Misconceptions in Projectile Motion and Conceptual Changes via Geogebra Applications

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Abstract:

The purpose of this work is to examine the issue of pre-service science teachers' (PSST) Geogebra applications on misconceptions about projectile motion (PM) and the permanence of learning concepts. In this study, quantitative research method was used as scientific research method, and semi-experimental design with pre-test, post-test control group was used as a pattern. The accessible population of this study is PSST who study in a university located in Kayseri, Turkey in the 2019-2020 academic year. Sample of the study included 36 freshman PSST, studying at the university level in Kayseri. 18 of the participants are experimental-group (EG) and 18 of them are control-group (CG). Both groups learned the subject of projectile motion (PM) together in the classroom. In addition to the traditional teaching method, the EG participated eight-week in the Geogebra course based on the conceptual change model and prepared physics simulations with Geogebra. "Conceptual Questions on Projectile Motion" was used as a data collection tool and the data were analyzed by means of statistics (t-test) based on the difference between averages. The results revealed that both the post-test's and permanence test's mean scores of the EG PSST were significantly higher than the mean score of the CG PSST (post-test: $t=2.525$; $p< .05$) (permanence test: $t=5.466$; $p< .05$). Furthermore, in this study, many misconceptions about the PM were identified.

Key Words: (Science Education, Projectile Motion, Conceptual Change, Geogebra Applications,)

Introduction:

The basic premise of constructivism is that knowledge is constructed "from physical interaction with objects in the world" (Fosnot & Perry, 1996). Thus, it is integral for students to actively engage with the material, manipulate objects and construct new works and then that they can fully interpret the issue. Although real physical interaction is not possible in virtual environments, the virtual environment can also lead to a lifelike experience with facts and material and can significantly aid the learning process. The proposals for defining constructivist learning views (Fox, 2001) are as follows:

1. Learning is a dynamic, continuous, active process.
2. Knowledge is not inherent or passively assimilated. It is structured.
3. Cognitive knowledge, neither discovered, nor invented.
4. All knowledge is unique and personal.
5. All knowledge is socially structured.
6. Learning is the process of understanding how the universe works.

7. To solve students' meaningful, open-ended, challenging problems effective learning is needed.

The expectation of knowledge in the area of science education has gone beyond the actual knowledge. Mindful learning which structured via scientific experiences is more significant than the ability to quickly solved many types of multiple-choice problems. Nowadays, recall of knowledge is perceived as inadequate in science education. Students should relate their old knowledge to new knowledge for meaningful learning. Knowledge that is incompatible with scientific facts may have been acquired from informal sources of knowledge, some of their own experiences in the physical and social world, misplaced metaphors embedded in the language, teaching plan (Klammer, 1998) and textbooks (Cho, Kahle, & Nordland, 1985). In addition, teaching may inadvertently promote these concepts and even create these misconceptions during teaching.

Students usually come to science class with their established misconceptions. These misconceptions must be taken into account by science teachers in order to plan and teach meaningful and efficient lessons. Science teachers require to recognize the students' misconceptions and change their teaching style according to misconceptions of students'.

As a result of a study about students' misconceptions or "Alternative Concept Movement" research, the following seven propositions about misconceptions are mostly accepted (Millar, 1989).

1. Students get into science class with deep-rooted knowledge about natural phenomena,
2. Alternative concepts of students may vary according to ability, nationality, gender and age,
3. Traditional teaching strategies are not enough for alternative concepts of students to change,
4. Alternative concepts of students are frequently similar to the explanations of natural phenomena presented by former generations of scientists.
5. The origins of students' alternative understanding are personal experiences, culture, perceptual experience, their language and school.
6. Teachers also have misconceptions like their students,
7. Alternative concepts of students' dispute with the knowledge taught in formal education.

Some studies (Clement, 1982; Gilbert & Watts, 1983; Minstrell, 1984) have shown that many students have beliefs that are somewhat or entirely different from accepted scientific views. Students' misconceptions create obstacles to meaningful learning in science. Consequently, students' misconceptions must be revealed and eliminated to provide meaningful learning and a passing on general scientific concepts.

In the last 40 years, an active research literature on students' conceptual understanding in science has been constituted. These researches provided science education community with detailed knowledge about students' conceptions of natural phenomena in a broad range of science topics (mechanics, optics, electricity, energy, particle physics, heat and temperature, astronomy and many other fields) (Duit, 1993). Constructivist learning approach has been the strongest source of motivation for research on students' understanding (and also teachers') (Duit, 1993). It forms students' understanding of natural phenomena with all their experiences, both in and out of school.

In the first studies on students' concepts, educational scientists considered students' concepts according to the subject and separately from other aspects of learning such as metacognition (Duit & Treagust, 2003). Many studies (Driver & Erickson, 1983; Driver, Guesne, & Tiberghien, 1985; Driver, Squires, Rushworth, & Wood-Robinson, 1994; Duit, Goldberg & Niedderer, 1992; McDermott, 1984; Novak, 1987; Osborne & Freyberg, 1985) showed that students do not enter classes without prior knowledge of the natural phenomena to be taught. In fact, students have deep-rooted concepts and ideas which are incompatible with contemporary scientific views and cannot be quenched by traditional teaching.

Since the 1970s, studies have been conducted investigating students' understanding of mechanics (Duit, 1993). A number of these studies have been reviewed in order to understand students' conceptual understanding of the concepts of the force and motion unit and the subject of the PM (Bayraktar, 2009; Clement, 1982; Clement, 1983; Dilber, Karaman, & Düzgün, 2009; Driver, Rushworth, Squires, & Wood-Robinson, 1994; Halloun & Hestenes, 1985a; Halloun & Hestenes, 1985b; Jimoyiannis & Komis, 2001; Klammer, 1998; Klein, Gröber, Kuhn, & Müller, 2014; McCloskey, 1983a; McCloskey, 1983b; McCloskey, Caramazza , & Green, 1980; Minstrell, 1982; Prescott, 2004; Prescott & Mitchelmore, 2005; Sadanand & Kess, 1990; Tao, 1997; Tao & Gunstone, 1999; Trowbridge & McDermott, 1980; Whitaker, 1983). Some of the misconceptions presented in these studies and their scientific equivalents are shown in Table 1 with references and more given Appendix-1.

	Misconception	Scientific equivalent	Reference
1.	An object released from constant horizontal velocity follows a linear path.	For an observer on the ground, the orbit of the object will be parabolic.	(Hallon & Hestenes, 1985b; McCloskey,1983b)
2.	An object falls back from the position where it was released with horizontal constant initial velocity.	For an observer on the ground, the orbit of the object will be parabolic.	(Hallon & Hestenes, 1985b; McCloskey, 1983b)
3.	No force is applied to an object released from a moving carrier.	A force is applied by the gravitational field of the ground to an object making a horizontal PM.	(Hallon & Hestenes, 1985b; McCloskey,1983b)
4.	From the same height, a released object falls before the object at a horizontal constant velocity because the released object takes a shorter path. Or the thrown object falls first because it has a greater velocity than the object released.	An object that is released from the same height and the other thrown with a horizontal constant velocity hit to the ground simultaneously.	(Dilber et al., 2009; Jimoyiannis & Komis, 2001; Prescott &Mitchelmore, 2005; Whitaker; 1983)
5.	The final velocity of an object which released to free fall depends on the force of gravity.	The final velocity of objects released to free fall depends on the height at which the objects are released and the gravitational acceleration.	(Dilber et al., 2009)
6.	A ball with greater mass will have a greater velocity when released into free fall.		(Jimoyiannis & Komis, 2001)
7.	The larger the mass, the greater the acceleration in free fall.	The acceleration of free-falling objects is the gravitational acceleration of the planet.	(Jimoyiannis & Komis, 2001)
8.	The higher the ball of two balls of different heights, the acceleration is greater because it moves more.		(Jimoyiannis & Komis, 2001)

Table 1. *Misconceptions about projectile motion and the scientific equivalents of them.*

Knowing that students bring strong misconceptions into science classes (Dekkers & Thijs, 1998; Duit & Treagust, 2003; McDermott, 1991) that are difficult to quench through traditional teaching, researchers have been looking for theoretical frameworks to explain how students reconstruct their current concepts. Researchers from different area of study (e.g: science education and educational psychology) have proposed different theoretical frameworks to explain the nature of students' misconceptions and how they replace them with scientifically accepted concepts.

Posner, Strike, Hewson, and Gertzog (1982) developed the Conceptual Change Model to provision explanations on how a student's existing understanding change when faced with recent understanding. The Conceptual Change Model has a common practice in the science education community since its development (Duit & Treagust, 2003). By the vision of Conceptual Change Model, a new understanding can be incorporated into the cognitive structure in two ways: if the student knows rare about the recent shown concept or if the recent concept can be adapted with the present conceptual structure new concept can be merged with the present concept. This process called as "assimilation" by Posner et al. (1982). By Hewson (1981) it is called as "conceptual capture". On the other hand, there is a possibility that students have alternative understanding of what they will learn that may conflict with new knowledge. In lodge to accept new knowledge, the students must reconstruct their existing understanding. This process has been named "conceptual change" by Hewson (1981), "accommodation" by Posner et al. (1982). The main focus of the Conceptual Change Model which is presented by Posner et al. (1982), is to clarify how accommodation takes place. There are four conditions that must be met for conceptual change to occur:

1. The student is not satisfied with the current understanding,
2. Finding that the new understanding is understandable,
3. The learner thinks that the new understanding is reasonable,
4. The learner should find the new understanding efficient and the new understanding should lead to new ones (Posner et al., 1982).

The learning view presented in Conceptual Change Model provides an explanation of how students can change their existing knowledge structures in a subject area. Different theoretical frameworks have been proposed to explain the nature of the change in students' current cognitive structure.

The proposed theoretical frameworks for explaining the improvement in students' understanding require that: reach an improvement in the current conceptual structure, students collocate existing concepts against the new concept, recognize existing and new concepts, and the relevant connection every day, integrate and evaluate. Planning lessons compatible with technology can facilitate conceptual change. In a technology-based lesson which is planned according to the conceptual change model, misconceptions can be eliminated by bringing students face to face with their misconceptions.

GeoGebra, developed in 2001 by Marcus Hohenwarter and Yves Kreis, is a free dynamic geometry software developed to teach and learn mathematics at primary, high school and university level (Hohenwarter & Preiner, 2007). Although the use of this software in the field of mathematics is quite common, it is very rare in science education (Erb, Wilhelm, & Kuhn, 2015; Hofmann, Klar, & von Aufschnaiter, 2012; Kerle, 2013; Solvang & Haglund, 2018; Völker, 2015; Walsh, 2017). However, some of them are limited to the use of graphics, figures and animations rather than the physics teaching process (Hofmann, Klar, & von Aufschnaiter, 2012; Völker, 2015). Moreover, Geogebra, where many applications can be made in terms of graphics and visuality, can also make up the ground for the elimination of misconceptions with the experience it will provide to students. Solvang and Haglund (2018) emphasized the importance of using digital tools in education for high school physics education in Sweden. Solvang and Haglund (2018) stated that they investigated the possibilities of using GeoGebra, which is very popular in mathematics education, in the teaching of physics subjects, and discovered the cognitive learning processes of students during their interactions with the software. They observed that there was a “high level of interaction” between students and Geogebra applications and that students came to different levels of understanding the subject of friction (Solvang & Haglund, 2018).

It is more common to use physics simulations where it can only change variables, and sometimes even not. However, Geogebra allows its users to manipulate it. Walsh (2017) states that when creating physics simulations in GeoGebra, Walsh can usually understand a subject or phenomenon more deeply. Furthermore, teaching a certain concept after many years, he can better understand the concept after figuring out how to simulate it with Geogebra.

Many studies (Jimoyiannis & Komis, 2001; Klein, et al.; 2014; Whitaker, 1983) have been conducted on the conceptual difficulties that students' mental models experience with regard to the phenomena of the PM. The motivation behind this study is to make up for the lack of studies on physical phenomena related to misconceptions of PM. Just a few studies have tried to change students' misconceptions about PM (Dilber et al., 2009; Gunstone, Gray & Searle, 1992; Thijs, 1992). In this study, it is aimed to define the misconceptions of PSST regarding the concepts of the PM and to examine the effectiveness of Geogebra applications based on conceptual change conditions on their understanding of the concepts of PM on traditionally designed physics education. In addition, in this study, it is aimed to reveal the misconceptions that PSST had in explaining the physical phenomena underlying the PM. For this purpose, in accordance with the nature of the study, in order to eliminate many misconceptions and to realize conceptual changes, lesson plans were prepared in Geogebra. Relatedly, an eight-week Geogebra course practice was made with PSST. Consequently, in this study, the misconceptions of PSST about PM were determined and Geogebra applications were used to overcome them by applying the conceptual change model.

METHOD

1. Research Model

The quantitative research method was applied in this study, in which the effect of the teaching carried out with Geogebra applications in the Physics lesson of PSST on the misconceptions of the "Force and Motion" unit of PSST on the subject of " Projectile Motion " was used. According to Fraenkel and Wallen (2006), since experimental research is the best way to establish cause-effect relationship, quasi-experimental design with control group was used to pre-test, post-test and permanence test to discover the effect of learning PM with Geogebra in the experimental group.

2. Population and Sample

The accessible population in this study is the PSST studying science education in Kayseri (Turkey). The sample of the study consists of 36 PSST, 18 in the EG and 18 in the CG, studying as a freshman in a university in Kayseri. The sample of the study was determined by the convenience sampling method.

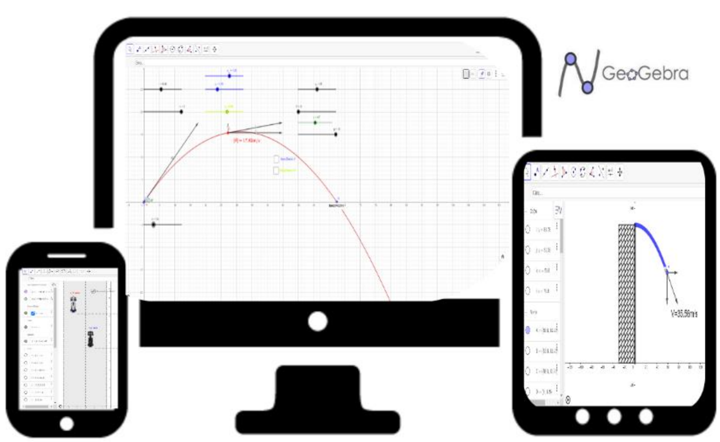

Figure 1. A few examples of the experimental group's Geogebra studies

Researchers choose convenience sampling; due to time, money and some limitations, the researcher determines the sample from easily accessible and practicable communities (Büyüköztürk, 2012). In this study, researchers included participants whom they could easily reach for logistical reasons. 36 students in the EG and CG took physics lessons together in the same class. In addition to these lessons, 18 students in the EG took an eight-week-long 16-hour course, practice using Geogebra in the computer laboratory, and at the end of this practice, they prepared simulations and animations on the subject of the PM. In Figure 1, some examples of physics simulations made by PSST in Geogebra course practice applied within the scope of this research are given.

3. Data Collection Tools

The "Conceptual Questions of Projectile Motion" (CQPM) scale consisting of seven open-ended question was used as a data collection tool in this study. This scale; was developed by Piten, Rakkapao, and Prasitpong (2017), it was translated into Turkish by the researchers and it was checked by taking the opinions of three experts (English, Physics and Turkish Language and Literature teachers). Seven open-ended questions with CQPM discuss the main ideas of the PM; velocity, acceleration and force (Q1, Q2, Q5), flight times (Q2), path (Q3, Q4, Q7), peak point, range and complementary angles (Q6). While Piten, et al. (2017) developed the questions, the consistency between an item and its behavioral goals was evaluated by eight physicists using the "item-goal fit form".

4. Data Collection and Analysis

SPSS 22.00 package program was used for the analysis of the data obtained in a period of three months. The obtained findings were evaluated at 95% confidence interval and 5% significance level. The minimum score that can be obtained from CQPM is null, the maximum score is 100. The detailed scoring made by the researcher for CQPM was checked by an expert in the field of physics education and found appropriate. Data collection process and applications are shown in Figure 2.

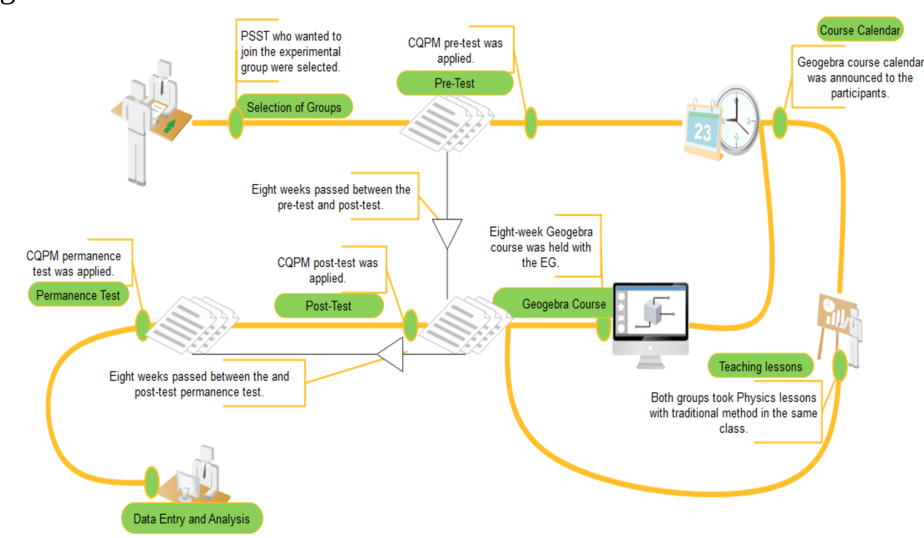

Figure 2. Flowchart diagram of data collection process and courses.

In descriptive statistics, the mean, median, mod, minimum and maximum test scores, standard deviation, skewness and kurtosis values of the pre-test, post-test and permanence test scores of the dependent variables were computed for both the EG and CG. In order to check whether there is a statistical difference between the groups, independent samples t-test was conducted as inferential statistics. All the assumptions of the tests were checked before testing.

FINDINGS

1. Descriptive and Inferential Statistics Results of Experimental Group and Control Group

In the study, t-test was applied to determine the effects of Geogebra applications on the misconceptions of PSST in physics lesson. The assumptions discussed in Pallant (2011) were checked before applying the independent samples t-test. These assumptions, normality and homogeneity of variances were checked for all test scores. The results of the descriptive analysis are included in Table 2-3. The normality of the data was evaluated by Kolmogorov-Simirnov and Shapiro-Wilk statistics and kurtosis, skewness, mod, median and mean values.

Group	Test	Skewness	Kurtosis	$\bar{X}$	Median	Mod
EG	Pre-test	.669	.202	26.72	24.50	19.00
	Post-test	.309	-.930	49.58	48.50	32.00
	Permanence	.746	-.158	30.69	28.00	16.50
CG	Pre-test	.153	-.882	27.38	27.50	16.00
	Post-test	-.086	-1.160	17.91	19.00	10.50
	Permanence	-.120	-.374	14.33	15.00	15.00

Table 2. *Descriptive statistics values for the test scores of the groups*

On the Kolmogorov-Simirnov, Shapiro-Wilk tests, the significance values of the pre-test PSST CQPM pre-test, post-test and permanence test results were greater than .05, and the kurtosis and skewness values were lower than 1, which indicates that the data showed normal distribution (p>. 05). As can be seen from Table 3, the kurtosis value of the post-test of the CG is slightly higher than -1 (-1.160) and the Kolmogorov-Smirnov significance value of the permanence test of the EG is less than .05 (p = 0.039).

Group	Test	Kolmogorov-Smirnov			Shapiro-Wilk		
		Statistic	df	p	Statistic	df	p
EG	Pre-test	.120	18	.200*	.961	18	.629*
	Post-test	.118	18	.200*	.959	18	.591*
	Permanence	.208	18	.039	.919	18	.124*
CG	Pre-test	.112	18	.200*	.974	18	.862*
	Post-test	.113	18	.200*	.954	18	.489*
	Permanence	.141	18	.200*	.959	18	.582*

*****p> .05

Table 3. *Kolmogorov-Smirnov and Shapiro-Wilk statistics for the test scores of the groups*

On the Kolmogorov-Simirnov, Shapiro-Wilk tests, the significance values of the pre-test PSST CQPM pre-test, post-test and permanence test results were greater than .05, and the kurtosis and skewness values were lower than 1, which indicates that the data showed normal distribution (p>. 05). As can be seen from Table 3, the kurtosis value of the post-test of the CG is slightly higher than -1 (-1.160) and the Kolmogorov-Smirnov significance value of the permanence test of the EG is less than .05 (p = 0.039). On the other hand, it was concluded that a normal distribution was shown by looking at the other results in the relevant tests. Based on these results, it was decided that the t-test results of the groups could be compared. The t-test results for the groups are given in Table 4.

Test	Group	N	$\bar{X}$	Sd	df	t	p
Pre-test	EG	18	26.722	10.814	-31.108	-.154	.878
	CG	18	27.388	14.817			
Post-test	EG	18	49.583	15.718	34	7.806	.000*
	CG	18	17.916	7.011			
Permanence	EG	18	30.694	11.582	34	5.466	.000*
	CG	18	14.333	5.207			

*****$p< .05$

Table 4. *t-test results for test scores of the groups pre-test, post-test and permanence*

In order to check whether there is a significant difference between the misconceptions of the groups in terms of PM, the comparison of the CQPM pre-test, post-test and permanence test scores was performed by independent samples t-test. As can be seen from Table 4, the analysis results show that there is no statistically significant difference between the pre-test averages of the groups (pre-test: $t = - .154$; $p> .05$), there is a statistically significant difference in terms of post-test and permanence test. (post-test: $t = 2.525$; $p< .05$) shows (permanence test: $t = 5.466$; $p< .05$).

2. Misconceptions Detected on the Conceptual Questions of Projectile Motion Scale

In this section, the answers given by PSST to CQPM are presented as a percentage on the basis of questions. The pre-test, post-test and permanence test results of the answers given by the PSST were evaluated separately as a percentage and EG and CG and are given in Table 5. In Figure 3, some of the answers containing misconceptions detected in this study are given. In addition, the summary of the misconceptions detected in this study, their scientific equivalent and their references in the literature are presented in Appendix-2.

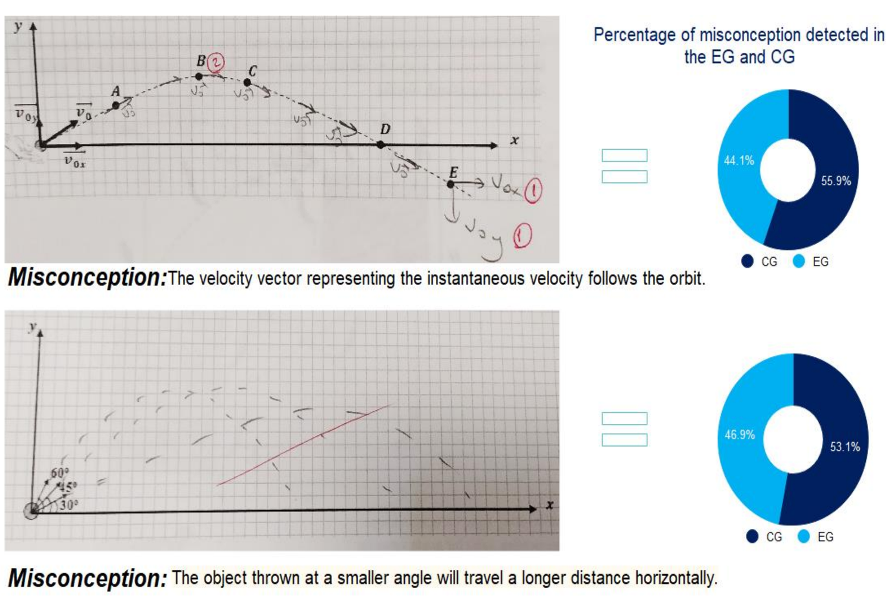

Figure 3. Examples of misconceptions detected in CQPM.

Table 5. *Percentage results of the EG and CG PSST on the basis of CQPM total and questions*

Conclusion and Discussion

The main purpose of this study is to investigate the effect and permanence of Geogebra applications on the detection and elimination of misconceptions of PSST about physics lesson PM. For this purpose, before comparing the experimental and control groups, independent samples t-test was used to determine whether the groups showed a significant difference in terms of misconception levels. There was no statistically significant difference in the CQPM pre-test results: $t = -.154$; $p > .05$ (Table 4). Accordingly, the groups' misconceptions before the Geogebra course are at the same level.

It is seen that there is a significant difference between the EG and the CG in terms of the mean CQPM post-test results: $t = 7.806$; $p < .05$ (Table 4). Thus, at the end of the Geogebra course in the EG, it was determined that the Geogebra applications in the physics lesson positively affected the misconceptions of PSST about the subject of the PM. Moreover, when we look at the pre-test and post-test averages of the PSST studying in the CG (Table 4), an increase of misconceptions observed. This might be resulted from the teaching plan and method, as reported by Klammer (1998) and Millar (1989). The traditional method supported the students' misconceptions and could not realize the conceptual change. While the PSST in the EG explained the physical phenomena, they encountered in the Geogebra course, they made many interactions with the PM while designing the simulation in Geogebra and discovered the scientific reality behind the PM subject. As Posner et al. (1982) mentioned, the EG interacting with the physical phenomenon with Geogebra was not satisfied with the existing understanding, found that the new understanding was understandable, thought it was reasonable, found it efficient, and the new understanding they acquired led to different new understandings. These are the necessary steps for conceptual change to occur. Furthermore, when the permanence test scores of the groups are examined, it is seen that the applied independent samples t-test is in favor of the EG: $t = 5.466$; $p < .05$ (Table 4). This result proves the effectiveness of simulations prepared with Geogebra applications in conceptual change.

Each of the question in CQPM tests one or a few misconceptions about PM in physics. The percentage of correct answers to these questions by the groups are given in Table 5. When Table 5 is examined, it is seen that the EG is successful in terms of questions compared to the CG. The misconceptions of the PSST in the EG about speed, acceleration and force decreased (Q1, Q2, Q5 test these misconceptions). Especially if we look at the percentage of Q5, it is seen that it increased from 1.66% to 86.6%. In other words, the misconception of PSST that "The direction of acceleration is the same as the direction of movement" (Tao, 1997, Tao & Gunstone, 1999) has been largely eliminated. When the permanence test results of the same question are examined, it is seen that the gains obtained from the post-test are mostly lost, although there is a numerical increase compared to the pre-test (5.55%). Woods and Thorley (1993) stated that students turned to misconceptions even after "strong" teaching. Moreover, they stated that it is difficult to help a student gain a deep and strong understanding when analyzing case studies for students' understanding before and during and about two months after teaching. In the later interviews about the subjects that the students were very successful during and after the teaching of the lesson, it was revealed that the students returned to their previous "alternative concepts", in some cases, they could remember the "correct answer" but could not verify or in some cases their answers were seriously misconfigured. The first part of Q7 in CQPM is choosing the path the ball will follow (Figure 4). The percentage of those who prefer the B path in the EG is 83.3% for the pre-test and 100% of the post-test. In other words, each PSST in the EG gave the correct answer to the first part of this question. The second part of the question is the explanation of this answer. Here, there is a decrease in the percentage of correct answers given by the EG. The result, which was 33.3% of the pre-test, dropped to 22.2% in the post-test and to 5.5% on the permanence test.

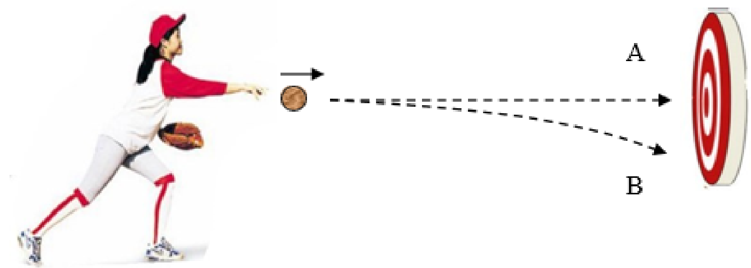

Figure 4. CQPM Q7: A girl throws the ball in a horizontal direction as shown in the figure. Which path does the ball follow? Why? (Piten, et al., 2017)

This result supports the idea of Woods and Torley (1993), that even if the students remember the correct answer, they cannot remember the reason and they go back to their old "alternative concepts" while explaining the physical phenomenon.

However, the misconceptions detected in this study on the subject of the PM are consistent with previous studies in the literature and contribute to the literature (Appendix-2). Since there was no previous study in the field of Geogebra applications and conceptual change in science education, it was compared with the results of the study conducted by Computer Aided Teaching in this area of science.

In a study conducted by Dilber et al. (2009) with 82 students (43 in the EG and 39 in the CG), results in favor of the EG were obtained. The EG was taught using conceptual change activities and computer simulations. The CG took traditional physics course. Conceptual change text and simulations were used as conceptual change applications in the EG. Simulations were used to represent the physical concepts in the EG. These simulations were used by the teacher for demonstration purposes only to visualize the concepts of PM in the class. According to Dilber et al. (2009), simulations and associated learning goals provide at least one answer to frequently asked questions about the purpose of learning the subject for which simulations are used. As a result of their study, it is shown that the conceptual change in the EG students' misconceptions compared to the CG has a positive and higher average ($p < .05$ and $t = 7.43$) (Dilber et al., 2009). In addition, computer simulations, which were used as an aid to conceptual change in Dilber et al. (2009) study, were used as a conceptual change tool to change the misconceptions PSST in this study. As can be seen from the results of this study, the simulations prepared with Geogebra applications will be effective in understanding the scientific reality behind the physical phenomenon in eliminating the misconceptions. As reported by Walsh (2017), a student can better understand and avoid misconceptions while creating physics simulations in GeoGebra while thinking about how to simulate a subject or phenomenon mathematically and graphically.

Suggestions

Teacher training programs should give PSST an opportunity to improve their knowledge of using technology for educational purposes. Additionally, in teacher training programs, courses suitable for conceptual change should be planned in the education process of PSST so that they do not convey their misconceptions to students. Teachers who are free from misconceptions will prepare a course by taking care of the students' misconceptions in their classes.

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Appendixes

Appendix-1 Misconceptions about projectile motion and the scientific equivalents of these errors.

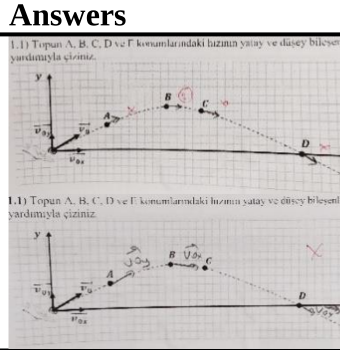
	Misconception	Scientific equivalent	Reference
1	After a cannon ball leaves the cannon, an impressed force acts on it.	After losing contact with the cannon, there is no force acting the cannon ball, except the weight of the cannon ball.	(Bayraktar, 2008; Tao & Gunstone, 1999; Hestenes at al., 1992; Hallon & Hestenes,1985b; McCloskey,1983; Whitaker,1983;Clement,1982)
2	The object moves in the direction of a force greater than its downward weight. At the peak of the orbit followed by the object, this force is exhausted and the object starts to fall due to its weight.	The object moves under gravitational force in a parabolic orbit. Its horizontal velocity is constant, but its vertical velocity changes over time.	(Hallon & Hestenes, 1985b; McCloskey, 1983; Whitaker, 1983; Clement, 1982)
3	An object thrown up vertically moves upwards with a force greater than its weight.	The only force affecting the object is the gravitational force exerted by the ground.	(Clement, 1982; Hallon & Hestenes, 1985b; McCloskey, 1983; Whitaker, 1983)
4	An object that launches or rolls in the horizontal direction of the cliff follows the reversed L path.	An object thrown off a cliff moves at a constant horizontal velocity on a horizontal road and accelerates slowly downward.	(Hallon & Hestenes, 1985b; McCloskey, 1983)
5	An object released from constant horizontal velocity follows a linear path.	For an observer on the ground, the orbit of the object will be parabolic.	(Hallon & Hestenes, 1985b; McCloskey,1983)
6	An object falls back from the position where it was released with horizontal constant initial velocity.	For an observer on the ground, the orbit of the object will be parabolic.	(Hallon & Hestenes, 1985; McCloskey, 1983)
7	No force is applied to an object released from a moving carrier.	A force is applied by the gravitational field of the ground to an object making a horizontal PM.	(Hallon & Hestenes, 1985; McCloskey,1983)
8	Since an air resistance is applied to an object released from a moving carrier, the object traces backwards.	The object follows a parabolic path forward.	(Hallon & Hestenes, 1985; McCloskey, 1983)
9	From the same height, a released object falls before the object at a horizontal constant velocity because the released object takes a shorter path. Or the thrown object falls first because it has a greater velocity than the object released.	An object that is released from the same height and the other thrown with a horizontal constant velocity hit to the ground simultaneously.	(Dilber et al., 2009; Jimoyiannis & Komis, 2001; Prescott & Mitchelmore, 2005; Whitaker; 1983)
10	Objects that are released and thrown at the same height hit the ground at different times because the projectile has horizontal velocity, acceleration, or force.	The object that is released from the same height and thrown with a horizontal constant velocity falls to the ground simultaneously.	(Dilber et al., 2009; Whitaker, 1983)

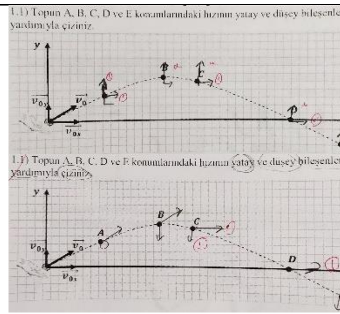
11	Students have confusion between position and velocity, velocity and acceleration.	The displacement per unit time is called velocity, and the change in velocity per unit time is called acceleration.	(Bayraktar, 2008; Hestenes et al 1992; Hallon & Hestenes, 198 Jimoyiannis & Komis, 200 Whitaker,1983)

Appendix-1 (continued)

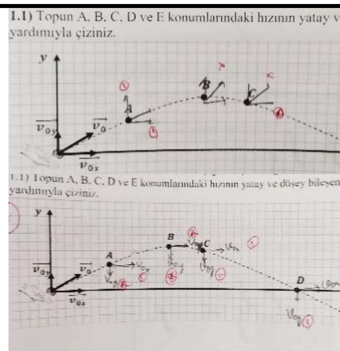
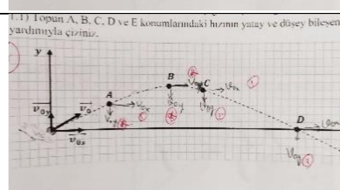
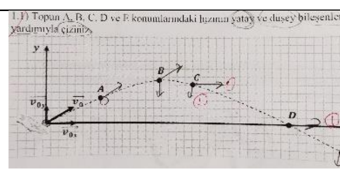
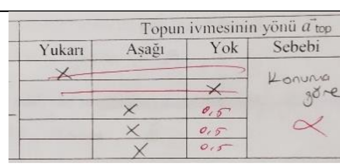
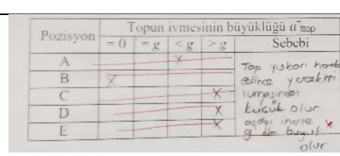
	Misconception	Scientific equivalent	Reference
12	In an environment where air resistance is neglected, objects with different mass values hit the ground at different times.	Objects that are released to fall hit the ground at the same time, because when the air resistance is neglected, only the force of gravity acts on the objects.	(Dilber et al., 2009)
13	The final velocity of an object which released to free fall depends on the force of gravity.	The final velocity of objects released to free fall depends on the height at which the objects are released and the gravitational acceleration.	(Dilber et al., 2009)
14	A ball with greater mass will have a greater velocity when released into free fall.		(Jimoyiannis & Komis, 2001)
15	The larger the mass, the greater the acceleration in free fall.	The acceleration of free falling objects is the gravitational acceleration of the planet.	(Jimoyiannis & Komis, 2001)
16	Since the higher of two balls of different height has a greater acceleration, when it hits the ground, it has a greater velocity.		(Jimoyiannis & Komis, 2001)
17	The higher the ball of two balls of different heights, the acceleration is greater because it moves more.		(Jimoyiannis & Komis, 2001)

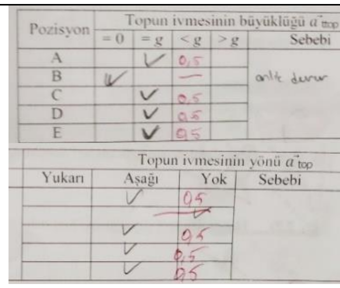
Appendix-2 Summary of the misconceptions of pre-service science teachers revealed in this study

Q	Misconceptions	Examples of Student Answers	Scientific equivalents	References
11	The velocity vector representing the instantaneous velocity follows the orbit.		To present the instantaneous velocity of a projectile, a vector is a line of contact with a parabolic path at a particular point. It consists of two vectorial components Vx and Vy.	Piten, Rakkapao, & Prasitpong, 2017

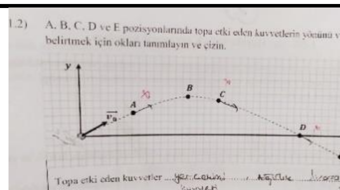
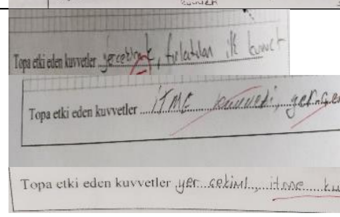
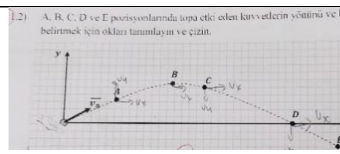
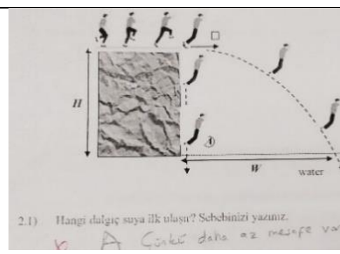
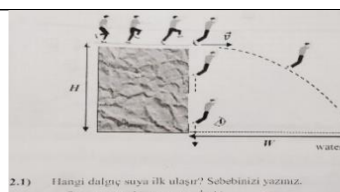
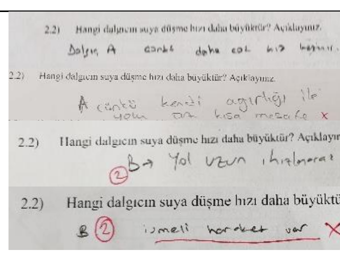
	The higher the position, the greater the velocity of an object (velocity-position confusion)		Instantaneous velocity is the rate of change in position over time.	Hestenes et al., 1992

Appendix-2 (continued)

Q	Misconceptions	Examples of Student Answers	Scientific equivalents	References
	The components of the horizontal velocity Vx and the vertical velocity Vy of the projectile are the same at every point.		The horizontal velocity Vx of the object is constant. The vertical velocity Vy varies as much as the acceleration of gravity over time.	
	The velocity of the object has a vertical component at maximum height. (Point B)		The velocity of the object has no vertical component at maximum height. The horizontal component is the same as when it was first thrown and does not change during the motion.	
11	When the object reaches the level at which it is thrown horizontally, the vertical component of its velocity ends.		When the object reaches the level at which it was thrown horizontally, the vertical component of its velocity is in the opposite direction of the same magnitude as when it was thrown.	
	The direction of acceleration follows the direction of motion.		The direction of the acceleration does not change, since the object moves with the acceleration of gravity, the acceleration of the object is always towards the center of the earth.	Tao, 1997, Tao & Gunstone, 1999
12	The magnitudes of acceleration and instantaneous velocity are always the same parameter.		The magnitude of the acceleration is the ratio of the change in speed to time. Acceleration for	Rosequist & McDermott, 1987

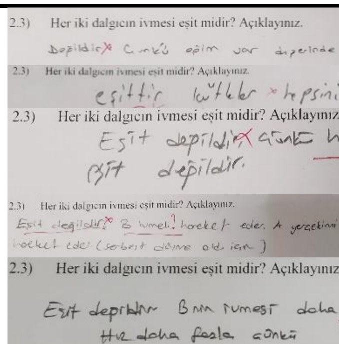
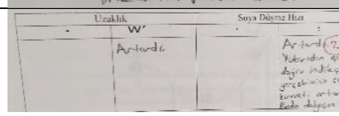
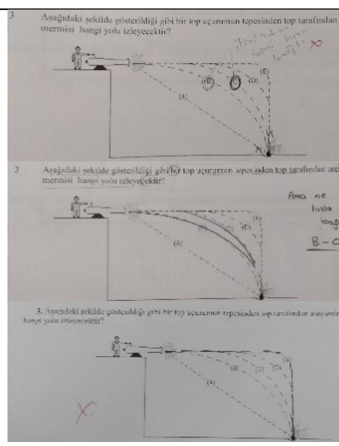
			projectile motion is the acceleration of gravity.	
	Acceleration "instantly stops" at the highest point of the motion of the object.		The direction and magnitude of the acceleration do not change, the acceleration of the object is always towards the center (down) of the earth, its magnitude does not change.	

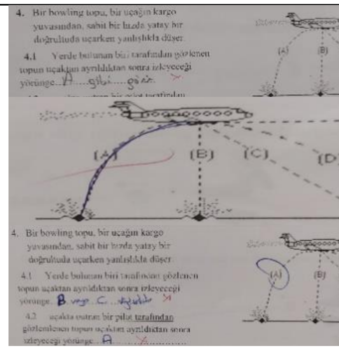
Appendix-2 (continued)

Q	Misconceptions	Examples of Student Answers	Scientific equivalents	References
	The direction of the force vector follows the path of the object in the projectile motion.		The direction of force and acceleration are the same, which is towards the center of the earth.	McCloskey, 1983; Toa, 1997; Toa & Gunstone, 1999; Prescott & Michaelmore, 2005
	After a hand force (or force thrown) loses contact with an object, it continues to affect the object.		There is only the gravitational force affecting the object in the projectile motion.	Bayraktar, 2008; Tao & Gunstone, 1999; Tao, 1997; Hestenes at al., 1992; Hallon & Hestenes, 1985b; McCloskey, 1983; Whitaker, 1983; Clement,1982
13	Force means motion.		Force, velocity and motion are different concepts.	Clement,1982
	A body falling free from flat falling objects at the same height spends less time to reach the ground than an object moving in a curve.		Two objects, one released for free fall and the other shot horizontally from the same height, reach the same height, reach the ground at the same time.	Prescott & Michaelmore, 2004
21	At the same height, an object with initial horizontal velocity (faster) reaches the water in a shorter time to reach the ground than an object moving without initial velocity.		Two objects, one released for free fall and the other shot horizontally from the same height, reach the ground at the same time.	Prescott & Michaelmore, 2005
22	From the same height, the velocity of the object released and launched into the water depends on the type of movement (straight or curved).		The velocity of an object hitting water depends on the composition of its horizontal and vertical components. The vertical component of the velocities of both divers	

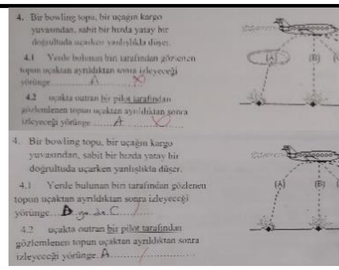
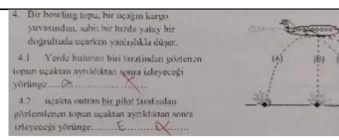
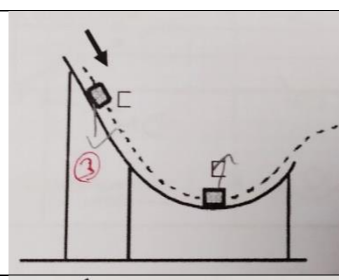
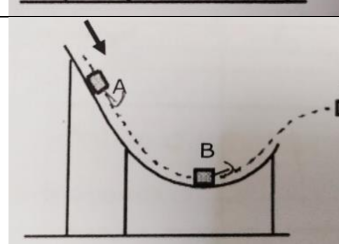
			is the same. Since diver B also has a horizontal component, the velocity of falling into water is greater.	

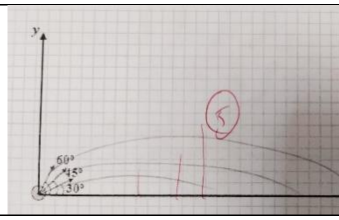
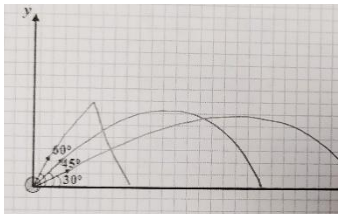
Appendix-2 (continued)

Q	Misconceptions	Examples of Student Answers	Scientific equivalents	References
2.3	Objects that are released and thrown at the same height hit the ground at different times because the object being thrown has horizontal velocity, acceleration, or force.		At the same height, bodies that are released and ejected have the same acceleration because the acceleration of both bodies is the acceleration of gravity.	(Whitaker, 1983; Dilber et al., 2009)
2.4	Since the acceleration of two balls of different height (if the height increases for this item) the higher one has greater velocity when it hits the ground.		If the altitude is increased, the velocity of hitting the ground will increase as the flight time will increase.	(Jimoyiannis & Komis, 2001)
3	The impulsive force acting on the fired ball more than the weight causes it to move in a straight line, then the initial impulse slowly decreases, and the downward gravitational force gradually moves over the ball so that the net force keeps the ball moving in a curved path.		The fired shell moves in a curved trajectory, this trajectory is not dependent on the initial firing velocity, and only gravitational force acts on it.	Whitaker, 1983; McCloskey, 1983; Halloun and Hestenes, 1985; Hestenes at al., 1992; Prescott & Michaelmore, 2005

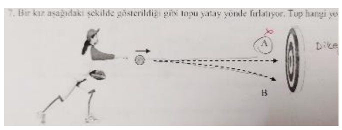
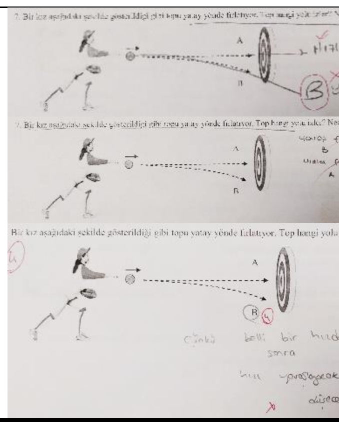
4.1	Observed by a person on the ground, the object dropped from an airplane moving at a constant velocity will move backward and land behind the point where it was released, or an object released from a constant horizontal velocity follows a linear path.		An object falling from a plane moving at a constant velocity is seen by a stationary observer on the ground, following a curved trajectory as in a projectile motion.	Hallon & Hestenes, 1985; McCloskey, 1983; Whitaker, 1983

Appendix-2 (continued)

Q	Misconceptions	Examples of Student Answers	Scientific equivalents	References
4.2	The object released from an airplane moving at a constant velocity will be observed by an observer on the plane that it will move backwards and land behind the release point.		The object released from a plane moving at a constant velocity will be observed by an observer on the plane as if it is moving linearly.	
	Any object suspended in air will remain in air until made aware of its situation.		The object falling from the plane moves in a curved orbit, which will be seen by a person on the plane in a linear direction.	McCloskey (1983),
5	The direction of acceleration indicates the lower position from the upper position.		The direction of acceleration is towards the center of the earth.	Whitaker, 1983; Hestenes et al., 1992;
	The direction of acceleration is the same as the direction of motion.		The direction of the acceleration does not change, since the object moves with the acceleration of gravity, the acceleration of the object is always towards the center of the earth.	Tao, 1997, Tao & Gunstone, 1999

	The object thrown at a greater angle will travel a longer distance horizontally.		A projectile launched in 45 °, at the same level of the starting point, will give the maximum horizontal distance.	
6	The object thrown complementary angles will travel different horizontal distances.		The object to be thrown from the same level, at complementary angles, will travel the same horizontal distance.	

Appendix-2 (continued)

Q	Misconceptions	Examples of Student Answers	Scientific equivalents	References
	Hand force (impetus) embedded in the ball directs the ball to hit the target straight.		After the ball thrown, there is no hand force embedded in the ball.	Whitaker, 1983; McCloskey, 1983; Hestenes et al., 1992; Halloun & Hestenes, 1985; Hestenes et al., 1992; Prescott & Michaelmore, 2005
7	If the initial velocity given to the ball is fast enough, the ball will move in a straight line unaffected by gravity. However, if its velocity is low, it will be affected by gravity.		A horizontally thrown ball as it will be affected by gravity regardless of the initial velocity given to the ball.	