

Algodoo for Interactive Learning: Effects on Students' Achievement and Motivation Towards Science

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Aslı Saylan Kirmizigül

PhD, Faculty of Education, Erciyes University, Turkey

 <https://orcid.org/0000-0001-5678-8050>

Abstract

This study investigates the effects of the Algodoo interactive learning program on fifth-grade students' achievement in science and motivation towards science. The research was carried out in the fall semester of the 2020-2021 academic year with the participation of 110 fifth grade students. In the study, a pre-test-post-test control group quasi-experimental design was used. Within the scope of the study, the “Force Measurement and Friction” unit was taught during three weeks through Algodoo in the experimental group and traditional teaching in the control group. In the study, data were collected through an achievement test including multiple-choice questions and Science Motivation Scale. Both instruments were applied to the groups twice as pre and post-test. Independent samples t-test was conducted separately for the quantitative data obtained from each instrument. Moreover, a paired-samples t-test was conducted to compare the pre-and post-test scores of each instrument. According to the findings, Algodoo applications had positive effects on science achievement and motivation towards science.

Keywords: Algodoo, Simulation, Science, Physics, Achievement, Motivation

Introduction

Science lesson is still not adequately associated with daily life and remains abstract. Therefore, students see science as a lesson that is difficult to learn and independent of daily life. Therefore their levels of success, attitude and motivation towards this course have decreased (Uzun, 2013). A significant number of science teachers still prefer direct instruction and question-and-answer teaching methods more frequently than other methods (Atıla & Sözbilir, 2016). This situation brings some problems, such as the students' loss of interest in the course and a decrease in the rate of active participation in the lesson as the course becomes monotonous. Teachers are expected to provide students with appropriate learning experiences rather than transferring information directly. In this context, it is thought that the teaching methods and approaches used in the course will affect students' affective characteristics such as attitude, self-efficacy, motivation and anxiety towards the course, and these affective factors will affect their performance in the course and thus their academic achievement.

In the science curriculum, life skills (analytical thinking, decision making, creative thinking, entrepreneurship, communication, teamwork), and engineering and design skills came to the fore in addition to science process skills (Ministry of National Education [MoNE], 2018). To gain these skills at school and use them in their daily lives, they need to learn each subject correctly and effectively with methods and approaches appropriate to the subject. There are characteristics such as gender, intelligence, ability, epistemological belief, motivation and anxiety that distinguish individuals from each other. For the science curriculum to reach its goals, considering that not all students can learn with the same activities, practices that emphasise individual differences should be included in the courses (MoNE, 2018).

Students' learning styles should be taken into consideration in the selection of teaching approaches and planning instructional activities. The fact that students have different characteristics makes it necessary to support the teaching process with different activities.

Theoretical Framework

Simulation-based learning is a constructivist learning model that provides a simplified and simulated world or system experience of working (Brookfield, 2015). In simulation-based learning, first of all, a problem is put forward. Secondly, students are asked to make predictions for the solution to this problem. Based on these predictions, a simulation or model is created. Then, the created model is tested, and data is collected. Finally, an evaluation is made (Koparan & Kaleli Yilmaz, 2015).

Due to the simulations, students are allowed to concretise abstract concepts and learn interactively and meaningfully. Simulation software aims to provide students with knowledge and skills about the event and situation by modelling the risky, expensive, troublesome, time consuming or dangerous events and situations in a computer environment. Thus, students will do experiments that they cannot do with real materials in a home environment using these applications, so they will not fall behind in the class.

In this study, a 2D physics simulation software called Algodoo was preferred since it is flexible in terms of usage and provides suitable activities for the STEM approach. In this software, which has a simple user interface, users can create interactive experiments in a short time without the need to write code. Algodoo software allows simulation scenes to be created using simple drawing tools such as box, circle, gear, rope, chain and by changing different parameters such as density, mass, colour, size, velocity, gravity, friction and refractive index. Students test their hypotheses on a computer, smartboard or tablet, and they can get a graph of the motion over time. Thus, students apply the formulas and laws and connect real-life phenomena to science. Algodoo also makes it possible to save and share these created simulations. On the Algodoo forum, educators, parents and students who are using this program worldwide can discuss interesting topics,

express their opinions about the program, and use the simulations and lesson plans created by each other, either the same as the originals or by modifying them.

Motivation towards Science

Motivation is very important for students to achieve success and the biggest role in increasing students' motivation level falls on the teacher. For this reason, teachers should aim to keep students' motivation high while deciding which activities, teaching methods and approaches to include in their lessons.

Physics Achievement

Force is one of the most important concepts in physics that can help students understand the physical world around them. However, it is known that the force concept is not fully understood in middle school (Sadler & Sonnert, 2016). This situation causes students to carry their misconceptions and lack of knowledge that they have in the first years to the following years and to create misconceptions in related physics concepts (Wells, Henderson, Traxler, Miller, & Stewart, 2020). "Force Measurement and Friction" units are quite suitable to be taught through simulation-based instruction.

According to Piaget's theory of cognitive development, children between ages 7 and 11 are at the concrete operations stage. During this stage, children can think logically about concrete events rather than abstract ones. Considering that students in this period, which corresponds to 1st to 5th grades students, have difficulty in learning abstract concepts and events, the share of teaching technologies in concretising these events is undeniable. Therefore, it was decided to investigate the effects of teaching the "Force Measurement and Friction" unit using Algodoo on students' academic achievement in force and motivation towards science.

Method

In the study, which aims to examine the effects of interactive learning with Algodoo on 5th-grade students' academic achievement level in force concept and motivation towards science, control group pre-test and post-test quasi-experimental design was used (Fraenkel, Wallen, & Hyun, 2012).

Convenience sampling, one of the purposeful sampling methods, was used to determine the school. The study was conducted in the fall semester of the 2020-2021 academic year with 110 fifth grade students from two middle schools in Turkey. The experimental and control group included 54 and 56 students, respectively.

Achievement test (AT) regarding “Measurement of Force and Friction”, including 30 multiple-choice items developed for 5th-grade students (Ozan & Ulucinar Sagir, 2019), was used in the study. Kuder-Richardson 20 reliability coefficient was calculated as 0.85.

Students’ Motivation Toward Science Learning Questionnaire (SMTSLQ), which is a 35-item five-point Likert scale developed for middle school students (Tuan, Chin, & Shieh, 2005), and adapted to Turkish (Yilmaz & Huyuguzel Cavas, 2007), was used in the research. The Turkish form of the scale has 33 items. The scale consists of six sub-dimensions: (1) Self-efficacy, (2) active learning strategies, (3) science learning value, (4) performance goal, (5) achievement goal, and (6) learning environment stimulation.

Before the implementation process, the necessary permissions for intervention were obtained from the MoNE and the middle schools. All participants were informed about the research aim and their right to leave the research at any time. In the research, the consent form that included detailed information about the voluntary and confidential nature of participation was signed by the participants and their parents. Therefore, the principle of voluntary participation was taken into consideration and students’ identities were kept confidential.

The implementation and data collection were both carried out online through live online classes via the Zoom platform. All four classes were taught by the same teacher, who has 15 years of professional experience. In the control group, the course notes were prepared by the teacher by using textbooks and various subsidiary sources within

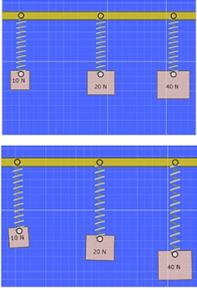
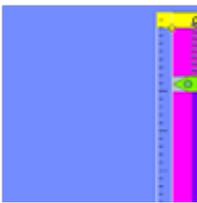
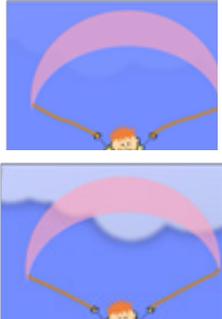
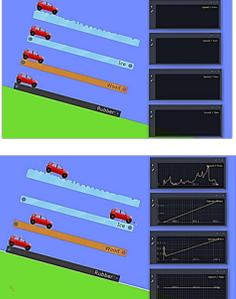
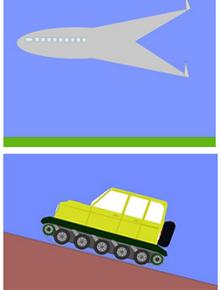
the framework of the process typically preferred in science courses. These notes were presented to the students for three weeks over 12 lesson hours through online synchronous live instruction using basic instructional technologies such as presentation and visual materials.

Before the implementation, the teacher was given training on Algodoo software and the simulation-based activities developed by the researcher. Then, students were informed about the use of the software by the teacher for two-course hours. Algodoo was downloaded by all students to their computers.

In the Turkish science curriculum, the 5th grade “Force Measurement and Friction” unit consists of two parts: “Measurement of the Force” and “Friction Force”. The first part includes two, and the second part includes three learning objectives. For the experimental group, lesson plans were prepared based on the curriculum and science textbook (see Table 1). All of the teaching practices were carried out through online synchronous live instruction. Throughout the process, the teacher only guided the students and tried to help them to construct their knowledge. She made efforts to keep the students’ curiosity alive and enable them to access information by questioning. Lessons are taught by using the 7E learning model and the engineering-design process. The activities in the textbook were adapted to the Algodoo activities to be carried out using the computer.

During the implementation, lessons were recorded with the permission of the teacher, students and parents. Adhering to the textbook, the course contents were mentioned equally in each group. The assessment and evaluation activities applied at the end of each lesson were determined jointly for all groups. Moreover, it was stated that only the relevant teaching approach should be used for each course and no other approaches should be used in any way. In this way, it was tried to prevent the implementation from posing a threat to the internal validity of this study.

Table 1: The sample activities paired with learning objectives in the science curriculum

Sample activity	Explanation	Learning objectives
	<p>The working principle of the dynamometer is explained practically.</p> <p>By testing different forces on dynamometer, students discovered the relationship between force and the extension of the spring.</p>	<p>Measures the magnitude of the force with a dynamometer.</p> <p>Newton (N) is used as the unit of force</p>
	<p>Students worked in groups of 3-4 people and designed a dynamometer using simple virtual tools such as spring.</p>	<p>Designs a dynamometer model using simple tools.</p>
	<p>Students designed simulations regarding the examples of friction force from daily life. They discussed what would happen if the current practices were different.</p>	<p>Gives examples of friction force from daily life.</p>
	<p>Students discovered the effect of friction force on motion on different surfaces such as ice, wood and rubber, and rough and slippery surfaces.</p> <p>For each environment, a velocity-time graph was automatically generated by Algodoo.</p>	<p>Discovers the effect of friction force on motion in various environments by experimenting.</p> <p>Experiments are carried out on the effect of friction force on movement on rough and slippery surfaces.</p>
	<p>Students worked in groups of 3-4 people and generated new ideas to increase or decrease friction in daily life. They mostly designed different vehicles such as plane, rocket and off-road vehicle etc.</p>	<p>Generates new ideas to increase or decrease friction in daily life.</p>

Findings

Findings Regarding Students' Motivation Toward Science Learning

Independent samples t-test was performed to determine whether there is a significant difference between the SMTSLQ pre-test scores of the experimental and control groups. The results of the analysis revealed that no statistically significant difference was found between the SMTSLQ pre-test scores of experimental (M=98.96, SD=4.220) and control groups (M=98.02, SD=4.684).

Independent samples t-test was conducted to compare the two groups' SMTSLQ post-test scores. Results revealed a significant difference between the SMTSLQ post-test scores of the groups ($p < .05$). Accordingly, the experimental group (M=142.64, SD=5.602) surpassed the control group (M=100.08, SD=7.184) in terms of average science motivation level. To test whether there is a significant difference between the SMTSLQ scores of the experimental and control groups before and after the application, the paired samples t-test was applied to the pre and post-test results of the groups.

Table 2: Paired samples t-test results for the groups' SMTSLQ pre-test and post-test scores

Group	Test	N	M	SD	T	p
Exp.	pre-test	54	98.96	4.220	-1.688	.000*
	post-test	54	142.64	5.602		
Control	pre-test	56	98.02	4.684	-2.844	.085
	post-test	56	100.08	7.184		

As seen in Table 2, as a result of the paired samples t-test, the SMTSLQ post-test score for the experimental group was significantly higher than the SMTSLQ pre-test score ($p < .05$). On the other hand, no significant difference was found between the control group students' SMTSLQ pre and post-test scores.

Findings Regarding Students' Science Achievement

Independent samples t-test was performed to determine whether there is a significant difference between the AT pre-test scores of the experimental and control groups. The results revealed that no significant difference was found between AT pre-

test scores of experimental (M=7.88, SD=8.120) and control groups (M=8.08, SD=8.868).

Independent samples t-test was conducted to compare the two groups' AT post-test scores. Results revealed that a significant difference was found between AT post-test scores of the groups in favour of the experimental group (M=22.68, SD=4.524; $p < .05$). To test whether there is a significant difference between the AT scores of the experimental and control groups before and after the application, the paired samples t-test was applied to the pre and post-test results of the groups (see Table 3).

Table 3: Paired samples t-test results for the groups' AT pre-test and post-test scores

Group	Test	N	M	SD	T	p
Exp.	pre-test	54	7.88	8.120	3.688	.000*
	post-test	54	22.68	4.524		
Control	pre-test	56	8.08	8.868	2.142	.000*
	post-test	56	14.26	6.162		

As seen in Table 3, the AT average post-test score for the experimental group was significantly higher than the AT pre-test score ($p < .05$). Similarly, a significant difference was found between the control group students' AT pre and post-test scores ($p < .05$).

Discussion, Conclusion and Suggestions

According to the results, they were using Algodoo in teaching force subjects positively affected students' motivation towards science. Although no study was reached that investigated the effects of Algodoo or any other simulation program on middle school students' science motivation, the findings of the studies revealed that middle school students, who use information and communication technologies even at home, have an increased motivation towards science (Inel Ekici, Kaya, & Mutlu, 2014). Therefore, one of the possible reasons why Algodoo activities affect students' motivation to learn science in this research is that technological devices such as computers, smartphones and tablets are frequently used by students outside of school while studying and doing homework. The active use of computers, which students frequently use in daily life, in an experimental group makes students feel

more comfortable. Furthermore, teaching the unit with simulations may have enabled the subject to be more concrete; and this situation may have facilitated the perception and retention of the subject and kept the students active by improving their concentration skills. Studies revealed that learning tools such as interactive activity, animation, video and simulation increase students' motivation and enable students to control their learning and actively participate in the lesson (Güven & Sulun, 2012; Kelly, Bradley, & Gratch, 2008).

One of the frequently used ways to increase motivation, which has an important role in the learning process, is to make the teaching process fun. Students feel more comfortable in an environment where they have fun, making learning easier (Say, 2016). The student who realises that s/he learns the subjects more easily sees that s/he can cope with the difficulties related to science, and so their motivation increases. In this context, it is thought that the inclusion of simulations that offer a fun environment is the main factor that increases students' motivation in the present study.

According to the findings, a significant difference was found between students' AT pre and post-test scores in both groups. The main reason for this situation is that the students learned the subject for the first time. For this reason, the post-test scores of the students whose pre-test scores were quite low increased significantly with the learning of the subject. Nevertheless, results revealed that a significant difference was found between AT post-test scores of the groups in favour of the experimental group. In other words, Algodoo activities are more effective in students' science achievement than textbook-based learning. It is known that simulation-based activities are precious for enhancing students' conceptual knowledge in science topics (Cayvaz, Akçay, & Kapıcı, 2020). Simulation-based learning is effective, especially in learning physics concepts (Rutten, van Joolingen, & van der Veen, 2012). Technology-supported learning environments allow the emergence of student creative engagement at the intersection of mathematics and physics (Euler & Gregoric, 2019). Students learn about physics, drawing on their existing mathematics knowledge easily using Algodoo.

Moreover, in simulation-based learning, feedback is given individually, not in a way that everyone can hear (Sevim, 2015). Algodoo applications often give feedback to the student without the need for a teacher, so the student does not worry about being criticised by the teacher or their friends if s/he makes a mistake. It is thought that this situation encourages students to participate more in the lesson. Undoubtedly, more participation in the lesson brings success with it.

In this study, the effects of Algodoo used in teaching the "Force Measurement and Friction" unit on students' achievement and motivation towards science were examined. To better determine the effects of Algodoo on these variables and make the findings more meaningful, different units related to the concepts of physics, chemistry and biology can be taught through Algodoo. Thus, it would be more meaningful to generalise the findings obtained to the science.

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Author Details

Ash Saylan Kirmizigül, PhD, Faculty of Education, Erciyes University, Turkey

Email ID: aslisaylan@erciyes.edu.tr