Research Article

Pamukkale University Journal of Education, 51, 65-91, [2021]
doi: 10.9779.pauefd.690966

The Impact of Mass on Action-Reaction Forces During a Collision: Using A Conceptual Change Text or Traditional Expository Text To Overcome Misconception*

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• ***Received:*** *18.02.2020* • ***Accepted:*** *28.05.2020* • ***Online First:*** *16.10.2020*

Abstract

When two bodies collide, the body with the larger mass exerts the greater force is a widely known but still common misconception. This study aims to compare the effectiveness of a conceptual change text and a traditional expository text to overcome this target misconception. Then to reveal the effect of students' readiness on this situation. For this, a case study was conducted with 92 students (ninth grade) from two different types of schools. One of these schools accepts students by a nationwide central placement exam, and the other does not need the exam. The students in the second type of school are generally very low in academic achievement. A focus group consists of 24 students examined in detail. The students in the focus group selected with a maximum variety of sampling based on the achievement. Multiple-choice questions in different contexts and simulation-assisted-interviews were used for data collection. It is seen that the type of text did not cause any difference in the school that students with high academic achievement. Conversely, a difference was found in favor of the conceptual change text in the second school. The results of the research point to the fact that the conceptual change text was more effective than the traditional expository text in the student group low in academic achievement.

Keywords: action-reaction law, misconception, conceptual change text, traditional expository text

Cited:

Aygün, M., & Tan, Mustafa. (2021). The impact of mass on action-reaction forces during a collision: Using a conceptual change text or traditional expository text to overcome misconception. *Pamukkale University Journal of Education, 51*, 65-91. doi:10.9779.pauefd.690966

* This study is based on the dissertation of the first author, prepared under the supervision of the second author.

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Introduction

In many researches, focusing on physics education, misconceptions about Newton's Motion Laws are widely encountered. A large number of misconceptions have been detected about the third law. These are given below: There may not be a reaction force in response to an action force (Fast, 1997; Kara, 2007). Static objects cannot exert contact forces (Clement, 1998; Montanero, Perez, & Suero, 1995; Yilmaz, Eryilmaz, & Geban, 2006; Yılmaz & Eryılmaz, 2009). Non-living objects cannot exert forces (Bryce & MacMillan, 2005; Finegold & Gorsky, 1988; Montanero et al., 1995). Reaction forces are less real than action forces (Sadanand & Kess, 1990). Action-reaction forces pairs acted on the same body and balanced each other (Atasoy &Akdeniz, 2005; Bayraktar, 2009; Jimoyiannis & Komis, 2003; Klammer, 1998; Zhou, Zhang, & Xiao, 2015). The normal force on an object always equals the weight of the object (Bryce & MacMillan, 2005; Klammer, 1998; Yip, Chung, & Mak, 1998). Action-reaction forces pairs are not equal in magnitude when one body accelerates another (Camp & Clement, 1994; Klammer, 1998; Yip et al., 1998; Yılmaz & Eryılmaz, 2009). The larger body exerts the greater force (Bao, Hogg, & Zollman, 2002; Montanero et al., 1995; Sadanand & Kess, 1990). When two bodies collide, the body moving faster exerts the greater force (Atasoy & Akdeniz, 2005; Bao et al., 2002; Bayraktar, 2009; Camp & Clement, 1994; Hestenes, Wells, & Swackhamer, 1992; Maries & Singh, 2016; Yılmaz & Eryılmaz, 2009). When two bodies collide, the harder body exerts the greater force (Camp & Clement, 1994; Yılmaz & Eryılmaz, 2009; Yilmaz et al., 2006;). When two bodies collide, the body that breaks exerts the smaller force (Camp & Clement, 1994; Yılmaz & Eryılmaz 2009). When two bodies collide, the body with the larger mass exerts the greater force (Atasoy & Akdeniz, 2005; Bao et al., 2002; Brown & Clement, 1987; Camp & Clement, 1994; Hestenes et al., 1992; Kara, 2007; Maloney, 1984; Maries & Singh, 2016; Savinainen & Scott, 2002; Yılmaz & Eryılmaz, 2009). In a distant interaction, the object with the larger mass exerts the greater force on the other (Kariotoglou, Spyrtou, & Tselfes, 2009).

Some of these misconceptions are related to the nature of the force, and some to the properties of the bodies. Misconceptions about the nature of the force can also form the basis of those related to the bodies' properties. For example, the belief that the force applied by the moving object to the stationary object is greater may be caused by misconceptions. Everybody in motion carries a force or that a standing object has a resistance (Montanero et al., 1995). The forces of action and reaction are seen as independent forces rather than as a

pair and interpreted as if they can balance each other cause different misconceptions (Hellingman, 1992; Yip et al., 1998). The fact that many students have identified these misconceptions in different countries and at different levels reveals that the understanding of the relationship between the magnitude of action-reaction forces is quite difficult to understand in a culture-independent way (Zhou et al., 2015).

Above, there are some similar misconceptions, like depending on the properties of an object such as speed, mass, and hardness are greater than the other object's, exerting greater force. It can be seen that these misconceptions can be detected when the two bodies are at rest, during collisions, or interacting at a distance. The context we encountered most was a collision. Also, Montanero et al. (1995) have found that students have more misconceptions about dynamics states than static states. In this context, misconceptions can be explained about differences in mass, speed, rigidity, and durability or if the body is living or inert. In the researches reviewed, the most common feature in the context of collision is the mass.

A physics teacher must have the content knowledge and pedagogical content knowledge and knowledge of how people learn (Etkina, 2010; Shulman, 1986). It should be kept in mind that the relationship between these types of knowledge is intricate. This requires the teacher to know what the action-reaction forces are, as well as what the students know about these concepts before the course, and to be able to predict whether their knowledge is consistent with the scientific knowledge. However, in some studies have conducted with teachers/teacher candidates, the situation was not as expected. For example, it is seen that pre-service science teachers (majors in physics) in China have had misconceptions about action-reaction forces in the context of collisions (Zhou, Wang, & Zhang, 2016); teaching assistants have had misconceptions in the case of a car pushing a truck and speeding up (Maries & Singh, 2016). For science and physics teachers in Spain, Newton's third law has a great unknown (Montanero et al., 1995). Secondary science teachers have had misconceptions about Newton's third law (Yip et al., 1998). Primary school teachers have not recognized that the ground or table exerts a reaction force to an object over it (Kruger, Summers, & Palacio, 1990). For student pre-school teachers and primary school teachers in Greece, the magnitude of action and reaction forces are equal is difficult to understand (Spyrtou, Hatzikraniotis, & Kariotoglou, 2009). According to these studies, teachers/pre-service teachers and even teaching assistants could have misconceptions about the action-reaction forces.

The fact that teachers/pre-service teachers have misconceptions is a problem for teaching. In such a case, even if the teacher has sufficient knowledge of instructional strategies to scaffold students' learning of key concepts, he/she may not realize students' mistakes. On the other hand, students could have misconceptions because of their teachers. Therefore, course materials that would enable the students to notice their misconceptions through personal effort and help them overcome their misconceptions are needed to be used both in and outside the classroom.

Conceptual Change Texts

Posner, Strike, Hewson, and Gertzog (1982) guided the preparation of such course materials with the conceptual change theory. These materials should point to the existence of situations where the students and teachers cannot bring an explanation based on their existing conceptual structures, and also demonstrate that the new conceptual structure is capable of explaining both their old experiences and the new experiences (Hewson & Hewson 1984; Posner et al., 1982). According to Posner et al., conceptual change is a process, and, for the conceptual change to actualize, the mind has to go through four main stages. These stages are the individuals being dissatisfied after realizing that their existing concepts are incapable of explaining the newly encountered situations; the new concept being intelligible by the individual; the new concept being plausible, and realizing that the new concept is much more fruitful than the previous one.

Although researchers agree that the individual needs to find various reasons to achieve conceptual change, they do not agree on a method that can be described as the most effective (Mildenhall & Williams, 2001). Roth (1985) proposed the conceptual change text (CCT) to search for material to provide conceptual change. It is understood that since 1985, the conceptual change text has preserved its structure and has not undergone any structural changes. The purpose of such texts is to enable individuals to realize the misconceptions they have just by reading a text and help them to develop conceptual structures compatible with scientific data. Text reproduction is easy and economical, but it is also important as the material that can be delivered to large audiences because they can be used without teacher support. However, there seems to be a gap in the literature in the search for a text whose effectiveness has been determined by Newton's third law. There are texts on heat and temperature (Baser & Geban, 2007a; Yürük & Eroğlu, 2016), electricity (Başer & Geban, 2007b; Chambers & Andre, 1997; İpek & Çalık, 2008), sound (Çalik, Okur, & Taylor, 2011;

Özkan & Selçuk, 2013), matter (Durmuş & Bayraktar, 2010) and pressure (Şahin, İpek, & Çepni, 2010) in various studies; however, no text on Newton's Laws have been found.

In order to determine the properties of the text that can be prepared, it was seen that in several studies, CCTs had been used with the assumption that they are effective materials that will allow the conceptual change in physics education (Beerenwinkel, Parchmann, & Grasel, 2010; Çil & Çepni, 2012; Dilber, Karaman, & Duzgun, 2009; Özkan & Selçuk, 2013, 2015, 2016; Sari, Feranie, & Winarno, 2017; Taşlıdere & Eryılmaz, 2009). Unfortunately, most of the studies involving the use of the CCT have focused not on the text's effectiveness alone but the combination of it with other teaching strategies. Therefore, CCT used in these studies is generally not present.

In a few studies, it is seen that CCT is compared with different text structures such as traditional texts, textbooks, and CCT enriched with meta conceptual process. Unfortunately, in two studies comparing CCT with traditional texts, only CCT has been given, but no traditional text has been encountered (Chambers & Andre, 1997; Baser & Geban, 2007a); in one study, instead of giving texts directly, features were compared (Beerenwinkel et al., 2010); also, in a study comparing CCT with textbooks, no texts were presented (Sari et al., 2017). In a study comparing CCT enriched with the metaconceptual process with descriptive texts and expository texts (Yürük & Eroğlu, 2016), only excerpts from the texts were presented. This situation makes it difficult to reveal the features in a CCT that would be useful in physics education.

Research Questions

Newton’s Third Law is one of the most fundamental laws in physics. Previous research has revealed that understanding it is quite complicated work for students, teachers, and texts (Bryce & MacMillan, 2005; Zhou et al., 2015). Therefore, instead of leaving the individuals by themselves to overcome the misconceptions, it is much more beneficial for the researchers to develop materials that will guide them to realize their misconceptions and help overcome them. Texts that are economically easy to reproduce and access can be valuable materials in this context. There are various types of texts, but CCT has been specifically developed for this purpose. However, previous studies obtained that it is both effective and ineffective in overcoming misconceptions (Chambers & Andre, 1995; Qian & Alvermann, 1995).

On the other hand, traditional expository texts (TET) in textbooks can also be used to try to overcome misconceptions. Similarly, studies that obtained TET are both effective and ineffective in overcoming misconceptions (Baser & Geban, 2007a; Chambers & Andre, 1997; Dilber et al., 2009; Wang & Andre, 1991). Most of these studies are from a quarter of a century ago. Moreover, after 2010, no study has been found to examine this issue. Nonetheless, it is seen that previous studies have not clarified this issue.

In this research, the aim was to determine which text type is the most effective when used to overcome the target misconception: 'When two bodies collide, the body with the larger mass exerts the greater force.' More specifically, the study addressed the following question: What is CCT and TET's effectiveness in eliminating the target misconception? (RQ1). In some previous studies, it is seen that the text was prepared as a worksheet, and the students were expected to answer the questions asked in the text by writing into the defined spaces on the paper. At the same time, some studies discuss the contents of the text under teachers' guidance in the classroom environment. In this research, these two applications were not preferred since the texts' effectiveness was determined independently from the external supports.

In the research process, to provide students' readiness variety in the study group, the study was conducted in two different types of schools. These are schools that accept students with and without the central placement exam. The nationwide central placement exam in Turkey is made in the transition of secondary school to high school. Multiple-choice-questions determine students' readiness for high school education according to their previous learning with this exam. In this research, there were significant differences between the findings of the two different school types. For this reason, in addition to the main research question, it was accepted as a secondary objective to investigate the effect of the texts in lower and higher former academic achievement students (RQ2). The main difference between these two groups of students is presumed readiness based on the nationwide central placement exam.

Method

This research was a part of a more comprehensive survey of six different target misconceptions in the force and motion unit. Due to the richness of the data, it is not possible to present the complete research in a single paper. However, it is useful to explain the implementation environment: In eight weeks, the subject of force and movement was

processed in accordance with the gains in the curriculum. The texts were given to the students after they had already been taught the gains related to the target misconceptions, and they were asked to read individually in the classroom. Before giving them the texts, no evaluation was made related to the target misconception. There was no discussion about the texts during and after the reading. Only the teacher asked students if they had finished reading and not to leave the class before they finished. The design of the study is presented in Table 1. Here X is the teaching carried out by the curriculum.

Table 1. *Design of the study*

School	N	Instrument*	Implementation	Instrument*	N	Instrument*
Accepts students without the exam	18	Standardized Test, Orienteering Test, Formula-1 Test	X+ CCT	Standardized Test, Orienteering Test, Formula-1 Test	6	Interview form
	23	Standardized Test, Orienteering Test, Formula-1 Test	X+ TET	Standardized Test, Orienteering Test, Formula-1 Test	6	Interview form
Accepts students by the exam	28	Standardized Test, Orienteering Test, Formula-1 Test	X+ CCT	Standardized Test, Orienteering Test, Formula-1 Test	6	Interview form
	23	Standardized Test, Orienteering Test, Formula-1 Test	X+ TET	Standardized Test, Orienteering Test, Formula-1 Test	6	Interview form

*Not all of the data collection tools seen in this table, but the parts covered in the study were used to access the data of this study.

The content of the texts is important for the credibility of the research. Since the two text types compared with each other, the weight of the written language, the suitability of the samples used for the students, and the number of samples used should be similar. In this

research, previously prepared and similar texts could be used. However, there seems to be a gap in the literature searching for a text whose effectiveness has been determined by Newton's Third Law. For this reason, researchers who are physics educators supported by other physics educators and a language educator developed the texts used in this study.

Development of the Conceptual Change Text and Traditional Expository Text

Roth (1985) stated that there should be four stages in the CCT. These are the questions that should be asked to enable the students to reveal their misconceptions (dissatisfaction), experimental or narrative examples should be provided to challenge the students' misconceptions and be persuasive (intelligibility), scientific definitions of the studied concepts should be repeated (plausibility), and appropriate questions should be asked where the new concept can be applied for different occasions (fruitfulness). The pilot CCT presented to ninety-nine students who have previously learned the force and motion chapter; they have been asked to read the CCT and asked, 'What did you understand from the text? And Write down the main points you could not understand in the text'. After examining the answers and texts with the support of four physics education experts and one language education expert, the final version of the CCT appeared (Figure 1).

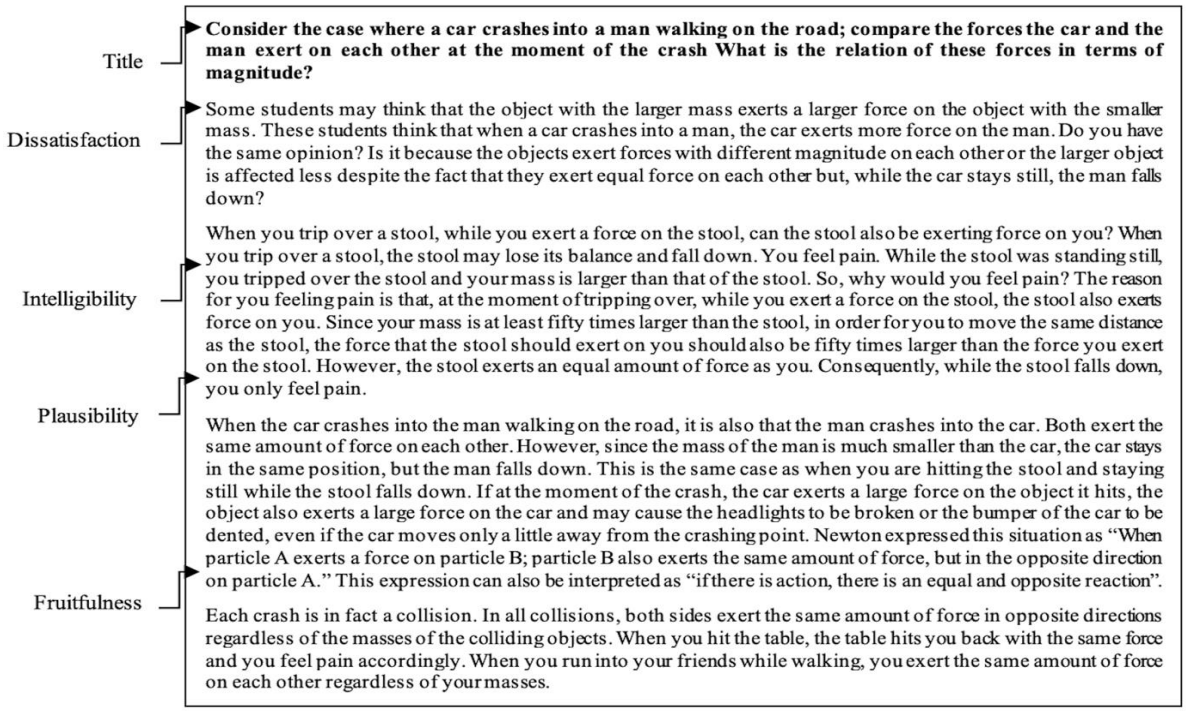

Figure 1. *Conceptual change text*

The stages of the TET were determined by examining the existing texts in the relevant textbooks. Many traditional expository texts have three stages. These are an introduction, giving examples and explaining the examples stages. In the introduction stage of TET, the scientific concept is described; in the giving examples stage, various examples related to the target misconception are presented with comparisons of objects; and in the explaining the examples stage, an example is explained by associating it with the target misconception by presenting a problem and giving the answer. While preparing the TET, all examples included in the CCT were also included. Two experts on physics education compared the TET with the previously developed CCT in terms of physics knowledge and its examples. Also, one expert on language education reviewed the text. After reviewing the experts, the researchers made the necessary changes, and the final version of the TET appeared (Figure 2).

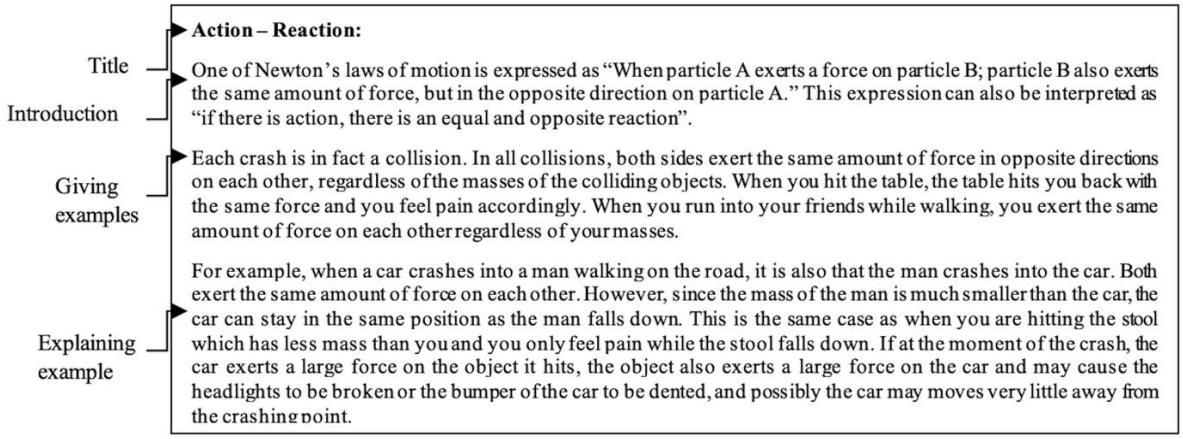

Figure 2. *Traditional expository text*

The researchers tried to keep both texts as short as possible. In the texts, the object with the larger mass crashes into the stationary object. Also, other misconceptions about Newton's Third Law were included in the texts as much as possible. Therefore, texts include situations where two non-living bodies and two living bodies collide and situations in which the non-living crashes into the living and vice versa. Moreover, the different durability and solidity were used as examples. However, since this study is only related to the effect of mass, issues such as vitality or durability are not particularly emphasized. In texts, there is the expression each crash is, in fact, a collision. The aim was to direct the reader to think of force to think as an interaction between two bodies instead of thinking of them as a push or pull (Young & Freedman, 2012).

Two experts on physics education compared the CCT and TET in terms of the scientific information's consistency. Although the texts are prepared with different stages, they stated that both convey the same scientific information by using the same examples. The readability value of the CCT and TET was found as 45,217 and 47,937 according to the formula from Reading Ease of Flesh, which was adapted to Turkish by Ateşman (1997). This value means they are difficult texts and has similarities with scientific texts. According to two language education experts, CCT was prepared with the cognitive approach and directed the students to query the information by making them think and interpret. On the other hand, TET was prepared with the behavioral approach, and it expects the students to accept the information as it is, without allowing them to think and interpret. However, while TET is only expository, CCT contains a few narrative elements in addition to being expository. The experts also stated that TET seems to be an ordinary text that can appear in the textbooks.

Participants

There were two types of schools that do not provide vocational training in Giresun: schools accept students with (three schools) and without (two schools) nationwide central placement exam. This exam in Turkey is made in the transition of secondary school to high school. Multiple-choice-questions determine students' readiness for high school education according to their previous learning with this exam. It is envisaged that the school students accepting the exam have a higher readiness means higher former academic achievement. One school from the two school types was determined randomly. In these schools, two different classes were chosen by taking into consideration the previous physics lesson grades. 41 and 51 students in grade nine participated in the schools' research and who have full participation in the relevant part of this study. In both schools, students in one class read the CCT while the others read the TET.

The students who attended the research were sorted into groups in descending order according to their average attainment scores, which are obtained from pre and post-application of three different achievement tests. The students were selected to focus group voluntarily, according to attainment groups. A maximum variety of sampling was done to examine the focus group in detail. Variations of characteristics were ensured by taking three groups from the top (01, 02, 07, 08, 13, 14, 19, 20), middle (03, 04, 09, 10, 15, 16, 21, 22) and bottom (05, 06, 11, 12, 17, 18, 23, 24) tiers. The focus group consisted of twenty-four students in total.

Instruments and Data Analysis

Three achievement tests were applied pre- and post-implementation in order to reveal the success (Standardized, Orienteering, Formula-1). Orienteering and Formula-1 tests consisted of context-based questions. The standardized test consisted of idealized questions. The reason for using three different tests is the possibility of measuring tools giving different results (Akpınar & Tan, 2011; Rennie & Parker, 1998) and asking the same problem in different contexts can cause differences in students' answers (Hestenes et al., 1992; Mildenhall & Williams, 2001). This can be called conceptual addition (Fensham, Gunstone, & White, 1994), competition (Maloney & Siegler, 1993), and profile (Mortimer, 1995). The concepts related to Newton's Third Law can also be interpreted differently by students, according to context (Bao et al., 2002). The validity and reliability of these tests have been explained in the relevant study (Akpınar & Tan, 2011).

In each test, there is only one question about Newton's Third Law. Using the tests that include questions about the objectives other than the target misconception is that it does not cause students to pay special attention to the target misconception in the course process. The related questions are below:

Standardized question: K and L are two people weighing 80 kg and 60 kg, respectively. If K pushes L, which of the following is correct for the moment of pushing?

a) K and L do not exert force on each other.

b) Only K exerts a force on L.

c) K and L exert force on each other. But K exerts a greater force on L.

d) K and L exert force on each other. But L exerts a greater force on K.

e) K and L exert equal force on each other.

Orienteering question: At the start point of an orienteering race, a little boy suddenly starts running towards the athletes. Though one athlete sees the child, he cannot stop and hits the child. Which of the following is correct for the moment of the collision?

a) The athlete and the child do not exert force on each other.

b) The athlete exerts a force on the child. But meanwhile, the child does not exert force on the athlete.

c) The athlete and the child exert force on each other. But the athlete exerts a greater force on the child.

d) The athlete and the child exert force on each other. But the child exerts a greater force on the athlete.

e) The athlete and the child exert equal force on each other.

Formula-1 question: In automobile races, car tires are placed on building a barrier at the sides of the runway. One F1 automobile loses control and hits a tire on the barriers. Which of the following is correct for the moment of the collision?

a) The automobile and tire do not exert force on each other.

b) Only the automobile exerts a force on the tire.

c) The automobile and the tire exert force on each other. But the automobile exerts a greater force on the tire.

d) The automobile and the tire exert force on each other. But the tire exerts a greater force on the automobile.

e) The automobile and the tire exert equal force on each other.

The correct answer to all the questions about the target misconception is the E choice. The C choice is the target misconception. The data were analyzed by concentration analysis. Coding ranges for this analysis and the formulas for the score and concentration are those proposed by Bao and Redish (2001): The cases (Score-Concentration) that emerge as a result of the answers given to the multiple-choice questions can be listed as one popular and

correct answer (high-high), one popular wrong answer (low-high/medium-high), possibility of two different wrong answers (low-medium), two popular answers where one is correct and the other one is wrong (medium-medium) and answers randomly distributed among choices (low-low).

In order to examine the focus group, students' answers to these questions were compared. Also, individual interviews were conducted with these students after the post-tests. The reason for not doing interviews with students before the implementation is not to cause them to pay more attention to the texts than to ordinary course material. A simulation was prepared, and two physics education experts were consulted on the suitability of the simulation. In the simulation, there are a truck and a car. After giving the start command, the truck moves forward and crashes into the car that is at rest. The masses of the car and the truck can be changed if required. This simulation was used by the predict-observe-explain method. In this method, the students first predict what would happen during or at the end of an event, then observe the event, and finally explain the differences between their expectations and the observation (White & Gunstone, 1992). Previously Tao and Gunstone (1999) used this method to eliminate students' misconceptions about force and movement issues. Since the prediction stage occurs before the reveal of the events' results, the students need to use their existing knowledge while answering the questions and have to predict the possible outcomes of the event and comment on them (Bahar, 2003). Three physics education experts stated that the semi-structured interview was suitable for the aim of the research. A trial application was conducted with two students who have already been taught the force and motion chapter. Individual face-to-face interviews were carried out with the focus group. In the interviews, the answer to the question for the case of a truck crashing into a stopping car, compare the forces exerted by the truck and the car on each other. ‘What is the relation between them in terms of magnitude?’ have been sought.

The obtained data were classified into two groups as correct and incorrect. Then, each group was divided into three further groups as the correct explanation, which includes the target misconception and includes a different misconception. One of the physics education experts reviewed the coding of the interview transcriptions. Another expert examined the categories and the quotes from the students’ answers in the table prepared by the researchers. Moreover, the last expert examined the comments made by the researchers.

Results

The results were presented in two stages. In the first stage, the classes where the students were located were considered as a whole. In the second stage, students in the focus group were examined separately.

General Situation Related to the Target Misconception

In the post-tests, it can be seen that there is a significant difference between the two schools in the frequency of marking the correct choice (E). For this reason, three different analyses were made: general overview, the school accepts students by exam and school accepts students without exam (Table 2).

Table 2. *Distribution and concentration analysis of the answers of students*

School	Text	N	Context of the question	Time	Choice						Score	Concentration	State
					A	B	C	D	E	No-mark			
Accepts students without the exam	CCT	18	Standardized	Pre	0	2	9	1	0	6	0.00	0.59	Low-High
				Post	0	0	11	2	1	4	0.07	0.64	Low-High
			Orienteering	Pre	0	1	8	0	0	9	0.00	0.81	Low-High
				Post	1	0	5	1	8	3	0.53	0.34	Medium-Medium
			Formula-1	Pre	0	2	7	1	1	7	0.42	0.91	Medium-High
				Post	0	1	8	5	3	1	0.18	0.25	Low-Medium
	TET	23	Standardized	Pre	1	5	10	3	1	3	0.05	0.25	Low-Medium
				Post	0	2	14	3	0	4	0.00	0.57	Low-High
			Orienteering	Pre	1	0	10	5	1	6	0.06	0.39	Low-Medium
				Post	4	0	7	1	3	8	0.20	0.24	Low-Medium
			Formula-1	Pre	0	1	8	6	1	7	0.06	0.33	Low-Medium
				Post	2	2	6	5	5	3	0.25	0.07	Low-Low
Accepts students by the exam	CCT	28	Standardized	Pre	0	5	23	0	0	0	0.00	0.71	Low-High
				Post	0	0	14	1	13	0	0.46	0.43	Medium-Medium
			Orienteering	Pre	0	0	25	2	1	0	0.04	0.81	Low-High
				Post	0	0	10	1	17	0	0.61	0.47	Medium-

												Medium
			Formula-1	Pre	1	0	24	2	1	0	0.04	0.75	Low-High
				Post	0	0	11	1	16	0	0.57	0.45	Medium-Medium
		TET	Standardized	Pre	0	3	17	1	0	2	0.00	0.68	Low-High
				Post	0	0	9	1	12	1	0.55	0.43	Medium-Medium
			Orienteering	Pre	0	1	18	3	0	1	0.00	0.69	Low-High
				Post	0	0	6	2	15	0	0.65	0.47	Medium-Medium
			Formula-1	Pre	0	6	15	1	0	1	0.00	0.52	Low-High
				Post	0	0	7	2	14	0	0.58	0.42	Medium-Medium
Both together	23		Standardized	Pre	0	7	32	1	0	6	0.00	0.67	Low-High
				Post	0	0	25	3	14	4	0.33	0.43	Low-Medium
		CCT	Orienteering	Pre	0	1	33	2	1	9	0.03	0.81	Low-High
				Post	1	0	15	2	25	3	0.58	0.42	Medium-Medium
			Formula-1	Pre	1	2	31	3	2	7	0.05	0.64	Low-High
				Post	0	1	19	6	19	1	0.42	0.30	Medium-Medium
		TET	Standardized	Pre	1	8	27	4	1	5	0.02	0.45	Low-Medium
				Post	0	2	23	4	12	5	0.29	0.35	Low-Medium
			Orienteering	Pre	1	1	28	8	1	7	0.03	0.54	Low-High
				Post	4	0	13	3	18	8	0.47	0.30	Medium-Medium
			Formula-1	Pre	0	7	23	7	1	8	0.03	0.38	Low-Medium
				Post	2	2	13	7	19	3	0.44	0.21	Medium-Medium

Overview: In pre-tests, E was only marked six times. The post-tests were marked more by students who read CCT than those who read TET. C was mostly preferred in the Orienteering question in pre-tests and the standardized question in post-tests; for E, this was the opposite. In pre-tests, the target misconception, C, was often the popular and wrong

answer (low-high). D and B were also popular in the standardized and Formula-1 questions for students who read TET. B is that the small mass object does not apply any force. D is the application of more force to the larger mass by the smaller mass. There were two popular answers in post-tests, usually C and E, one right and one wrong (medium-medium). In the standardized question, the frequency of marking E generally did not exceed C. In Orienteering and Formula-1 questions, the situation was the opposite.

In the school which accepts students without the exam: In pre-tests, the students who read the TET had two popular and wrong answers in three questions (low-medium): C and D. For students who read CCT, C was the only popular wrong answer (low-high). In post-tests, students studying TET C were the only popular and wrong answer to the standardized question (low-high); in the orienteering question, A and C were two popular wrong answers (low-medium). A indicates that the two objects do not apply force to each other. In the Formula-1 question, the options are randomly distributed (low-low). For students studying CCT, C was the only popular and wrong answer in the standardized question (low-high). In the orienteering question, E and C were two popular answers (medium-medium). In the Formula-1 question, C and D were two popular and wrong answers.

In the school which accepts students by the exam: In pre-tests, for students who read both text types, C was the only popular wrong answer (low-high). In post-tests, for students who read both text types, C and E were two popular answers, one wrong and one right (medium-medium).

When the classes were examined as a whole, an increase was observed in the number of correct answers given by the students in both CCT and TET classes to the questions asked in relation to the effect of mass on action-reaction forces. Yet, no significant difference was observed between the CCT and TET classes when this increase was examined for each school. Thus, it cannot be argued that one of the two texts has a greater effect than the other. On the other hand, the increase in the number of students giving correct answers is greater in the school accepting its students with exam than the school accepting its students without an exam. However, it is not possible to associate this increase with the effect of text type.

In the pre-tests, the high majority of the students in both schools marked the option, including the target misconception. However, in the post-tests, the number of students marking the correct answers from the school admitting its students without exam increased. Yet, this increase is not high, and some of the students marked the distracters instead of the correct answers. This indicates that the students recognized their misconceptions, yet they

could not find the correct answer. Yet, there is no certain evidence for this. The number of students marking the correct answers from the school admitting its students with exams also increased, and this increase is higher than the other school. However, again, all the students have not chosen the correct answer, and there have been many students who have continued to choose answers with misconceptions. Yet, the shift in the students' answers from the school admitting its students with exams was mostly from the options, including the misconception towards the correct option. This might be because of the individual differences and the fact that permanence of misconceptions varies from individual to individual and because misconceptions develop over the course of years, based on the personal experiences of the individual and they are exceptionally resilient to change (Suping, 2003, Yağbasan & Gülçiçek, 2003). Moreover, the texts prepared in the current study might not have been suitable for all the students' profiles in the study group. Thus, different strategies may become helpful at overcoming misconceptions in different students (Gülçiçek, 2009). Also, Chambers and Andre (1995) state that when comparing the impact of CCT and TET on student success, gender and interest may also become factors that impact the results. However, since gender and interest are not within the scope of this study.

Focus Group's Situation Related to the Target Misconception

The answers of each student in the focus group to the multiple-choice questions and the interview question are presented in Table 3.

Table 3. *The students' answers to the multiple-choice questions and the interview question*

School	Text	Student	Multiple-choice questions						Interview	
			Standardized		Orienteering		Formula-1			
			Pre	Post	Pre	Post	Pre	Post	Answer	Explanation
Accepts students without the exam	CCT	01	C	C	B	E	C	C	Correct	Correct
		02	C	C	C	E	C	C	Correct	Correct
		03	D	C	C	E	-	E	Correct	Correct
		04	-	C	C	C	B	C	Incorrect	TM-DM
		05	C	C	-	E	D	D	Incorrect	DM
		06	C	C	C	C	-	D	Incorrect	TM
	TET	07	D	C	C	-	B	C	Incorrect	TM-DM

		08	C	C	C	-	D	D	Incorrect	TM
		09	C	C	C	A	-	D	Incorrect	TM-DM
		10	C	C	-	E	C	C	Incorrect	TM
		11	B	B	C	-	D	B	Incorrect	TM
		12	C	D	-	C	C	D	Incorrect	TM
Accepts students by the exam	CCT	13	C	E	C	E	C	E	Correct	Correct
		14	C	E	C	E	D	E	Incorrect	TM
		15	C	E	C	E	A	E	Correct	Correct
		16	C	E	C	E	C	E	Correct	Correct
		17	C	E	C	E	C	E	Correct	Correct
		18	B	C	C	C	C	C	Incorrect	TM
	TET	19	B	C	C	C	C	C	Incorrect	TM
		20	C	E	C	E	C	E	Correct	Correct
		21	C	C	C	E	B	E	Correct	Correct
		22	D	C	C	E	C	C	Correct	Correct
		23	C	D	C	D	C	D	Incorrect	TM
		24	-	C	C	C	-	C	Incorrect	TM

TM: Target misconception, DM: Different misconception

In pre-tests, E was not marked in any question in both schools; C, D, and B options were marked. In post-tests, E was marked in Orienteering, Formula-1, and Standardized questions, respectively.

Overview: In post-tests, 13 students (9 CCT – 4 TET) marked E in at least one question. In the interview, ten students (7 CCT – 3 TET) explained the situation correctly, and the target misconception was not detected in 11 students (8 CCT – 3 TET). This is in favor of CCT. Students who could explain the interview question correctly had explanations such as S20: *"They are the same. ...Does not depend on its mass."* and S13: *"Action-reaction forces... are in the opposite direction but have the same magnitude."*. Students who were found to have misconceptions had explanations such as S19: *"The force exerted by the truck will be larger because it has more mass…"* and S06: *"The truck will exert a larger force on the car since its mass is larger…"*. Another misconception that states action-reaction forces depend on the velocity of the objects was detected with (S04, 07, 09) and without (S05) the target misconception. These students had explanations such as S09: *"…the*

truck will exert a larger force because it hits with very large velocity" and S05: *"Because when the truck hits the car it may hit it slowly but when the truck hits it directly like this, the reaction…will be larger."*

The school accepts students without the exam: In post-tests, five students (4 CCT – 1 TET) marked E in at least one question. In the interview, three students (3 CCT – 0 TET) explained the situation correctly, and the target misconception was not detected in four students (4 CCT – 0 TET). This is in favor of CCT. In the interview, all of the students who read TET gave statements containing the target misconceptions such as S12: *"The higher the mass of the truck, …the more the truck acts on the car."*. Target misconception was detected in two students who read CCT (S05,06).

In the school which accepts students by the exam: In post-tests, eight students (5 CCT – 3 TET) marked E in at least one question. In the interview, seven students (4 CCT – 3 TET) explained the situation correctly. Due to the proximity of the numbers here, there is no significant difference that can be considered in favor of CCT or TET. The target misconception was detected in three students (S19,23,24) who read TET. For example, the description of S23 was as follows: *"…the larger the mass, the greater the force on the smaller."* Four of the students reading CCT gave answers that did not include misconceptions in the interview, while the target misconceptions were determined in S14. S14*: "…the truck acts with more force… Because the weight [mass] is higher"*. For S18 in addition to marking C in all the questions, the target misconception was determined in the interview. S18: *"Applies more [force] with large mass due to action-reaction force…"*.

When the answers given to the post-test and interview questions by the focus group made up of the students selected from the CCT and TET classes through the maximum variety sampling method were examined, more misconceptions were found in the answers given by the students having read TET than the answers given by the students having read CCT in the context of the school accepting its students without an exam. This indicates that reading CCT or TET does not significantly differ in the school admitting its students with an exam. Still, it leads to a larger difference in the school admitting its students without an exam. It should be taken into consideration that the main difference between the two schools is the level of readiness determined by a centralized exam.

Similar to the case of concentration analysis of the classes as a whole, in the post-tests and during the interviews, the target misconception has been detected in some students. These are all of the six students who have read the TET from the school accepting students

without an exam, and three of the students who have read the TET from the school accepting students with an exam. In both schools, two of the students who have read the CCT have been detected with the target misconception.

Conclusion and Discussion

One main question and one spontaneously developed question were posed in this study via three multiple-choice questions and simulation aided interview. These were the effectiveness of a CCT and a TET in eliminating the target misconception (RQ1) and the effect of texts on students with different readiness levels (RQ2). For the spontaneous RQ2, when comparing the impact of CCT and TET on student success, gender and interest may also become factors that impact the results, and this view may be useful to design different studies by considering Chambers and Andre (1995). However, since gender and interest are not within the scope of this study, the texts' effectiveness is not investigated to the extent of such factors.

The use of a CCT and a TET developed by the researchers in this research seems to be a limitation. However, there are no suitable texts in the literature for this purpose. At the same time, the researchers prepared these texts not only on their own but also with many field education experts' opinions. In order to provide the readers with the opportunity to comment on the impact of the study by seeing its contents, all of the texts were presented within the scope of the study, and the development stages were explained in detail. With this feature, the study differs from similar studies in the literature. Nevertheless, it should be noted that different results may be obtained by using texts developed by other researchers. It is also known that students' comprehension is dynamic and may change over time. We cannot know whether the result found here can provide continuity. Nevertheless, by accepting the above limitations, the research questions can be answered as follows:

The target misconception in this study is when two bodies collide; the body with the larger mass exerts the greater force. Unfortunately, at the end of the study, misconceptions continued in most of the students. This might be because of the individual differences and the fact that permanence of misconceptions varies from individual to individual and because misconceptions develop over the course of years, based on the personal experiences of the individual and they are exceptionally resilient to change (Chambers & Andre, 1995; Suping, 2003, Yağbasan & Gülçiçek, 2003). Moreover, the texts prepared in the current study might not have been suitable for all the students' profiles in the study group. Thus, different strategies may become helpful at overcoming misconceptions in different students

(Gülçiçek, 2009). Also, Chambers and Andre (1995) state that when comparing KDM and GAM's impact on student success, gender and interest may also become factors that impact the results. However, since gender and interest are not within the scope of this study. In this regard, Palmer and Flanagan (1997) found that although the students aged 15-16 read refuting texts about the misconception 'movement requires force', only 44% of them corrected this misconception. Moreover, as stated in the discussion about the concentration analysis, there are studies in the literature that state that neither TET nor CCT can be effective in overcoming the misconceptions (Wang & Andre, 1991; Chambers & Andre, 1991, 1997; Baser & Geban, 2007a; Demir, 2010; Dilber et al., 2009; Akgül, 2010).

However, CCT was found to be more effective than TET, but it was found that this effectiveness could not be generalized to all students. Because it was found that the source of the difference in favor of CCT was the school that accepts students without the exam. However, there is no difference in favor of CCT or TET for the school that accepts students by the exam. Thus, KDM is more effective than GAM in students with low readiness; however, it was revealed that there was no difference between the effectiveness of texts in students with high readiness. Some of the literature studies state that TET fails at providing help in student success (Chambers & Andre, 1991, 1997; Wang & Andre, 1991; Baser & Geban, 2007a; Akgül, 2010; Demir, 2010). However, there is no definite result in the current study, implying the failure of TET in both schools. Moreover, Chambers and Andre (1995) provide cases where TET can be more successful than CCT.

When the research process is viewed from a different perspective, when the students' answers in the focus group were examined in detail, their answers to the orienteering related question and answers to the interview question were consistent. The same situation was encountered less about the standardized and Formula-1 related questions. Thus, it can be argued that independent of the purpose of the current study, the differences that can emerge between the students' achievements evaluated with data collection tools in different contexts may result from the characteristics of the data collection tools. This result is similar to Kaiser, Jonides, Alexander's (1986), Heller, Keith, and Anderson's (1992) studies. Therefore, it is beneficial to note that different measurements can be obtained by using measuring instruments with idealized questions and measuring instruments with context-based questions.

Recommendations

Considering everything, although CCT is seen as an effective material in eliminating physics misconceptions in the literature, a TET containing the same examples may show similar effects. Here, the level of readiness of the student groups is important. In this study, CCT was more effective than TET in the group of students who could not settle in a school where students were admitted through the central placement exam. The contribution of this study to the literature was to reveal the effect of two different text types on students with different readiness levels. This knowledge can provide teachers with ideas for making the selection among various texts and provide researchers with data to make predictions about the various texts they develop to overcome the misconceptions.

Ethical Approval: *This study was prepared based on a thesis study prepared by the first researcher under the second researcher's supervision. The text of the study sent to Pamukkale University Journal of Education for its evaluation on publication was also examined by Giresun University Scientific Research and Publication Ethics Committee. It was decided that it was prepared ethically with the decision numbered 2020-3/3 dated May 11, 2020.*

References

Akpınar, M., & Tan, M. (2011). Context-based multiple-choice tests for measuring students' achievement. In Z. Kaya, & U. Demiray (Eds.), *2nd International Conference on New Trends in Education and Their Implications Papers,* Antalya (pp. 1239-1242). Ankara: Siyasal Kitabevi.

Atasoy, Ş., & Akdeniz, A. R. (2005, September). *Newton'un hareket kanunları ile ilgili öğretmen adaylarının sahip oldukları kavram yanılgıları* [The Conceptual Misconceptions of Prospective Teachers Related to Newton's Laws of Motion]. Proceeding presented at XIV. Ulusal Eğitim Bilimleri Kongresi [XIVth National Educational Sciences Congress], Denizli, Turkey.

Ateşman, E. (1997). Türkçede okunabilirliğin ölçülmesi [Measuring readability in Turkish]. *Dil Dergisi [Journal of Language]*, 58, 71-74.

Bahar, M. (2003). Misconceptions in biology education and conceptual change strategies. *Educational Sciences: Theory and Practice, 3*(1), 55-64.

Bao, L., & Redish, F. (2001). Concentration analysis: A quantitative assessment of students states. *American Journal of Physics, 69*(7), 45-53.

Bao, L., Hogg, K., & Zollman, D. (2002). Model analysis of fine structures of student models: an example with Newton's third law. *American Journal of Physics*, *70*(7), 766-778.

Baser, M., & Geban, Ö. (2007a). Effectiveness of conceptual change instruction on understanding of heat and temperature concepts. *Research in Science and Technological Education*, *25(*1), 115–133.

Başer, M., & Geban, Ö. (2007b). Effect of instruction based on conceptual change activities on students' understanding of static electricity concepts. *Research in Science and Technological Education*, *25*(2), 243–267.

Bayraktar, S. (2009). Misconceptions of Turkish pre-service teachers about force and motion. *International Journal of Science and Mathematics Education*, *7*(2), 273-291.

Beerenwinkel, A., Parchmann, I., & Gräsel, C. (2010). Conceptual change texts in chemistry teaching: a study on the particle model of matter. *International Journal of Science and Mathematics Education*, *9*(5), 1235-1259.

Brown, D. E., & Clement, J. (1987). Overcoming misconceptions in mechanics: a comparison of two example-based teaching strategies. Paper presented at the Annual Meeting of the American Educational Research Association, 2-35.

Bryce, T., & MacMillan, K. (2005). Encouraging conceptual change: The use of bridging analogies in the teaching of action–reaction forces and the 'at rest' condition in physics. *International Journal of Science Education*, *27*(6), 737–763.

Çalik, M., Okur, M., & Taylor, N. (2011). A comparison of different conceptual change pedagogies employed within the topic of ''sound propagation''. *Journal of Science Education and Technology*, *20*, 729-742.

Camp, C. W., & Clement, J. (1994). *Preconceptions in mechanics: Lessons dealing with students' conceptual difficulties*. Dubuque, Iowa: Kendall/Hunt.

Chambers, S. K., & Andre, T. (1995). Are conceptual change approaches to learning science effective for everyone? gender, prior subject, matter interest, and learning about electricity. *Contemporary Educational Psychology*, *20*, 377-391.

Chambers, S. K., & Andre, T. (1997). Gender, prior knowledge, interest, and experience in electricity and conceptual change text manipulations in learning about direct current. *Journal of Research in Science Teaching*, *34*(2), 107–123.

Cil, E., & Cepni, S. (2012). The effectiveness of the conceptual change approach, explicit reflective approach, and coursebook by the ministry of education on the views of the nature of science and conceptual change in the light unit. *Educational Sciences: Theory and Practice*, *12*(2), 1107-1113.

Clement, J. J. (1998). Expert novice similarities and instruction using analogies. *International Journal of Science Education*, *20*(10), 1271-1286.

Dilber, R., Karaman, I., & Duzgun, B. (2009). High school students' understanding of projectile motion concepts. *Educational Research and Evaluation*, *15*(3), 203–222.

Durmuş, J., & Bayraktar, Ş. (2010). Effects of conceptual change texts and laboratory experiments on fourth-grade students' understanding of matter and change concepts. *Journal of Science Education Technology*, *19*, 498–504.

Etkina, E. (2010). Pedagogical content knowledge and preparation of high school physics teachers. *Physical Review Special Topics-Physics Education Research*, *6*, 020110-1-26.

Fast, G. R. (1997). Using analogies to overcome student teachers' probability misconceptions. *The Journal of Mathematical Behaviour*, *16*(4), 325-344.

Fensham, P. J., Gunstone, R. F., & White, R. T. (1994). *The content of science: A constructivist approach to its teaching and learning*. London: The Falmer Press.

Finegold, M., & Gorsky, P. (1988). Learning about forces: Simulating the outcomes of pupils' misconceptions. *Instructional Science*, *17*, 251-261.

Hellingman, C. (1992). Newton's third law revisited. *Physics Education*, *27*(2), 112-115.

Hestenes, D., Wells, M., & Swackhamer, G. (1992). Force concept inventory. *The Physics Teacher*, *30*(3), 141-158.

Hewson, P. W., & Hewson, M. G. B. (1984). The role of conceptual conflict in conceptual change and the design of science instruction. *Instructional Science*, *13*(1), 1-13.

İpek, H., & Çalık, M. (2008). Combining different conceptual change methods within the four-step constructivist teaching model: A sample teaching of series and parallel circuits. *International Journal of Environmental and Science Education*, *3*(3), 143-153.

Jimoyiannis, A., & Komis, V. (2003). Investigating Greek students' ideas about forces and motion. *Research in Science Education*, *33*(3), 375-392.

Kara, İ. (2007). The revelation of general knowledge and misconceptions about Newton's laws of motion by drawing method. *World Applied Sciences Journal*, *2*, 770-778.

Kariotoglou, P., Spyrtou, A., & Tselfes, V. (2009). How student teachers understand distance force interactions in different contexts. *International Journal of Science and Mathematics Education*, *7*(5), 851-873.

Klammer, J. (1998). *An overview of techniques for identifying, acknowledging, and overcoming alternate conceptions in physics education.* Klingenstein Project Paper, Teachers College, Columbia University.

Maloney, D. P. (1984). Rule-governed approaches to physics-Newton's third law. *Physics Education*, *19*(1), 37-42.

Maloney, D. P., & Siegler, R. S. (1993). Conceptual competition in physics learning. *International Journal of Science Education*, *15*(3), 283-295.

Maries, A., & Singh, C. (2016). Teaching assistants' performance at identifying common introductory student difficulties in mechanics revealed by the force concept inventory. *Physical Review-Physics Education Research*, 12(1), 010131-1-26.

Mildenhall, P. T., & Williams, J. S. (2001). Instability in students' use of intuitive and Newtonian models to predict motion: The Critical Effect of The Parameters Involved. *International Journal of Science Education*, *23*(6), 643-660

Montanero, M., Perez, A. L., & Suero, M. I. (1995). A survey of students' understanding of colliding bodies. *Physics Education*, *30*(5), 277.

Mortimer, E. F. (1995). Conceptual change or conceptual profile change? *Science and Education*, *4*(3), 267-285.

Özkan, G., & Selçuk, G. S. (2013). The use of conceptual change texts as class material in the teaching of "sound" in physics. *Asia-Pacific Forum on Science Learning and Teaching*, *14*(1), 1-22.

Özkan, G., & Selcuk, G. S. (2015). The effectiveness of conceptual change texts and context-based learning on students' conceptual achievement. *Journal of Baltic Science Education, 14*(6), 753-763.

Özkan, G., & Selcuk, G. S. (2016). Facilitating conceptual change in students' understanding of concepts related to pressure. *European Journal of Physics*, *37*(5), 1-20.

Palmer, D. H. (2001). Investigating the relationship between students' multiple conceptions of action and reaction in cases of static equilibrium. *Research in Science & Technological Education, 19*(2), 193-204.

Posner, G. J., Strike, K. A., Hewson, P. W., & Gertzog, W. A. (1982). Accommodation of a scientific conception: Toward a theory of conceptual change. *Science Education, 66*, 211-227.

Qian, G., & Alvermann, D. (1995). Role of epistemological beliefs and learned helplessness in secondary school students' learning science concepts from text. *Journal of Educational Psychology*, *87*(2), 282-292.

Rennie, L. J., & Parker, L. H. (1998). Equitable measurement of achievement in physics: High school students' responses to assessment tasks in different formats and contexts. *Journal of Women and Minorities in Science and Engineering*, *4*, 113-127.

Roth, K. J. (1985, April). *Conceptual change learning and students' processing of science text*. Paper presented at Annual Meeting of the American Education Research Association, Chicago.

Sadanand, N., & Kess, J. (1990). Concepts in force and motion. *The Physics Teacher*, *28*(8), 530-533.

Şahin, Ç., İpek, H., & Çepni, S. (2010). Computer-supported conceptual change text: Fluid pressure. *Procedia Social and Behavioural Sciences*, *2*, 922–927.

Sari, B. P., Feranie, S., & Winarno, N. (2017). The use of conceptual change text toward students' argumentation skills in learning sound. *Journal of Physics: Conference Series*, *895*(1), 1-5.

Savinainen, A., & Scott, P. (2002). Using the force concept inventory to monitor student learning and to plan teaching. *Physics Education*, *37*(1), 53-58.

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher, 15*(2), 4-14.

Spyrtou, A., Hatzikraniotis, E., & Kariotoglou, P. (2009). Educational software for improving learning aspects of Newton's third law for student teachers. *Education and Information Technologies*, *14*(2), 163-187.

Tao, P. K., & Gunstone, R. F. (1999). The process of conceptual change in force and motion during computer-supported physics instruction. *Journal of Research in Science Teaching*, *36*(7), 859-882

Taşlıdere, E., & Eryılmaz, A. (2009). Alternative to traditional physics instruction: Effectiveness of conceptual physics approach. *Eurasian Journal of Educational Research, 35*, 109-128.

Wang, T., & Andre, T. (1991). Conceptual change text versus traditional text and application questions versus no questions in learning electricity. *Contemporary Educational Psychology, 16*(2), 103-116.

White, R., & Gunstone, R. (1992). *Probing Understanding*. London: The Falmer Press.

Yilmaz, S., Eryilmaz, A., & Geban, Ö. (2006). Assessing the impact of bridging analogies in mechanics. *School Science and Mathematics, 106*(6), 220-230.

Yip, D. Y., Chung, C. M., & Mak, S. Y. (1998). The subject matter knowledge in physics related topics of Hong Kong junior secondary science teachers. *Journal of science Education and Technology*, *7*(4), 319-328.

Yılmaz, S., & Eryılmaz, A. (2009). The development of anchoring analogy diagnostic test. *Hacettepe University Journal of Education*, *37*, 243-256.

Young, H. D., & Freedman, R. A. (2012). *Sears and Zemansky's University Physics with Modern Physics* (13th edition), Addison-Wesley: Pearson.

Yürük, N., & Eroğlu, P. (2016). The effect of conceptual change texts enriched with metaconceptual processes on preservice science teachers' conceptual understanding of heat and temperature. *Journal of Baltic Science Education*, *15*(6), 693-705.

Zhou, S., Wang, Y., & Zhang, C. (2016). Pre-service science teachers' PCK: Inconsistency of pre-service teachers' predictions and student learning difficulties in Newton's third law. *Eurasia Journal of Mathematics, Science and Technology Education*, *12*(3), 373-385.

Zhou, S., Zhang, C., & Xiao, H. (2015). Students' understanding on Newton's third law in identifying the reaction force in gravity interactions. *Eurasia Journal of Mathematics, Science and Technology Education, 11*(3), 589-599.