new topics in accordance with the framework of the categories in their minds. In these cases, if the concept to be given has its own characteristics, co-operation should be made with different disciplines or the methods and techniques should be selected suitable for their ontological characteristics. This feature should be provided to the student at first before trying to teach the concept. The ontological study to be made on the concepts to be given in the lessons will be very useful for us in selecting effective methods and techniques.

Suggestions

In order for the students to be able to build solid-based knowledge about the nature of the concepts in their minds, they should be informed that the examples given from daily life situations in traditionally conducted studies, and the related animations, the models used in the lessons, and the experimental studies used to make course contents clearer may not be true itself and may not express the situation completely.

It is understood that the teacher candidates have confused concepts such as work, the work as a scientific term, friction force, kinetic energy, potential energy, mechanical energy, friction force, the springs and the energy stored in springs. The emphasis on the differences between the basic concepts that resemble each other in the class can be a barrier to the formation of such confusion. In order to make the students categorize such concepts correctly and imagine them in their minds, it should be kept in mind that the students need a transition period. In the course of their lives, any practice that they can do themselves on the concepts will create opportunities to organize the categories in their minds.

The emphasis given on the stages of the realization process and the sub-dimensions under the process category in the lessons while talking about the concepts of physics, many of which are process-based, may result in further reducing the ontological category mistakes. For this reason, revealing the ontological features of the concepts to be given and giving the concept by emphasizing these features in the activities before the lessons to be given by the teachers will contribute to the easier progress of the learning process.

When the research results were examined, it was seen that the students had many misconceptions about the topic of “Force and Motion”. The topic of “Force and Motion" is a unit of elementary and middle school course content and it is one of the fundamentals of the physics course. Trying to teach other subjects to the students at further grades without correcting the misconceptions about this topic will bring out other problems and will lead to the formation of other different misconceptions. Therefore, learning the students' misconceptions about the subject and organizing the teaching process to cover and prevent these misconceptions will create opportunities for a full learning environment in the classroom.

The course syllabus arrangements by the teachers are also closely related to the curriculum. Therefore, some changes should be made in the curriculum. For example, the course content can be organized to prevent misconceptions about “Force and Motion”. Various measurement tools can be used to determine these misconceptions. The test covering the two-tier questions used in this study can help to determine both the misconceptions related to the “Force and Motion” issues and the causes of these misconceptions.

In the study, the assessment of the misconceptions according to ontological categories was facilitated understanding the reasons that lead these misconceptions. Knowing the causes of misconceptions is very important for this study and for the similar ones. Misconceptions can only be avoided by focusing on their causes, and preparing studies, teaching methods, etc. that can prevent their occurrence. Therefore, ontological categories are very important because they facilitate revealing the causes of misconceptions. The studies such as determination, evaluation, and elimination of misconceptions should be made using ontological categories.

Studies can be done on the development of concept maps based on ontological categories. Because the structure of ontologies is like the structure of concept maps.

Ontologies help teachers to easily build the concept maps and discover unconnected pieces in concept systems of subjects. Ontology-based concept maps may be necessary for effective science teaching.

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