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Determination of Secondary School Fifth-Grade Students' Misconceptions about Friction Force Using Concept Cartoons[1]

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Abstract: The aim of this study is to determine secondary school fifth-grade students' misconceptions about friction force through concept cartoons. The case study survey model, one of the quantitative research methods, was used in the study. The sample of the study consists of fifth-grade students (N=54), including 27 girls and 27 boys, studying at a secondary school in the Marmara Region of Türkiye. The sample was determined using the appropriate sampling method, taking into account the principle of accessibility. The data were obtained by using concept cartoons developed by the researcher. Descriptive statistics were used in the analysis of the data. As a result of the research, it has been determined that fifth-grade middle school students have many misconceptions regarding the topic of frictional force. 51.85% of the students ignore the frictional force due to air, stating that the inside of the cup is empty. It was determined that 50% of the students had the misconception that there is no friction force on smooth surfaces such as polished wood or ice. In the study, it was seen that concept cartoons were effective in determining misconceptions. Concept cartoon-supported argumentation teaching method can be used to eliminate students' misconceptions about excessive specialization about friction force.

Keywords: *Science Education, Concept Cartoon, Misconception, Friction Force*.

1. INTRODUCTION

The science course, which enables the observation of nature and natural events and their systematic examination, has a subject area that includes knowledge and concepts in many fields such as physics, chemistry, biology, environment and health. In this respect, concepts are a type of knowledge that has an important place in science teaching. In order for the information and thoughts formed in the minds of individuals as a result of their experiences to be permanent, they must be grouped and classified. Concepts are the building blocks of knowledge and thought that enable individuals to group and organize what they have learned (Cansüngü Koray & Bal, 2002). Concepts formed by individuals based on their experiences are a product of mental activities. Therefore, incorrect grouping or classification of information and thoughts in the mental process can create misconceptions called alternative concepts in individuals. Misconceptions are students' prior knowledge that conflicts with scientific truths or incorrect

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relationships they establish between schemas while creating a new cognitive schema (İnel, Balım & Evrekli, 2009). In the literature, misconceptions are expressed with many different terms. Some of those; "misunderstanding", "alternative concepts", "child science", "pre-concepts", "spontaneous knowledge" and "intuitive beliefs" (Feyzioğlu, 2006; Köse, Ayas & Taş, 2003; Lavoie, 1997; McCloskey, Washburn & Felch 1983; Trowbridge & Mintzes, 1985; Yalcin et al., 2009).

The basis of the constructivist learning approach adopted in science teaching programs in Türkiye since 2005 is the understanding that new information is learned by associating it with pre-existing information in the mind. The process by which information is structured in the mind in this way is shaped by the individual's previous experiences, observations, comments and thoughts (Kabapınar, 2006).

If there are misconceptions in the preliminary knowledge structured in various ways, this may cause incorrect structuring of new learning. In some studies, it is stated that misconceptions cannot be completely eliminated even after the subject is explained, and that this situation arises from misconceptions referred to as "ossified misconceptions" in the preliminary information (Akbulut, Şahin & Çepni, 2013). Therefore, planning a new teaching after identifying the misconceptions in students' prior knowledge will ensure more solid learning. For this reason, it is thought that detecting misconceptions is at least as important as eliminating misconceptions.

2. LITERATURE REVIEW

It is seen that conceptual change texts, concept maps, interviews, drawings, multiple choice tests, analogies and concept cartoons are used in studies on identifying and eliminating misconceptions in the literature (Akbulut, Şahin & Çepni, 2013; Şenel Çoruhlu & Çepni, 2015; Tekin et al., 2004). It is seen that multiple choice questions are used in most of the studies carried out to determine misconceptions (Aydoğan & Köksal, 2017; Khurshid & Iqbal, 2009). However, some researchers do not find it appropriate to use multiple choice questions in determining misconceptions because multiple choice questions cannot distinguish misconceptions from incorrect and incomplete information (Eryılmaz & Sürmeli, 2002). According to Keogh and Naylor (1999a), concept cartoons are one of the effective techniques in identifying misconceptions. Concept cartoons are interesting and surprising cartoon drawings in which each character reflects his or her own perspective on an event in daily life (Keogh & Naylor, 1999b; Martinez, 2004). However, concept cartoons are different from regular cartoons. In particular, the fact that concept cartoons do not aim to make individuals laugh and that they make them think and question their knowledge is one of the features that distinguish these cartoons from normal cartoons (Keogh & Naylor, 1999a).This feature is important in terms of making individuals think about a certain concept or situation and questioning their own thoughts and revealing misconceptions in their prior knowledge. As a matter of fact, in the literature, it is seen that the use of concept cartoons is effective in determining and eliminating misconceptions about some physics concepts (Atasoy, Tekbıyık & Gülay 2013; Atasoy & Ergin, 2017; Serttaş & Türkoğlu, 2020; Uzoğlu et al., 2013). In the

study conducted by Serttaş and Türkoğlu (2020), concept cartoons were used to diagnose misconceptions about a number of basic astronomy concepts including the Universe, the Sun, Comets and Constellations, and it was found that they were effective in identifying misconceptions. In the study conducted by Uzoğlu et al (2013), the effectiveness of open-ended questions and concept cartoons in determining alternative thoughts on the subject of light was compared. The study conducted by Uzoğlu et al. (2013) found that concept cartoons were at least as effective as open-ended questions in identifying misconceptions. Therefore, concept cartoons were used in this study to identify the misconceptions fifth-grade middle school students have regarding the topic of frictional force.

Friction force is a concept related to force and motion, which are fundamental subjects of physics. The first achievements regarding the concept of friction force are included in the fifth-grade "Measurement of force and friction" and seventh-grade "Force and Energy" units of secondary school (Ministry of National Education [MoNE], 2018). Therefore, it can be said that the concept of friction force forms the basis of the subject of force and motion in upper education levels. Friction force is a difficult concept to be learned by students and taught by teachers (Çeltek, 2019; Develi & Namdar, 2019; Kakız, 2019; Mulhall & Gunstone, 2012). In this respect, it is very important to determine the misconceptions about friction force. When the literature is examined, it is seen that most studies have studied misconceptions about friction force at high school and university levels (Atasoy & Ergin, 2017; Kaplan, Yılmazlar & Çorapçıgil, 2014; Kurnaz & Eksi, 2015; Prasitpong & Chitaree, 2009; Prasitpong et al., 2010; Tavukçuoğlu, 2018). On the other hand, studies on determining conceptual understanding, mental models and misconceptions about friction force at the secondary school level are relatively less (Tekbıyık, 2015; Yüzbaşıoğlu & Kurnaz, 2022). For the aforementioned reasons, this study aimed to determine the misconceptions of secondary school fifth-grade students about friction force by using concept cartoons.

2.1. Research Problem

What are the misconceptions of fifth-grade secondary school students about friction force?

2.1.1. Sub-Problems of the Research

In line with the purpose of the study, concept cartoons were used while determining misconceptions. Therefore, a concept cartoon was developed by the researchers for each of the three learning outcomes of the friction force subject in the secondary school fifth-grade curriculum. For this reason, the misconceptions of fifth-grade secondary school students about friction force will be examined separately according to these learning outcomes. The sub-problems of the research are; What are the misconceptions of fifth-grade middle school students regarding the learning outcome;

1) "F.5.3.2.1. Provides examples of frictional force from daily life"?
2) "F.5.3.2.2. Discovers the effect of friction force on motion in various environments by experimenting"?
3) "F.5.3.2.3. Generates new ideas to increase or decrease friction in daily life."?

3. METHODOLOGY

3.1. Research Model

This study is a descriptive research conducted in a survey model aimed at identifying the misconceptions of fifth-grade middle school students regarding the topic of frictional force. Survey models are research approaches that aim to describe the existing situation regarding the research subject as it is in its own conditions (Büyüköztürk et al., 2015). In this study, the case study survey model, which is one of the survey models, has been used. The case study survey model allows for in-depth research with small samples (Karasar, 2008). Additionally, this method is considered suitable for individually conducted studies as it provides the opportunity to examine the possible causes of an event in detail within a short period of time (Çepni, 2007; Karasar, 2008). As a result, since the aim of the study was to determine the misconceptions of a limited number of middle school fifth-grade students (N=50) about the friction force by using cartoons, the case study survey model was used in the research.

3.2. Population and Sample of the Research

This study aims to determine misconceptions about friction force at secondary school level. According to the MEB (2018) science course curriculum, the outcomes learning related to this subject are first included in the fifth-grade. Therefore, the population of the research consists of fifth-grade secondary school students studying in a secondary school in the Marmara Region of Türkiye. The sample of the research consists of a total of 54 fifth-grade secondary school students, 27 boys and 27 girls, determined from the population using the appropriate sampling method. Appropriate sampling allows selecting samples that are close to the researcher and easy to access (Yıldırım & Şimşek, 2016). Therefore, since this study was conducted with fifth-grade students at the school where one of the researchers teaches, the participants were determined by appropriate sampling. The distribution of the students participating in the research by gender is presented in Table 1.

Table 1. *Distribution of Students Participating in the Research by Gender*

Gender	**N (%)**
Female	27 (%50)
Male	27 (%50)
Total	54 (%100)

3.3. Data Collection Tools

The data in the study were obtained through concept cartoons developed by the researcher on the topic of friction force. Concept cartoons are one of the most effective techniques for identifying misconceptions (Keogh & Naylor, 1999a). It is thought to be particularly suitable for the age group in the sample of the study in terms of its aim to make people think about a certain scenario situation and its visual element. For this reason, concept cartoons were preferred as a data collection tool in determining the misconceptions of fifth-grade middle school students about the friction force. To ensure the content validity of the prepared data

collection tools, the opinions of two field experts were consulted. After examining the data collection tools in terms of content, spelling and visuality, some linguistic corrections were made in line with expert opinions. After the corrections, the data collection tools were applied to four fifth-grade middle school students outside the sample in order to examine their applicability. After this application, the data collection tools took their final form.

3.3.1. Concept Cartoon on Friction Force

To identify the misconceptions of fifth-grade middle school students regarding the concept of friction force, the researcher developed three separate concept cartoons targeting three different learning outcomes from the fifth-grade friction force topic in the MoNE (2018) curriculum. These cartoons were administered to 54 students. The concept cartoons are provided in Appendices 1, 2, and 3. Table 2 presents which learning outcomes the concept cartoons in the appendices correspond to.

Table 2. *Learning Outcomes Related to the Topic of Friction Force*

Learning Outcome Number	**Learning Outcome**	**Concept Cartons**
F.5.3.2.1.	Provides examples of frictional force from daily life.	Appendix 1
F.5.3.2.2.	Discovers the effect of friction force on motion in various environments by experimenting.	Appendix 2
F.5.3.2.3.	Generates new ideas to increase or decrease friction in daily life.	Appendix 3

In the developed concept cartoons, three of the four characters' speech bubbles contain misconceptions related to friction force as found in the literature, adapted to the scenario depicted in the cartoon. The misconceptions in the speech bubbles were created by making use of the misconceptions about friction force determined in the studies conducted by Bostan Sarıoğlan (2014) and Demir et al. (2012). One character's speech bubble is left blank for the student to write the correct statement related to the scenario themselves.

3.4. The Analysis of the Data

The analysis of the data obtained through concept cartoons was conducted using descriptive statistics. While creating categories in the analysis of the data, we were inspired by the categories created by Abraham et al. (1992). While the answers given by the students to the concept cartoon were categorized, the answers of the students who made the correct prediction and defended it with the right reasons were collected under the *"Correct Answer"* category. The responses of students who made correct predictions regarding the scenario depicted in the concept cartoons but included misconceptions in their reason were categorized under the *"Partially Correct Answer"* category. Finally, answers from students who made incorrect predictions were categorized as *"Incorrect Answer"* and answers that only made predictions without providing reasoning were grouped under the *"Uncodable Answer"* category. Frequency and percentage calculations were performed for these answer categories as well.

4. FINDINGS

The findings obtained according to the sub-problems of the research have been presented under three main headings.

4.1. Findings Related to the First Sub-Problem

In order to obtain data regarding the first sub-problem of the research, In the concept cartoon prepared for the learning outcome of "***F.5.3.2.1.*** *Provides examples of frictional force from daily life.*", the problem situation in Figure 1 is given.

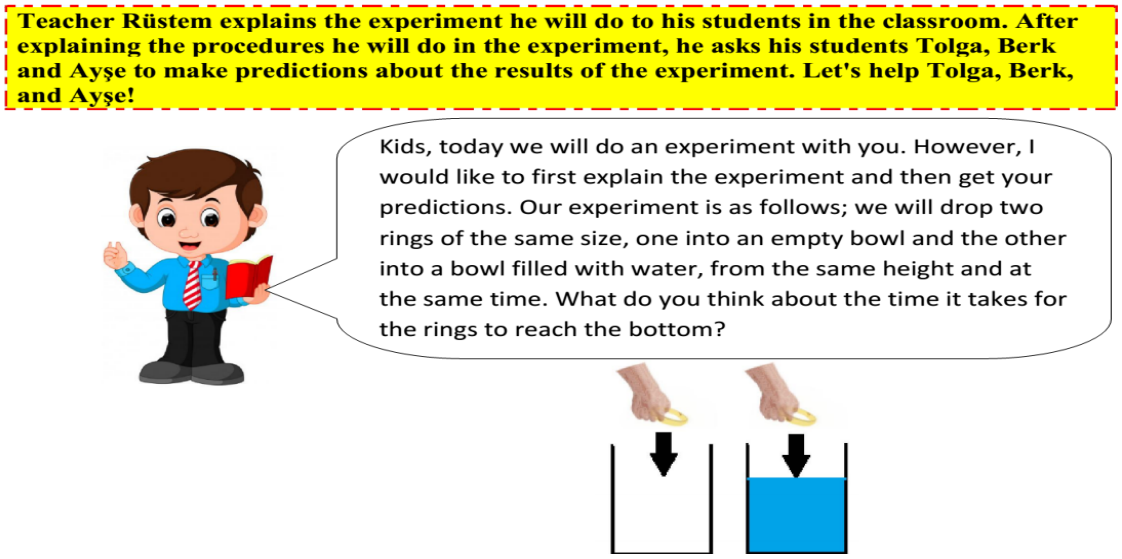

Figure 1. *The Concept Cartoon for Learning Outcome Numbered F.5.3.2.1.*

The findings obtained from the concept cartoon containing the problem situation in Figure 1 are given in Table 3.

Table 3. *Misconceptions of Secondary School Fifth-Grade Students about the F.5.3.2.1. Learning Outcomes*

Answer Type	Answers Given	Frequency (%)
Correct Answer	❖ Answers predicting *"I think the ring will reach the bottom quicker in an empty bowl"* and expressing the reason that the ring will reach the bottom more slowly in a water-filled container because the resistance of water is greater than the resistance of air.	16 (%29.63)
Partially Correct Answer	❖ Answers accepting the thought *"The ring will reach the bottom quicker in the empty bowl because there is no friction force"* as correct and reasoning that water resistance is a type of friction force that makes it difficult for moving objects to move.	28 (%51.85)
Incorrect Answer	❖ *"The ring will reach the bottom faster in a water-filled bowl because the friction force in the water is low, so the water pulls the ring to the bottom more quickly."* ❖ Answers accepting the thought *"I think both will reach the bottom at the same time because the weights of both rings are equal"* as correct and reasoning that water resistance and air resistance are types of friction force or incorrectly expressing the effects of friction force on the movement of the object.	7 (%12.96)
Uncodable Answer	❖ *"I think all three are wrong. They did not mention air resistance."* ❖ *"It will go further in the empty bowl because air resistance is much lower than water resistance, allowing it to move faster."* ❖ *"I think the ring will take a long time to reach the bottom in the water-filled bowl, but it will reach the bottom in a very short time in the empty bowl."*	3 (%5.56)

In the concept cartoon containing the problem situation in Figure 1, it is aimed to give examples of friction force from daily life such as water resistance and air resistance, and to reveal the misconceptions of fifth-grade secondary school students about comparing water resistance and air resistance. Three (5.56%) of the students participating in the research only wrote their own predictions about the experiment in the problem situation, without stating any scientific justification and without agreeing with any character. Therefore, such responses were categorized as uncodable answers because they did not provide any data. 28 students (51.85%)

participating in the research have the misconception that there is no frictional force in the empty (air-filled) bowl. However, the students who gave this answer said, "*The ring reaches the bottom faster in an empty bowl.*" It was evaluated in the partially correct category because they stated in their justification that water resistance is a kind of friction force and makes the movement of moving objects difficult. On the other hand, 7 students (12.96%) defended their incorrect predictions, which included misconceptions, with sentences asserting that water resistance is less than air resistance, that water resistance pulls the ring to the bottom, or that there is no water and air resistance, and they will reach the bottom in equal time because their weights are equal. 16 students (29.63%) gave the correct answer that the ring moves more slowly in water because water resistance is greater than air resistance, and therefore, it will reach the bottom later.

4.2. Findings Related to the Second Sub-Problem

To obtain data related to the second sub-problem of the research, a problem situation in the concept cartoon prepared for the learning outcome "***F.5.3.2.2.*** *Discovers the effect of friction force on motion in various environments by experimenting*" is presented in Figure 2.

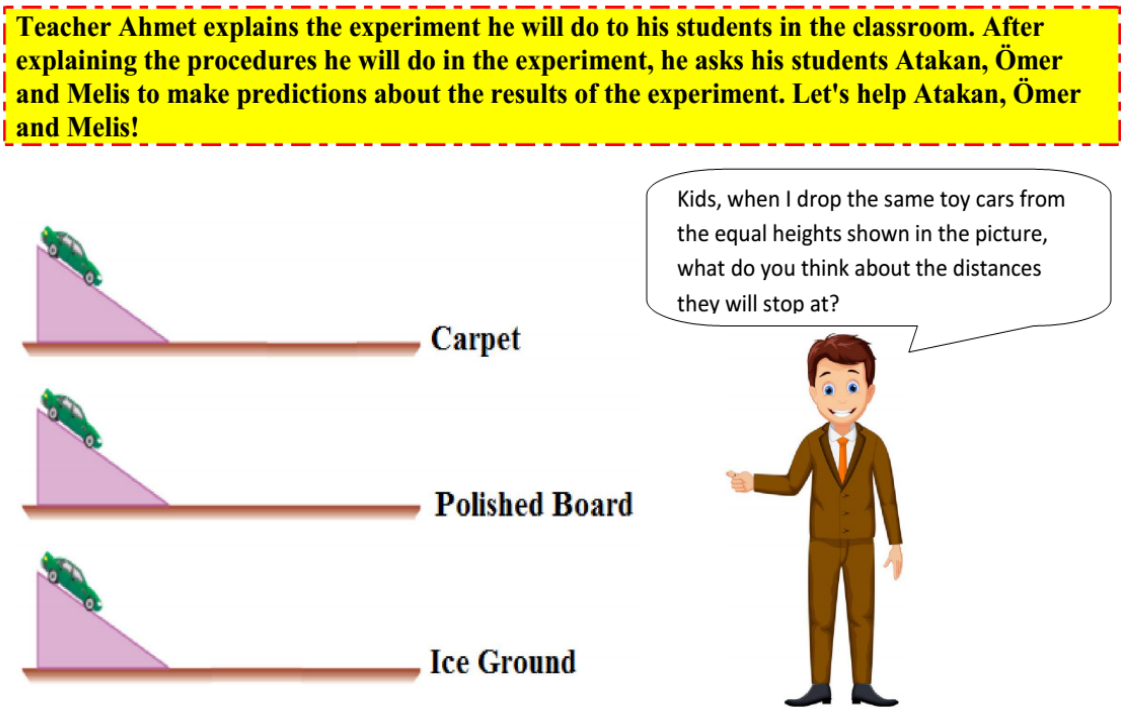

Figure 2. *The Concept Cartoon for Learning Outcome Numbered F.5.3.2.2.*

The findings obtained from the concept cartoon containing the problem situation in Figure 2 are given in Table 4.

Table 4. *Misconceptions of Secondary School Fifth-Grade Students about the F.5.3.2.2. Learning Outcomes*

Answer Type	Answers Given	Frequency (%)
Correct Answer	❖ *"The car travels further on ice." Answers that make a prediction and state in their justification that ice is slippery because it is smoother and that the friction force is less on less rough surfaces.*	26 (%48.15)
Partially Correct Answer	❖ *"I think the toy car travelled a longer distance on ice and stopped. Because the ice is slippery, the friction force does not affect the toy car."*	14 (%25.93)
Incorrect Answer	❖ *"The toy car travelled a longer distance and stopped on the polished board. Because the polished surface is smooth, the friction force does not affect the toy car."* ❖ *"Since the weights of all three toy cars are equal, the friction force acting on the vehicles is the same. That's why all three of them stopped at an equal distance."* ❖ *"I think toy cars can travel longer distances on carpet. Because cars slow down on carpets because they rub on the carpet."* ❖ *"The toy car moves further on ice. Because the ice is slippery and smooth, it rubs more with the ice."*	13 (%24.07)
Uncodable Answer	❖ *"I think the car goes down faster on ice. On carpet, it goes down slower. In my opinion, it goes down faster on polished wood."*	1 (%1.85)

In the concept cartoon containing the problem situation in Figure 2, it is aimed to reveal the misconceptions of fifth-grade secondary school students regarding the effect of friction force on movement in various environments (rough and smooth surfaces). One of the students participating in the research (1.85%) did not make an explanation about how long the car would travel. Therefore, since this answer did not provide any data for the research, it was included in the uncodable answer category. 14 (25.93%) of the students participating in the research have the misconception that there is no friction force on ice. However, although the students who gave this answer correctly guessed that the toy car traveled the furthest on ice, it was evaluated in the partially correct category because there was a misconception in their justification. 13 (24.07%) of the fifth-grade secondary school students defended their incorrect predictions that the toy car would travel a longer distance on polished wood, that all three cars would stay at equal distances because their weights are equal, and that it would travel a longer distance on carpet, with sentences containing misconceptions. 26 (48.15%) students correctly answered that they travel further on ice and that the friction force in ice is less than others.

4.3. Findings Related to the Third Sub-Problem

To obtain data related to the third sub-problem of the research, a problem situation in the concept cartoon prepared for the learning outcome "***F.5.3.2.3.*** *Generates new ideas to increase or decrease friction in daily life.*" is presented in Figure 3.

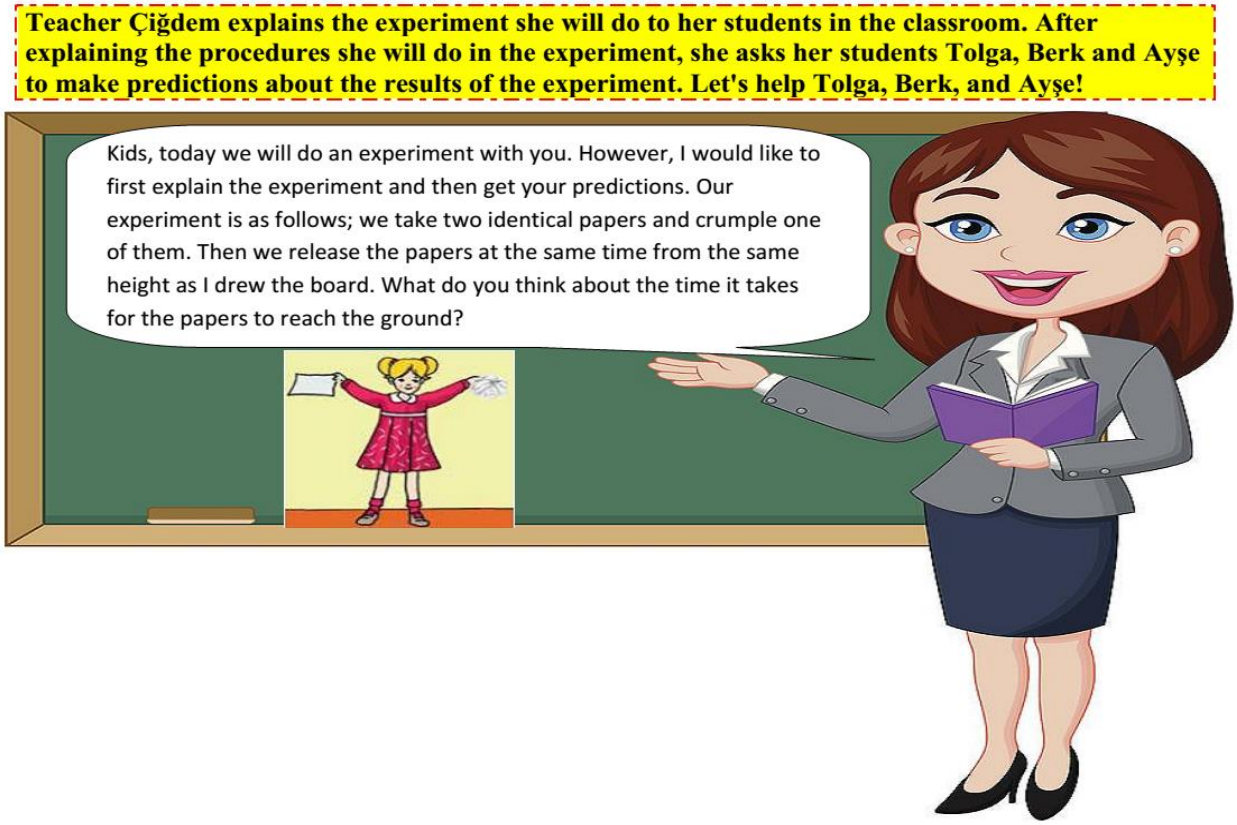

Figure 3. *The Concept Cartoon for Learning Outcome Numbered F.5.3.2.3.*

The findings obtained from the concept cartoon containing the problem situation in Figure 3 are given in Table 5.

Table 5. *Misconceptions of Secondary School Fifth-Grade Students about the F.5.3.2.3. Learning Outcomes*

Answer Type	Answers Given	Frequency (%)
Correct Answer	❖ Answers that predict *"The crumpled paper falls to the ground first, then the flat paper"* and explain it with examples such as the air resistance on large surfaces being greater and this slowing down the falling movement, and the gliding of a parachute.	9 (%16.67)
Partially Correct Answer	❖ *"I think flat paper falls to the ground later. Because flat paper is thinner, its weight is less. Therefore, less friction force acts on the flat paper. Thus, the flat paper falls to the ground later."*	35 (%64.81)
Incorrect Answer	❖ *Crumpled paper falls to the ground later. Because the friction force is greater on rough surfaces, the friction of the air slowed down the crumpled paper."* ❖ *"I think they will both reach the ground at the same time. Since the weights of both papers are equal, the friction force acting on both papers is equal."*	6 (%11.11)
Uncodable Answer	❖ *"In my opinion, crumpled paper goes down first, while normal paper goes down slower than crumpled paper."* ❖ *"Crumpled paper reaches the ground faster."* ❖ *"It seems logical to me, it explained the friction force well."* ❖ *"Because rough paper goes down faster."*	4 (%7.41)

The concept cartoon containing the problem situation in Figure 3 aims to reveal the misconceptions of fifth-grade secondary school students about what can be done to increase or decrease friction in daily life. 4 (7.41%) of the students who participated in the research only wrote their own predictions without stating any scientific justification for the experiment in the problem situation and without participating in any characters. Therefore, such answers were categorized as uncodable answers because they did not provide any data. 35 (64.81%) of the students participating in the research have the misconception that since flat paper is thinner, its weight is less and therefore it will have less friction force. However, although the students who gave this answer correctly predicted that flat paper would fall to the ground later, it was evaluated in the partially correct category because there was a misconception in their justification. 6 (11.11%) of the fifth-grade secondary school students defended their incorrect predictions that the crumpled paper falls to the ground later or that both papers will fall to the

ground in equal time because their weights are equal, with sentences containing misconceptions. 9 (48.15%) students answered correctly that the reason why flat paper falls to the ground later than crumpled paper is that flat paper has more surface area and will have more air resistance.

5. DISCUSSION, CONCLUSION AND RECOMMENDATIONS

The findings obtained from the study showed that secondary school fifth-grade students have many misconceptions about friction force that are different from scientific facts. When the research data is examined in general, the scarcity of uncoded answers is a striking finding. Based on this finding, it can be said that concept cartoons are effective in detecting misconceptions. This situation is similar to the results of many studies in the literature (Chin & Teou, 2009; Keogh &Naylor, 1999a; Önal, 2023). In a study conducted by Chin and Teou (2009), it was investigated how concept cartoons should be used to encourage discussion within the scope of students' peer assessment and self-assessment. The study stated that concept cartoons are an effective tool in providing feedback to the teacher about students' misunderstandings towards conceptual change (Chin & Teou, 2009). In addition, the fact that concept cartoons visually reflect a certain scenario situation and that various characters reflect their thoughts with justifications in speech bubbles can be interesting for fifth-grade secondary school students and make it easier for them to understand the problem situation. Therefore, it can be said that concept cartoons are an effective technique in determining the misconceptions of young age students and that concept cartoons can be used in studies conducted in this direction. As a matter of fact, the results of many studies are similar to this finding of the study (Çiğdemtekin, 2007; Ekici et al., 2007; Kabapınar, 2005; Uzoğlu et al., 2013).

In the first sub-problem of this study, which was conducted to determine the misconceptions of fifth-grade secondary school students about the friction force, the students' misconceptions about the friction force in daily life were examined. In the prepared concept cartoon, a problem situation regarding air and water resistance, which is an example of friction force from daily life, was presented to the students. 51.85% of the students have the misconception that there is no friction force in an empty bowl (filled with air). The students' inability to express air resistance in the cartoon because they cannot see the air, focusing instead on tangible things, may stem from their transition from the concrete operational stage to the formal operational stage in cognitive development. This finding is similar to the results of the study conducted by Genç (2008) to reveal the understanding levels and misconceptions of sixth grade students about "Force and Motion" in the primary school science course. On the other hand, this study, unlike the literature, shows that 12.96% of the students have conceptual misconceptions such as water resistance being less than air resistance, water pulling the object downwards, the absence of water and air resistance, and the rings reaching the bottom in equal time because their weights are equal.

In the second sub-problem of the research, students' misconceptions regarding the effect of friction force on motion in various environments were examined. In the prepared concept cartoon, students were presented with a problem situation regarding the movement of identical

toy cars on carpet, polished wood, and ice surfaces by releasing them from an inclined plane of equal height. A total of 50% of the students have the misconception that there is no friction force on smooth surfaces such as polished wood or ice. This finding of the study is parallel to the results of the study conducted by Genç (2008). On the other hand, in Hapkiewicz's (1992) study, it was determined that students held the misconception that friction is caused solely by the roughness of the surface, similar to this line of thought. In addition, unlike the studies in the literature, students with 50% misconceptions, ignoring the environment factor, say that equal friction force will be applied because the weights of toy cars are equal, that the car will move further because there is more friction on the icy ground, or that it will take longer because the friction force is high on the carpet. It seems that there are misconceptions such as it can go a long way.

In the third sub-problem of the research conducted to determine the misconceptions of fifth-grade secondary school students regarding the friction force, misconceptions about what can be done to increase or decrease friction in daily life were examined. In the prepared concept cartoon, students were presented with a problem situation regarding the time it takes for two identical papers, one crumpled and the other flat, to fall to the ground when thrown from equal heights. 64.81% of the students have a misconception that since flat paper is thinner and lighter in weight, it will fall to the ground later due to less friction force. Additionally, some of the 11.11% of the students said, "*Since the crumpled paper is rough, the friction force slows down the rough paper and causes it to reach the ground later.*" has a misconception. Additionally, some of the 11.11% of the students said, "*Since the crumpled paper is rough, the friction force slows down the rough paper and causes it to reach the ground later.*" has a misconception. While saying this expression, "The friction force is high on rough surfaces." It is seen that they based on their knowledge. Another part of the students said, "*Since the weight of both papers is equal, equal friction force acts and the papers reach the ground in equal time.*" It was determined that he had a misconception. While expressing this, "Equal friction force acts on objects of equal weight." It was seen that they started from their knowledge. In the other sub-problems, it was also observed that the students excessively focused on the idea that "if the weight is equal, the friction force is equal," while ignoring many factors specific to the problem situation. It can be said that these types of misconceptions fall into the over-specification misconception type, which is based on the idea of learning information and adapting that information to every situation. In order to eliminate or prevent such misconceptions, it may be recommended to use the argumentation teaching method supported by concept cartoons. In fact, in argumentation-based teaching, students can see the correctness or incorrectness of the arguments they produce through concept cartoons during in-class discussions, either within groups or between groups. A study by Cin (2013) examined the effects of argumentation-based concept cartoon activities on students' levels of conceptual understanding and scientific process skills. The study found that in the seventh grade "Electricity in Our Lives" unit, argumentation-based concept cartoon activities created a significant positive difference in students' levels of conceptual understanding.

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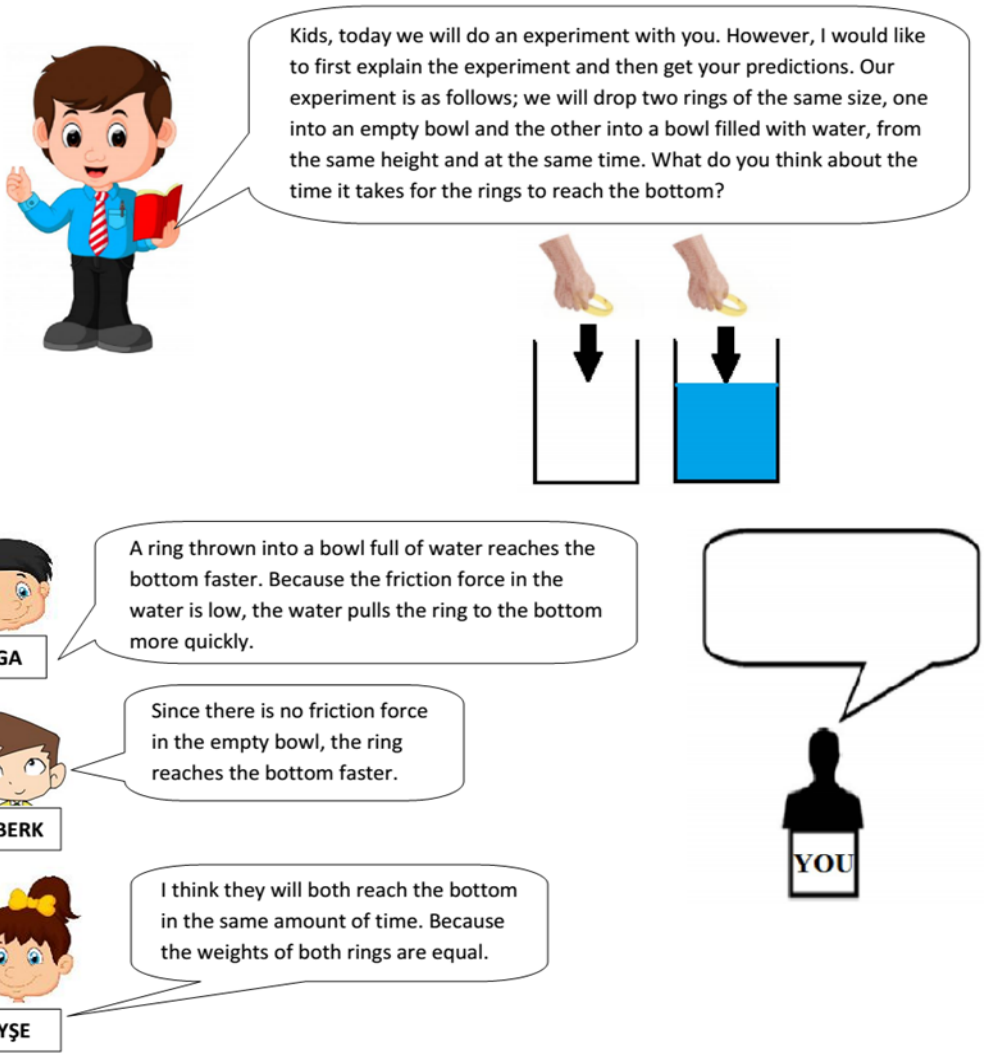
Appendices

Appendix-1: The Concept Cartoon for Learning Outcome Numbered F.5.3.2.1.

Teacher Rüstem explains the experiment he will do to his students in the classroom. After explaining the procedures he will do in the experiment, he asks his students Tolga, Berk and Ayşe to make predictions about the results of the experiment. Let's help Tolga, Berk, and Ayşe!

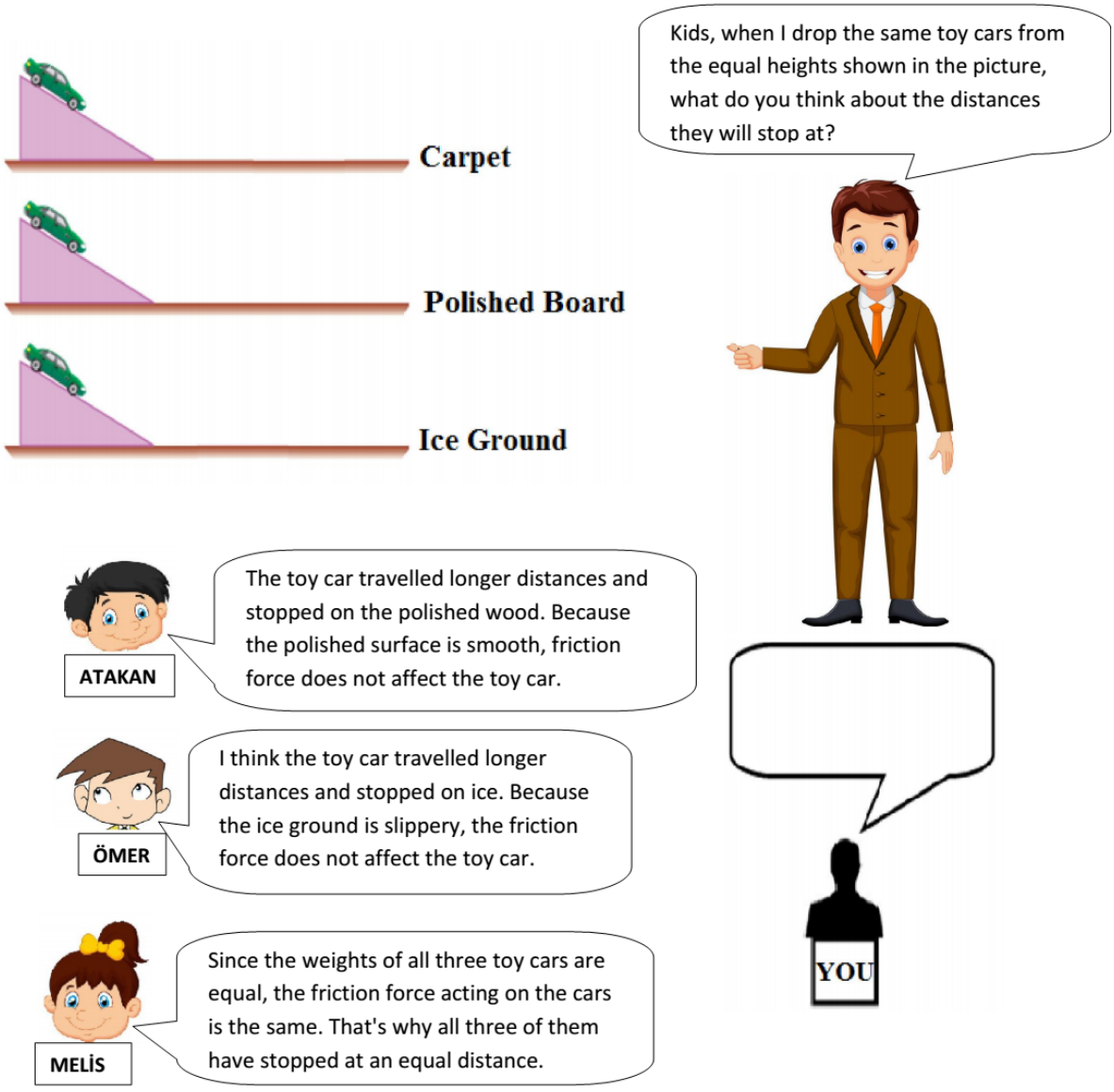


Examine the cartoons.

- **Which student do you think thinks correctly about the incident in the cartoon? (If you do not agree with any of these students, write your opinion with the reason in the balloon of the "you" character.)**
- **Explain the reason for this thought?**

Appendix-2: The Concept Cartoon for Learning Outcome Numbered F.5.3.2.2.

Teacher Ahmet explains the experiment he will do to his students in the classroom. After explaining the procedures he will do in the experiment, he asks his students Atakan, Ömer and Melis to make predictions about the results of the experiment. Let's help Atakan, Ömer and Melis!

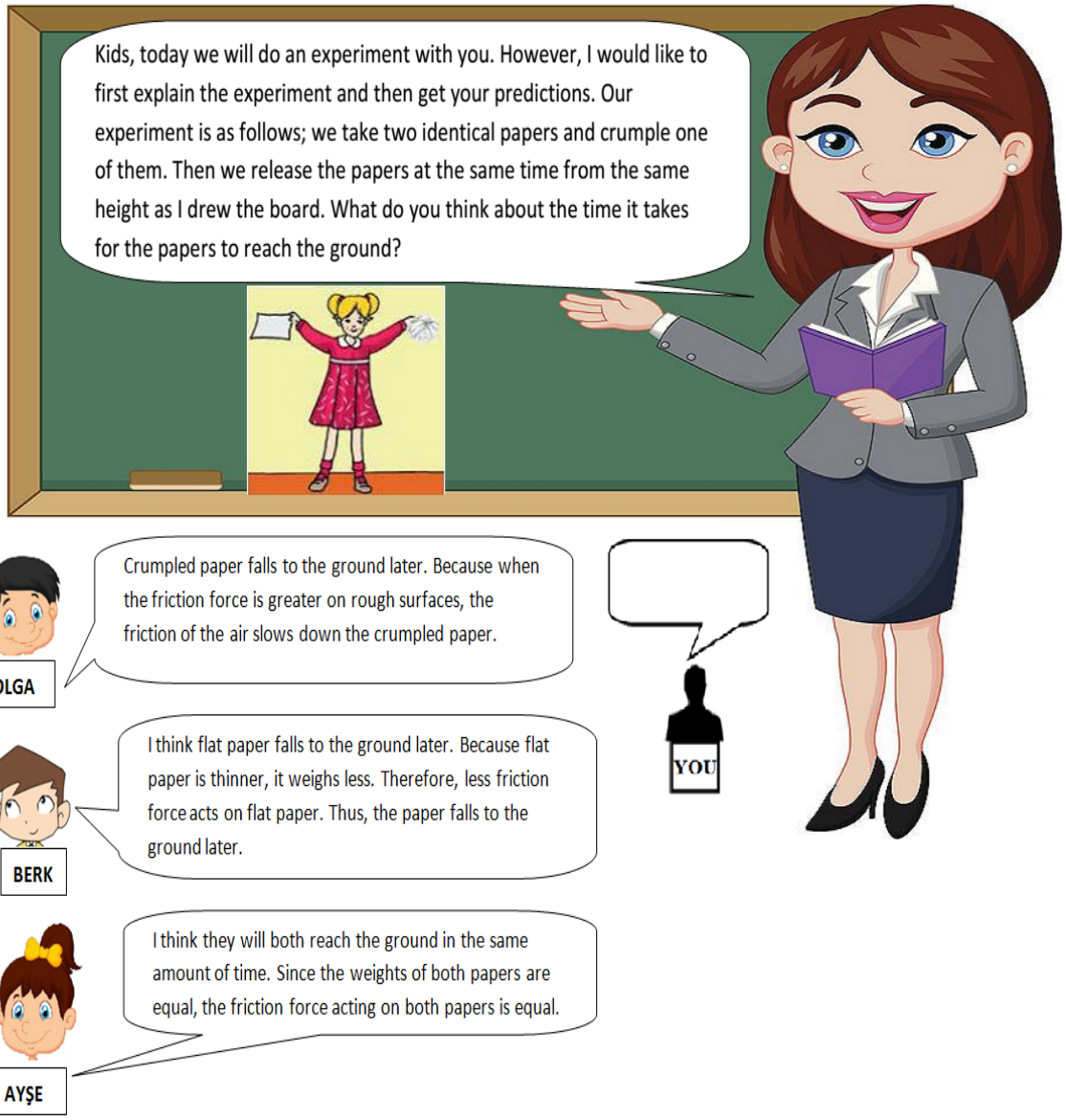


Examine the cartoons.

- **Which student do you think thinks correctly about the incident in the cartoon? (If you do not agree with any of these students, write your opinion with the reason in the balloon of the "you" character.)**
- **Explain the reason for this thought?**

Appendix-3: The Concept Cartoon for Learning Outcome Numbered F.5.3.2.3.

Teacher Çiğdem explains the experiment she will do to her students in the classroom. After explaining the procedures she will do in the experiment, she asks her students Tolga, Berk and Ayşe to make predictions about the results of the experiment. Let's help Tolga, Berk, and Ayşe!



Examine the cartoons.

- **Which student do you think thinks correctly about the incident in the cartoon? (If you do not agree with any of these students, write your opinion with the reason in the balloon of the "you" character.)**
- **Explain the reason for this thought?**