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The effect of laboratory experiment and interactive simulation use on academic achievement in teaching secondary school force and movement unit

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Abstract. The aim of this study is to investigate effects of laboratory experiments and interactive simulation techniques within the framework of 5E model on academic achievement in teaching of Force and Movement unit in 6th grade science course in secondary school. The research is conducted in 6th grade of a public school in the first semester of 2017-2018 academic year. Research design of the study is quasi-experimental design with pre-test and post-test control group, which is one of quantitative research methods. The sample of the study consists of 52 students. One experimental and one control group are used in the study. Courses in the experimental and the control group are conducted with 5E model in the constructivist learning environment for sixteen course periods in four weeks. In experimental group, interactive simulations are conducted in the explore step of the 5E model while, in the control group, laboratory experiments are used in same step of the 5E model. The paired sample t-test and 2x2 mixed ANOVA are applied to the data obtained from the study towards academic achievement. According to the findings of the study results, it is found that interactive simulations are more effective than laboratory experiments in increasing students' academic achievement.

Keywords: Simulation, science, secondary school, force and movement unit, experimental design, laboratory experiments

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INTRODUCTION

Until recently, it is thought that experiment and theory are two complementary ways to do science. However, a third way has emerged as an alternative to these ways in recent years. It is said that this way is computer simulations (Feurzeig and Roberts, 1999). According to Feurzeig and Roberts (1999), computer simulations, which are the products of our age, is a strong and novel paradigm that functions as a bridge between traditional experiments and theoretical knowledge. After computer simulations come to be used as a means to advance scientific knowledge, they become a key part of existent scientific researches. Although it cannot be predicted exactly what scientific discoveries there will be in 21st Century, it is foreseen that discoveries and experiments to be achieved using computer models will play a crucial and active role in achieving major developments. Simulation technology finds its roots 5000 years ago, and first simulation that is known as WEICH were reproduced from Chinese war games (Shah, Gor and Soni, 2007). These games were employed to develop army and navy strategies and, after 1800s, Edward Link modeled first plane as a consequence of employment of simulation in armies (Patrik, 2002). Simulations are a technology which enables one to do studies in places where he can model in real life conditions (Mıdık and Kartal, 2010). According to De Jong and Van Joolingen, simulations are the process of modeling real situations or a system. It can be said that the characteristic of simulations, which changes certain variables and makes results coordinated with the study, is more advantageous when compared with animations (Akkağıt and Tekin, 2012). Since computer systems, which provide a wide range of possibilities for simulations, present moving images and sounds interactively, they have become an important tool in education (Feurzeig and Roberts, 1999).

According to Tan (2012), simulations provide an advantage when they are used in educational environments as they are interesting and contribute to students' problem-solving and decision-making skills. Simulations enhance students' participation in lessons, keep learning away from being abstract, and ensures learning by doing and experiencing (Tan, 2012). In addition, it contains many applications that appeal to many senses, including diagrams, graphs, animations, sounds, and videos, which can make learning easier (Ainsworth and Van Labeke, 2002). According to Blake and Scanlon (2007), these are the reasons of use of simulations in educational environments as illustrated in Figure 1.

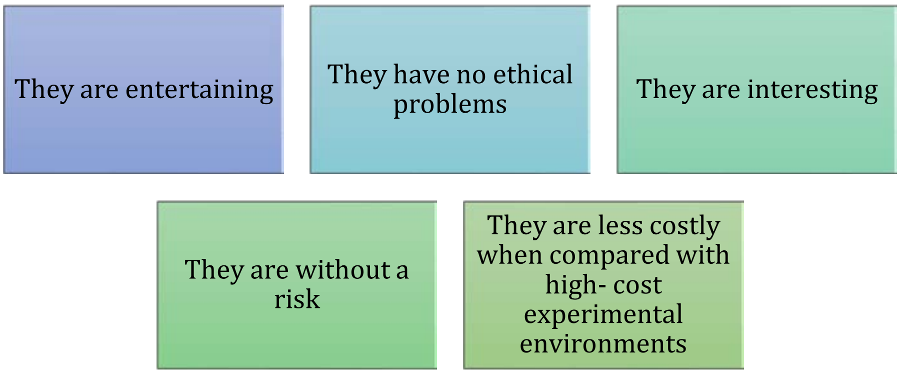


FIGURE 1. *Reasons of simulation use*

According to Gülçiçek and Güneş (2004), in science education, the aim is to have students understand concepts correctly. However, this aim cannot be achieved at a desired level as some subjects of sciences enjoy abstract concepts. For that reason, one of most studied subjects by researchers of science education is how abstract notions can be made concrete.

Use of techniques/tools that embody abstract concepts in science subjects gives effective results in terms of learning (Jaakkola and Veermans, 20015). One of tools used in teaching of these concepts are interactive simulations (Goldstone and Sakamoto, 2003). While embodying abstract notions, use of various teaching materials or creation of experimental set-ups in classroom environment are needed. However, because of problems regarding financing, safety or time, these needs, mostly, cannot be satisfied. In solving such problems, use of simulation will be greatly beneficial (Gülciçek and Güneş, 2004). Thus, simulations have many characteristics such as embodying the subject, attracting students' attention, eliminating risky situations, which support science teaching (Wellington, 2004). Special risk of doing an experiment in certain subjects, difficulty in the provision of experimental materials or lack of laboratory environments in every school limits practicality of experimental method. Hence, simulation method creates safer environments to students and offers more entertaining learning possibilities. It is also known that simulations increase understandability by embodying subjects (Tan, 2012). Also, by enabling students to use simulations, it can be possible that students gain a different point of view, looking at apparently complicated matters from a wider perspective (Feurzeig and Roberts, 1999). Even though interactive simulations has a great potential as to facilitating comprehension of abstract science subjects, the fact that some schools may not have a computer is a serious problem. To overcome such a problem, use of different teaching methods like flipped classroom approach is suggested (Bo, Fulmer, Lee and Chen, 2018). Kohnle, Benfield, Hähner and Paetkau (2017) states that use of simulations is important in science teaching and those simulations can be used as well when giving students homework. On the other hand, Moore, Chamberlain, Parson, and Perkins (2014) points out that use of simulations are very suited for lessons, laboratories, and homework especially in chemistry teaching.

In the literature, although positive aspects of simulations stand outs, there can be some difficulties in its use in education. In Figure 2, according to Tan (2012), difficulties in simulation use and points to consider are summed up.

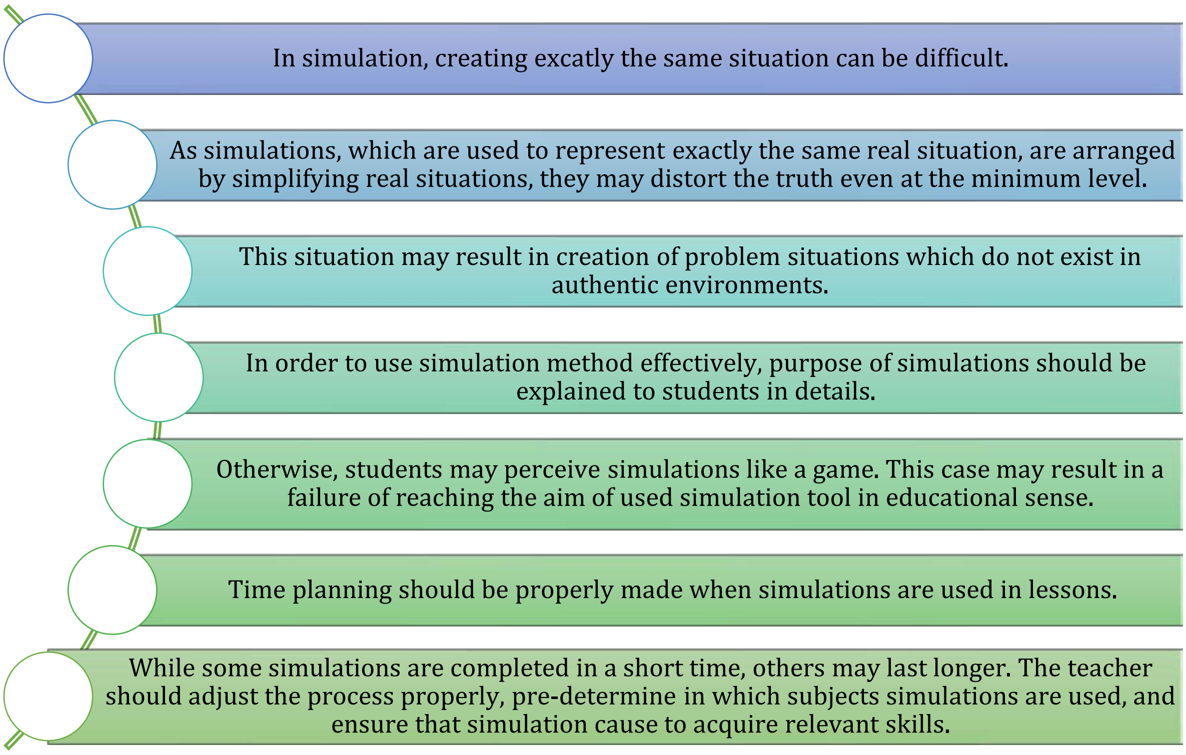


FIGURE 2. *Difficulties in simulation use and points to consider*

When reviewed studies regarding simulations in the literature, obtained results reveal that simulations are effective in increasing academic achievement (Aycan, Arı, Türkoğuz, Sezer and Kaynar, 2002; Blake and Scanlon, 2007; Bozkurt and Sarıkoç, 2014; Büyükkara, 2011; Daşdemir and Doymuş, 2016; Van der Meij and De Jong, 2006; Dinsmore and Zoellner, 2018; Dinçer and Güçlü, 2013; Dudding and Nottingham, 2018; Göriş, Bilgi and Bayındır, 2014; Griffiths and Preston, 1992; Gülçiçek and Güneş, 2004; Küçük, 2011; Lawless et, al., 2018; Mıdık and Kartal, 2010; Minaslı, 2009; Pekdağ, 2010; Sevgi, 2006; Sevgi and Uluışık, 2006; Şendir and Doğan, 2015; Teke, 2010; Winberg and Berg, 2007). It is stated that interactive simulations provide more effective learning environment to students (Van der Meij and De Jong, 2006). According to Winberg and Berg (2007), simulations have a positive effect on increasing students' academic achievements. According to Griffiths and Preston (1992), simulations decrease students' misconceptions considerably. And according to Gülçiçek and Güneş (2004), simulations contribute to learning and play role in the process of conceptual change. Aycan, Arı, Türkoğuz, Sezer and Kaynar (2002), in their study with university students on 'movement on the Earth' unit, researched on computer-aided simulation technique's effects on student achievement in science and physics teaching and concluded that simulations increase achievement. Lawless et al. (2018), in their study with secondary school students, concluded that simulations have a positive effect on students' scientific literacy. Rutten, Van Joolingen and Van der Veen (2012) reviewed (quasi) experimental researches carried out on computer simulations' effect on learning in science education of last ten years and, as result of their analysis, concluded that there are significant findings that computer simulations can improve traditional education especially when there are laboratory activities. Blake and Scanlon (2007) put forward three different evaluations relating use of simulation in distance learning and found that success of simulation depends on effective use.

We encounter 'constructivist approach' as an important approach in the modern science education (Matthews, 1998). According to constructivist approach, a student learns not as a passive receiver of information but relating new information to prior knowledge and actively constructing knowledge (Tan, 2012). In science teaching, teaching process is perfected with 5E model, this model is especially used in constructivist approach, and steps of this model are as follows: (1) engage, (2) explore, (3) explain, (4) elaborate, and (5) evaluate(Tan, 2012). On the other hand, experimental method reveals scientific facts, analyzes principles using cause and effect relation, and requires safety measures for some potentially dangerous situations. In the study, a teaching activity is carried out in the constructivist environment and according to 5E model. In the 'explore' step, interactive simulations are used for experimental group whereas laboratory experiments are used for control group. Interactive simulations are selected from among PhET simulations (https://phet.colorado.edu/). These simulations belong to University of Colorado and are suggested by Sokolowski and Rackley (2011) for science education. They were produced by Physics Education Technology (PhET) project and have been presented as free online applications. Interactive simulations are identified as 'Easy Jawa Simulations (EJS)' (Fan, Geelan and Gillies, 2018). There are simulations on physics, chemistry, and biology fields. The main purpose of PhET simulations is to help students learn by questioning and to support making practice in learning (Fan, Geelan and Gillies, 2018). Their design principles are based on researches of how students learn.

Cengiz, Uzuoğlu and Daşdemir (2012), in their study, point out that one of reasons for failure in science lesson is that subjects are abstract, and students have difficulty in learning especially subjects that belong to physics course content. For that reason, in the study, 'Force and Movement' unit is preferred. Because the concept of 'force' is abstract, students have difficulty in learning that subject, and simulation make easy to learn such science subjects (Jaakkola, 2012), interactive simulations are used for experimental group. In addition, for control group, laboratory experiments are used to compare their effects with effects of interactive simulations on achievement. Finally, the study aims to analyze effects of interactive simulations and effects of laboratory experiment on students' academic achievements. In line with this purpose, research problems of the study are set out as below:

1. Is there a significant difference between pre-test scores and post-test scores of academic achievement test, which belongs to 'Force and Movement Unit', of control group students?
2. Is there a significant difference between pre-test scores and post-scores of academic achievement test, which belongs to 'Force and Movement Unit', of experimental group students?
3. Is there a significant difference between post-test score means of experimental group students and control group students in academic achievement test that belongs to 'Force and Movement Unit'?

METHODS

Research Model

In this study, which is carried out to research on effects of use of laboratory experiments and interactive simulations on students' academic achievements in science education, quasi-experimental design, which is one of quantative research methods, is employed. A researcher, in experimental studies, randomly chooses groups, decides on how the application is conducted on each group, controls external variables, and observes the effect on groups at the end of study (Mcmillan and Schumacher, 2014). Designs where subjects are not randomly allocated to groups but experimental and control groups are randomly chosen are called quasi-experimental design (Fraenkel, Wallen and Hyun, 2012). When it is impossible to randomly allocate subjects to groups, quasi-experimental design can be employed by the researcher (Fraenkel, Wallen and Hyun, 2012). Hence, in the study, quasi-experimental design, one of research method, with pre-test post-test control group is employed. With quasi-experimental design with pre-test post test control group, effect of independent variable on dependent variable is researched (Karasar, 2012). In the reseach, one experimental group and one control group are used. Because study groups are chosen from ready classes and no student are allocated to classess, one of existent class is chosen as experimental class, and other existent class is chosen as control group. Research is implemented during 4 weeks (16 course periods) as part of 'Force and Movement Unit'.

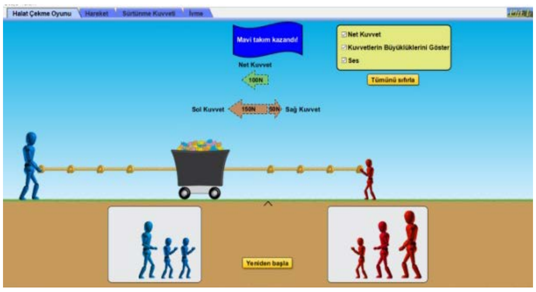
Sample

Research sample consists of students of A and B classes of 6th grades of a public school located in District of Erzurum. As sampling method, convenience-sampling method is used. Reasons for choosing convenience sampling method are knowing school environment and subject teacher, thus, minimizing potential situations that may affect negatively validity and reliability of the study, and availability and low-cost of transportation means to school. There has been no manipulation on sample selection for the study: Existent classes that are taught by the same teacher are randomly chosen. As a result, Class A is chosen as experimental group, and Class B is chosen as control group. There are 28 students in the experimental group, 24 students in the control group, and totally 52 students. In the experimental group, there are 19 girls and 9 boys while there are 13 girls and 11 boys in the control group.

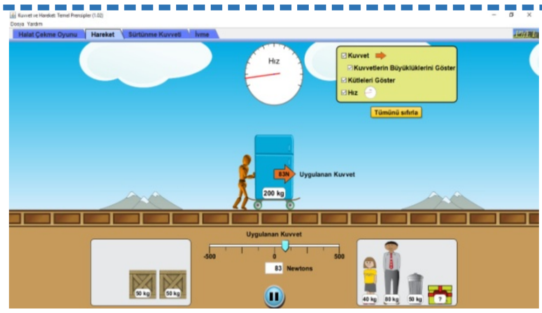
Application Process

Before the study, students are informed about that the course will be conducted within an academic study considering ethical principles. In addition, it is declared that collected data will not be shared anywhere. In course periods in which study activities are carried out, students are free to attend lessons. As a result of a decision taken by parent-teacher association, taking photos are not allowed. Therefore, students are informed about that no visual will be used in the study, and it is not really used.

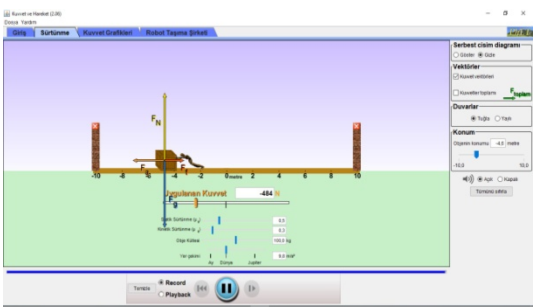
In both groups, lessons are taught by the subject teacher in classroom in accordance with daily plans prepared according to constructivist approach. In the experimental group where the research is conducted, the course is conducted in accordance with 5E model prepared according to constructivist approach during four week application period, and simulations are used in explore step. In addition, in the control group, laboratory experiments are used in explore step. Interactive simulations used in experimental group include setups consisting of experiments such as force calculation, force friction effect on movement, resultant force, balanced and unbalanced forces effect on object movement. Screenshots regarding PhET (2018) interactive simulations are shown in Figure 3.



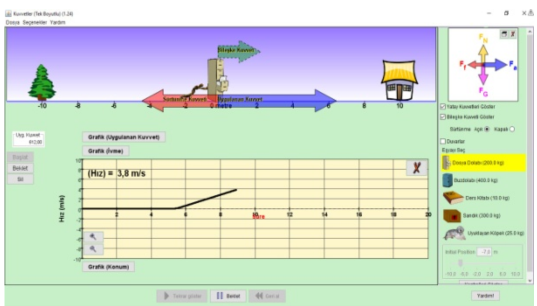
Net Force- Balanced/Unbalanced Force Simulation



Movement- Speed Simulation



Friction Simulation



Resultant Force- Speed Simulation

FIGURE 3. *Screenshots regarding simulations*

While simulations that are selected relevantly to the content of the unit and that present friction force effect on movement, resultant force, and balanced and unbalanced forces effect on object movement are used for experimental group students, experimental setups about the same subjects, which are relevant to the content of the unit, are used for control group students.

In the process, for the experimental group, teacher conducts the course in accordance with course curriculum. Then, the teacher introduces simulations, demonstrates how simulations are used and how results are evaluated by personally applying simulations to whole class, helps groups be formed homogenously, and support student so that they can do proper works during application period. For the use of simulations, the class is divided into seven groups that consist of four students, and each group presents simulations on smart board and discusses results of simulations. In another stage, groups present their findings one to another and compare results. Thus, application process is concluded.

For control group, teacher conducts the course according to daily plan. Then, after subjects are taught, and relevant concepts are introduced, experiment setups about subjects are prepared by the teacher, and students are divided into homogenous groups. The teacher helps students do experiments in line with the purpose of experiment objectives. For doing experiments, the class is divided into seven groups, and each group does relevant experiments and discusses their results. In another stage, groups present their findings one to another and compare results. Thus, application process is concluded.

Data Collection Tool

Before the study, a science achievement test that can assess achievements of 6^{th} Grade Force and Movement Unit is developed for experimental and control group students, and this test is applied to both groups as pre-test and post-test. Science achievement test consists of 20 multiple-choice questions which have been developed to assess achievements of 6th Grade Force and Movement Unit. In choosing test items, an expert opinion is taken, and opinions of science teachers on it are asked. A table of specifications that has formed according to achievements ratio as a result of achieved knowledge is added to the test. To determine compatibility of test items with student's levels and achievement objectives of the unit, opinion of two science teacher is taken. In test development stage, 25 questions are developed and applied to 6^{th} grade students consisting of 100 participants in Yakutiye, one of central districts of Erzurum, in the second semester of 2016/2017 academic year. As a result of this application, because two test items are below 0.20 item discrimination index, they are eliminated. Item discrimination indices of other questions are above 0.40. Hence, no changes are made on them but, considering table of specifications that has been prepared according to achievement objectives, test is arranged with 20 questions. Also, an expert opinion is taken for the validity of test. In conclusion, final version of test is obtained. As a result of pilot application for validity, Cronbach alpha coefficient is calculated. Cronbach alpha coefficient of academic achievement test is found 0.84. Validity and reliability studies in preparation and application process of academic achievement test are completed. This process is finalized with compliance with ethical principles.

Data Analysis

For the analysis of data, firstly, assumptions of analysis are tested. These assumptions are normal distribution, variance homogeneity, and minimum evenly spaced assessment instrument (Pallant, 2017). It is found out that data are normally distributed. Levene statistic test is carried out to test homogeneity of group variances, and obtained results show that group variances are homogenous (p>,05.).2x2 ANOVA mixed test is employed to test if there is a difference between pre-test - post-test achievement scores in experimental and control group students. The paired sample t-test is employed to compare pre-test means and post-test means of experimental and control group students.

Validity and Reliability

To eliminate risks regarding validity and reliability, measures set out by Mcmillan and Schumacher (2014) are taken. A pilot application is conducted for validity, and reliability coefficient of assessment instrument is calculated. Cronbach alpha coefficient of academic achievement test consisted of 20 multiple-choice questions and applied as pre-test and post-test is calculated as 0.84. Application is planned to last for four weeks in order to prevent elements affecting negatively validity, and necessary measures are taken to prevent maturation and subject loss. The course is conducted by the same teacher in both groups. A pre-test is applied for the purpose of determining if there is a difference between prior knowledge of groups or not so that groups prior knowledge will not affect study results, and as a result of this test, it is found out that groups are identical (p>,05). By taking measures against threatening elements, validity and reliability try to be ensured.

RESULTS

Comparison of Academic Achievement Pre-test and Post-test Scores of Control Group

In the control group for which interactive simulations are not used, the course is conducted according to 5E model which is arranged in accordance with National Education Ministry Curriculum and constructivist approach and, in the explore step, laboratory experiments are used. In order to determine if there is a difference between pre-test scores and post-test scores of control group students or not, the paired sample t-test is conducted. Obtained results are presented in Table 1.

Table 1. *The difference between pre-test score mean and post-test score mean of control group students*

Variable	N	$\overline{X}$	SS	*t*	sd	*p*
Pre-test Score	24	37,29	8,47	13,19	23	*,00*
Post-test Score	24	69,79	13,40			

When Table 1 is analyzed, according to the paired sample t-test results, it is found out that there is a statistically significant difference between pre-test (M= 37,29, SS= 8,47) scores and post-test (M= 69,79, SS= 13,40) scores in favor of the post-test [$t_{(23)}$=13,19, p<,05]. According to obtained results, laboratory experiments have contributed to increase the academic achievement of students.

Comparison of Academic Achievement Pre-test and Post-test Scores of Experimental Group

In order to determine whether there is a difference between pre-test scores and post-test scores of experimental group students or not, the paired sample t-test is conducted. Obtained results are presented in Table 2.

Tablo 2. *The difference between pre-test score mean and post-test score mean of experimental group students*

Variable	N	$\overline{X}$	SS	*t*	sd	*p*
Pre-test score	28	36,43	10,31	22,94	27	*,00*
Post-test score	28	77,32	12,38			

When Table 2 is analyzed, according to the paired sample t-test results, it is found out that there is a statistically significant difference between pre-test (M= 36,43, SS= 10,31) scores and post-test (M= 77,32, SS= 12,38) scores in favor of the post-test [$t_{(27)}=22{,}94$, $p<{,}05$]. According to obtained results, interactive simulations have contributed to increase the academic achievement of students.

Comparison of Academic Achievement Scores of Experimental Group and Academic Achievement Scores of Control Group

To determine which group has a better academic achievement improvement and whether there is a difference between pre-test and post-test scores of experimental and control group students or not, 2x2 mixed ANOVA test is employed. Descriptive findings regarding achievement scores which belong to different measurement times of experimental and control groups are presented in Table 3.

Table 3. *Descriptive findings regarding achievement scores which belong to different measurement times of experimental and control groups*

Variable	Group	n	$\overline{X}$	SS
Pre-test	Experimental Group	28	36,43	12,39
	Control Group	24	37,29	8,45
Post-test	Experimental Group	28	77,32	10,31
	Control Group	24	69,79	13,40

When Table 3 is analyzed, while mean of experimental group students' pre-test score is 36.43, this score rises to 77.32 in post-test score. Mean of control group students' pre-test score is 37,29 and mean of their post-test score is 69.79. These results show that the increase in experimental group is higher than in control group.

Mixed ANOVA results of pre-test and post-test academic achievement scores of experimental and control group students are presented in Table 4.

Table4. *Mixed ANOVA results of pre-test and post test academic achievement scores of experimental and control group students*

	KT	Sd	KO	*F*	p	*η2*
Inter- groups						
Group	287,179	1	287,179	1,448	*,234*	,028
Residual	9913,542	50	198,271			
In-groups						
Academic Achievement	34805,151	1	34805,151	605,025	***,000***	,924
Academic Achievement*Group	455,151	1	455,151	7,912	***,007***	,137
Residual	2876,339	50	57,527			

When Table 4 is analyzed , measurement time and group factors interacts and affect achivement scores ($F=7{,}912$, $p<.05$, $\eta 2=0{,}137$). The source of this interaction is illustrated in Figure 4.

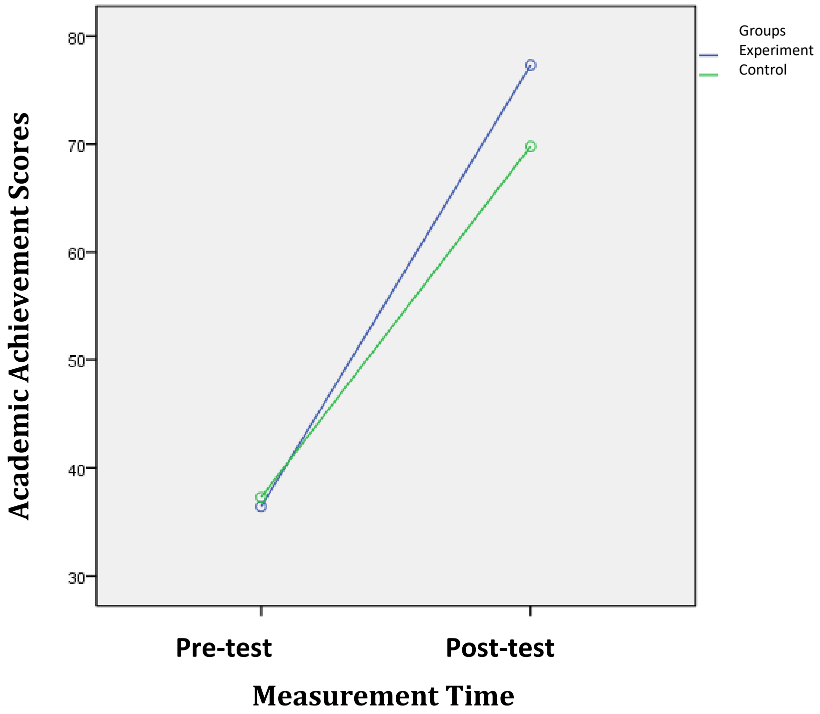


FIGURE 4.*The effect of use of interactive simulation on academic achievement scores of experiment and control groups*

While there is an increase of 40,89 points in the mean of pre-test and post-test academic achievement total score of experimental group, there is an increase of 32,5 points in the mean of academic achievement total score of control group. This finding reveals that interactive simulations are effective in increasing the academic achievement scores of experimental group. To sum up, it can be said that use of interactive simulation is more effective in increasing academic achievement when compared with use of laboratory experiments.

DISCUSSION and CONCLUSIONS

In the study, it is researched on the effect of interactive simulation use and laboratory experiment use on academic achievement of students in secondary school 6th Grade Science Course 'Force and Movement' Unit. In the explore step of 5E teaching method which is arranged according to constructivist approach, interactive simulations are used for experimental group, and laboratory experiments are used for control group. With this application, it is investigated that if there is a difference or not between experimental group students, who are taught using interactive simulations, and control group students, who are taught using laboratory experiments, with regard to their academic achievements. Before the application, it is seen that there is no statistically significant difference in pre-test scores of experimental and control groups. Relying on this result, it is concluded that readiness level of groups is similar. On the other hand, there is a rise in post-test scores of both group students when compared with their pre-test results. However, the rise in the mean of experimental group students from pre-test to post-test score is 40.80 while the rise of the mean of control group students is 32.50. This shows that the rise in the experimental group is more than the rise in control group.

To determine statistically in which group academic achievement improvement is better, pre-test and post-test achievement scores is tested with 2x2 mixed ANOVA, and, according to obtained results, it is found out that there is a statistically significant difference between students' post-test scores. That this difference is on behalf of experimental group students reveals that interactive simulations used in 6thGrade Force and Movement Unit in the explore step of 5E model and in the constructivist learning environment are more successful in increasing students' academic achievement than use of laboratory experiments. When the literature is reviewed, it is seen that there are very few studies which investigate the effect of interactive simulation use on academic achievement. (Bozkurt and Sarıkoç, 2014; Büyükkara, 2011; Daşdemir and Doymuş, 2016; Van der Meijand De Jong, 2006; Dinsmore and Zoellner, 2018; Dinçer and Güçlü, 2013; Dudding and Nottingham, 2018; Goris, Bilgi and Bayındır, 2014; Griffiths and Preston, 1992; Gülçiçek and Güneş, 2004; Hensberry, Moore, and Perkins, 2015); Küçük, 2011; Lawless et al., 2018; Mıdık and Kartal, 2010; Minaslı, 2009; Pekdağ, 2010; Sevgi, 2006; Sevgi and Uluışık, 2006; Şendir and Doğan, 2015; Teke, 2010; Winberg and Berg, 2007). In parallel with this study, other studies in the literature also observe that use of interactive simulation increases students' academic achievements. It can be thought that use of interactive simulations in the experimental group creates a novelty effect as it is a new situation for students. To prevent novelty effect, application process is not kept short; it is spread to four weeks. Students might have interest in interactive simulation for earlier weeks, but this interest is assumed to lessen in following weeks

Studies in the literature usually compare simulations with traditional teaching (narration, question-answer, presentation). This study differentiates from previous studies in that simulations used in the study and teaching and learning approach in the application are different. In addition, study group consists of students from different teaching level. Particularly, comparison of interactive simulations in 5E model which is arranged according to constructivist approach and laboratory experiments constitutes original part of the study. In the study by Finkelstein et al. (2005) on the subject of university students and electricity, when use of PhET interactive simulation is compared with laboratory equipment, it is seen that students who use interactive simulations achieve better results with regard to learning. In the study by Fan, Geelan and Gillies (2018) on the subject of mass and gravity, it is found that Easy Java Simulations (EJS) which belong to PhET improve conceptual learning of students in physics. And in this study, the effect of interactive simulations is dealt with together with the method. Since studies where both method and technology are used have importance, this study has a unique value.

As a result of the study, we emphasize on obtained findings and results as well as the offers below:

- In schools where there are no science laboratories, interactive simulations can be use in classrooms.
- Necessary instructions should be given beforehand so that students will use interactive simulations in line with their purpose.
- To benefit from interactive simulations at the highest level, results should be discussed in groups, and individual presentations should be ensured.
- With the generalization of use of simulations by conducting similar studies in different regions and in socio-economically different circles, equality of opportunity should be ensured.
- PhET interactive simulations which is used within scope of the study can be extended to different domains of science course (Physics, Chemistry, Biology, Earth Sciences, etc.), to different units of the course, and to classes in different levels.
- This study only focuses on academic achievement variable. Apart from this, other cognitive and affective variables in relation with achievement can be focused on. Also, it can be investigated on the effect of interactive simulations together with laboratory experiments on the development of students' psychomotor skills.
- Use of interactive simulation may cause a novelty effect on students. To lessen novelty effect, we recommend that main application take place at least 5 weeks (20 course periods) together with pilot application.

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