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AKADÉMIAI KIADÓ

Virtual laboratory use in science education with digitalization

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RESEARCH ARTICLE

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ABSTRACT

In science class, students learn by making and living information, enabling them to make sense of knowledge effectively and permanently and to associate it with daily life. Applied science courses make learning more qualified. While science teaching is carried out in application areas such as laboratories, virtual laboratories are used with the development of information technologies today. Virtual laboratories are auxiliary tools that make teaching and learning easier. Virtual environments offer the opportunity to experiment through simulation programs and modeling. In the study, it was examined which of the experiments in the PhET simulation software was suitable for the student gain in the science course curriculum according to the grade level. In the research, a qualitative research method was employed. Simulation programs on the web address "phet.colorado.edu" were examined by document analysis. According to the findings of the study, there are 80 interactive simulation applications in the PhET application that are suitable for student gains in the science curriculum prepared by the Ministry of National Education. In the PhET simulation software, it was determined that most physical experiments can be done according to the student gains in the science course curriculum, and the experiments in the field of biology are limited.

KEYWORDS

PhET simulation software, virtual laboratory, science education

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INTRODUCTION

The COVID-19 pandemic, which affected the whole world, has also affected Turkey in social, economic, and educational fields. Due to the COVID-19 pandemic, academic institutions around the world have had to move to learn environments by doing distance education. At the beginning of the global pandemic, a lot of effort was made to carry out training activities without interruption. While some countries have an easy transition to distance education, some countries have not. In these conditions, it is indicated that it is very difficult to develop and present original laboratory-based experiences, especially in experimental sciences (Bobowski, 2021). In the learning process of science and physics courses, it has become mandatory for teachers to use digital simulation software to achieve high-level gains in interactive and participatory environments. In this context, science and physics teachers should make use of information and communication technologies. They can benefit from traditional teaching tools as well as information and communication technologies such as simulation software. Information and communication technologies are needed more in cases where it is mandatory to switch to a distance education system in education system. Therefore, it is thought that digital simulation software will serve as a solution to the distance education system. Simulation software has unique features that are not found in many other learning tools such as interaction, animation, dynamic feedback, and exploration (Podolefsky, Perkins, & Adams, 2010).

Today, there are various simulation software developed to be publicly available for common network use, such as PhET Colorado, Crocodile, Scilab, Vascak. cz and The Physics Aviary. These simulation programs are designed to be flexible tools to support a wide range of application styles and teaching environments (Moore, Chamberlain, Parson, & Perkins, 2014). PhET is an interactive simulation program among simulation software. It is a non-profit project product that incorporates various simulation experiments. PhET is fun and research-based physical simulation software (Batuyong & Antonio, 2018; Correia, Koehler, Thompson, & Phye, 2019; Potane & Bayeta, 2017). Public access is also a source of education, making PhET important for the education system. McKagan (2008) has indicated in a study that simulations in PhET contain several basic features that will help students create mental models. According to Darrah, Humbert, and Finstein (2014), PhET simulation is a virtual physics laboratory. This virtual physics laboratory is a next-generation computerized resource that aims to combine research-based active learning capabilities.

PhET is a project developed by the University of Colorado Boulder in 2002. This project was founded by Nobel Prize laureate Carl Wiman (Finkelstein et al., 2005; Khatri, Henderson, Cole, & Froyd, 2013; Perkins et al., 2006; Potane & Bayeta, 2017; Wieman, Adam, Loeblein, & Perkins, 2010). The abbreviation, PhET, is derived from the initials of "Physics Education Technology". Although only the term physics is used in the word PhET, other disciplinary areas are included in it. PhET includes physics, chemistry, biology, earth science, and mathematics simulations. The animations contained in the content are prepared to demonstrate reality. While the PhET interactive simulations project was initially a local resource, over time it became an international resource. Thanks to this project, 88 interactive simulations have been developed since 2002. Simulation software is an access program developed to the level that students at the elementary, secondary, high school, and university levels can benefit from in the courses.

Studies have shown that interactive simulation programs such as PhET are widely used in science teaching in developed countries. Simulations are animated, interactive, and game-like

environments that students learn through exploration. They also seek to make visual and conceptual models more accessible to students by emphasizing the relationships between real-life events and basic sciences (Perkins et al., 2006). In this context, simulations provide dynamic access to multiple representations. They make the invisible visible, engaging, and fun for students and teachers, as well as provide safer and faster access to multiple attempts. In other words, simulations create an insight into the visible or unseen aspects of concepts and abstract representations (Batuyong & Antonio, 2018; Moore et al., 2014; Luliyarti & Prasetyo, 2020). In their study, Liu, Bano, Zowghi, and Kearney (2021) stated that PhET simulations help users visualize and understand the concepts taught. Sandoval (2011) found that students learn complex scientific concepts through fun in the natural environment of cyberspace. It has been emphasized that it has a feature that encourages even the most reluctant student to think at a high level. The researcher pointed out that the PhET simulation program is effective, interesting, and easy to use on the website. In addition, it is stated that simulations are used in many different teaching environments including courses, individual or group inquiry activities, homework, and laboratory (Wieman et al., 2010). Digital simulations are used as educational resources for observation, communication, analysis and to improve students' critical thinking skills (Nafidi, Alami, Zaki, El Batri, & Afkar, 2018).

When the studies in the literature in Turkey are examined, a study is found that explains the functionality of PhET simulation. In this research, PhET simulation is shown as an alternative to traditional laboratory applications in science and mathematics education. PhET simulation is classified in terms of various variables, and information about the application has been given (Ceylan & Saygıner, 2017). When other studies in the field of science are examined; when PhET simulation is used in computer-aided or simulation-assisted science teaching, it is seen that the effect of simulation on students' academic gains, the levels and attitudes of the learned information are determined (Aktaş, 2016; Dağdalan & Taş, 2017; İlyasoğlu & Aydın, 2014; Küçük, 2014; Şimşek, 2017; Ulukök, Çelik, & Sarı, 2013; Ünal & Şeker, 2020). In the vast majority of studies, it has been stated that simulation experiments are used in challenging situations such as easily showing abstract facts within the scope of a model, preventing dangerous situations, saving time, cost, and accessibility of experimental materials. In the studies, it is seen that PhET simulation is used and especially on the subjects in the "Electric" unit (Çoban & Akgün, 2018; İlyasoğlu & Aydın, 2014; Koç Ünal, & Şeker, 2020; Kolçak, Moğol, & Ünsal, 2014; Mırçık, 2018; Şimşek, 2017; Yilmaz & Eren, 2014). However, in the PhET simulation software, it was determined that there was no comprehensive study on which experiments could be performed in other units related to student gains according to the class level in the science course curriculum.

Simulation programs are an information and communication technology tool that is considered effective in case of experiments that cannot be carried out due to a lack of materials in the classroom environment or that are considered dangerous (Özer, Bilici, & Karahan, 2016; Pekdağ, 2010). They are effective programs in reviving abstract concepts or facts of science through a model and scientifically revealing their relationship with daily life. It is thought that the use of such simulation programs in the courses will make important contributions to science teaching. PhET simulation software was examined in detail in this research based on this idea. In addition, the experiments contained in this software and the situations that can be done in the experiments and the limited situations were explained. In emergency situations, where digital education is required and in formal education, it is thought that the PhET simulation program should be used more in basic sciences such as science, physics, and chemistry.

Conducting experiments in courses will help students gain high-level scientific process skills. It is foreseen that it will not be enough to transfer conceptual knowledge to students and to associate conceptual knowledge with daily life. At this point, the importance of helping students to make connections between real-life phenomena and basic sciences is revealed through experiments. However, experiments may not always be carried out in a laboratory or classroom environment. For this reason, it is suggested that teachers be informed about the content of the PhET simulation software and the activities that can be done in practice, especially at the elementary and secondary levels of the education system in Turkey. It is necessary to raise awareness about simulation programs to use as alternatives for experiments that cannot always be done in the laboratory in science courses and to inform students that it is a source of education that is open to everyone. In this context, in the study, the aim is to examine the experiments included in the PhET simulation software according to the grade level and student gains in the science course at the secondary level. For this purpose, the following problem situations have been determined.

- According to the grade levels in the science course curriculum, which experiments match the courses included in the PhET simulation software?
- Which discipline is most associated with experiments that match students' gains in the PhET simulation software?
- What are the conditions in which the experiments in the PhET simulation software are feasible and limited?

PhET simulation

PhET Colorado interactive simulation application has many language cycles according to primary, secondary and university level, as well as Turkish translation. In order to access the Program in Turkish, it is enough to write 'PhET Physics' in the search engine. Access to the experiments in the application is free. The platforms on which the experiments will be run are indicated by the icon. For example, some experiments can be run directly with an Internet browser that supports HTLM5, while platforms such as Java via CheerpJ, Java and Flash must be installed on the user's computer to run some experiments. It is stated that some of these platforms are needed together in order for some experiments to work smoothly. When the platforms specified on the experiment are selected, the experiment becomes interactively viable.

In order for the experiment to run in the PhET simulation application, the following operations must be performed in order. First, it is necessary to choose which discipline area and which subject to experiment on. Then, after the grade level and the platform specified for the study of the experiments are selected, the experimental mechanism becomes actively operational. As Fig. 1 shows, the subject, grade level, and compatibility options are subordinated in the PhET simulation software.

All experimental simulations in PhET application can be accessed online and offline. After the test simulations are downloaded to the computer, they work through the PhET web address. PhET app is a mobile application that can be run on PC, tablet, smart board and smartphones. According to Bozkurt (2015), mobile technologies have changed the way of learning. In this context, mobile learning is emerging as an effective learning model, creating flexible learning opportunities everywhere at any time. Mobile learning enables uninterrupted learning.

Today, it is possible to make learning more effective and enjoyable by using interactive applications in digital environment in science courses by using information technologies to

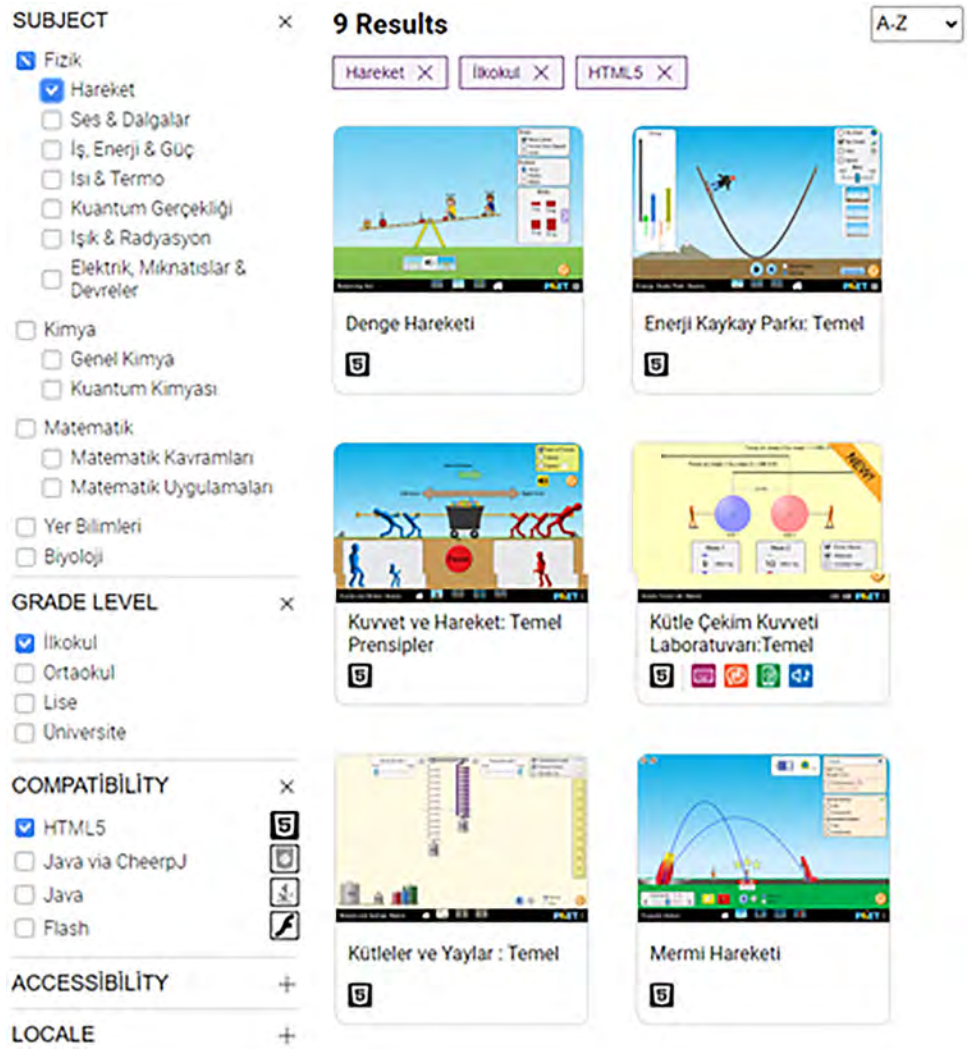

Fig. 1. In PhET interactive simulation, the subject, grade level, and program software language display of compliance

create effective learning environments. Tekdal (2002) states that simulation applications are one of the learning methods in which learners can change parameters and actively take part in the learning process. Simulation applications can be used not only to replace experiments that cannot be performed for some reason in daily life, but also to create effective learning environments by using them in place of experiments that cannot be performed in extraordinary situations. PhET simulation applications also allow students to independently design experimental devices. In this context, thanks to simulation applications, students perform learning by exploring as if they were conducting experiments in a similar way to the real thing.

Method

Since technology is an important tool in structuring information, it is important to include interactive applications in science education. The experiments included in the PhET application, a "simulation" study aimed at improving the applicability of open access programs, were examined. Document analysis method from qualitative research methods was used in the study. In qualitative research, document analysis is used for the purpose of making sense, to create an understanding of the relevant subject, to examine and interpret the data to develop empirical information (Corbin & Strauss, 2008). According to Wach and Ward (2013), document analysis is a data collection tool used to meticulously and systematically analyze the content of written documents. According to Yıldırım and Şimşek (2016), the document review covers the analysis of written materials containing information about the facts or facts intended to be investigated. Types of documents that can be used as data sources in studies include textbooks, manuals, books and brochures, diaries, magazines, program registrations, newspapers, official documents related to education and curriculum guidelines (Labuschagne, 2003; Yıldırım & Şimşek, 2016). Websites, blogs and social media can be used to obtain qualitative data on the Internet. PhET simulation software is an enterprise document according to Corbetta's (2003) classification, as it is a project product developed by the University of Colorado.

Data collection tool

All experiments in PhET simulation software were analyzed by examining the web address "phet.colorado.edu". In the application on the web address, it was determined that there were 61 simulation experiments related to physics, 26 related to chemistry, 21 related to earth science and 10 related to biology for secondary school level. Since the experiments common in different disciplines are not separated, the number is seen as high. In total, there are a total of 80 simulation experiments that can be used in physics, chemistry, earth science and biology at the secondary school level.

It has been determined which of the experiments in PhET simulation application coincide with the student gains related to the subjects in each unit in the Science course curriculum for the fifth, sixth, seventh and eighth grades in secondary education (Ministry of National Education, 2018).

According to the main objectives of the Turkish Education System, we need to educate students in such a way that they have knowledge, skills and behaviors integrated with our values and activities. Therefore, it is important for us to give students skills such as learning to learn, basic competence in science or technology, and digital competence. In this context, it is necessary to provide these basic skills to students at all levels by providing greater use of national or international public networks through the Internet.

Data analysis

The descriptive analysis method was used in data analysis. Data obtained in descriptive analysis the method is arranged and interpreted according to predetermined themes (Yıldırım & Şimşek, 2016). In this context, "PhET review form" developed by the researcher was used to analyze the simulation experiments in PhET application in detail (Appendix 1). After the simulation experiments on the web address "phet.colorado.edu" were examined in accordance with the

purpose of the research, the topics to be discussed in the PhET review form were determined. After a draft was created in the preparation of this form, it was checked by a faculty member working in field education, and the final form was finalized after the necessary arrangements. In this form used as a data collection tool, the headings are "class", "unit name", "subject name", "discipline area in PhET application" and "content name of PhET application" are organized into categories. Thus, the data of the research were analyzed in accordance with the descriptive analysis.

Reliability of the data analysis

The reliability of descriptive analysis in qualitative research depends on the coding process. Within the scope of the study, coding reliability was looked at to determine how consistently the researcher coded the categories he organized. In the study, the consistency of the researcher himself was examined by coding twice by the researcher three weeks apart from which of the experiments included in the PhET simulation program were properly available.

In the study, the gains in the science course curriculum were analyzed by the encoder twice (three weeks apart) by coding which of the experiments included in the PhET simulation program could be used appropriately. To look at the consistency of the researcher in himself, the percentage of compliance was calculated to determine the reliability of coding. The percentage of fit was calculated using the formula developed by Miles and Huberman (1994) (Reliability = Consensus/[Consensus + disagreement]×100). Coding reliability was calculated as 0.94 using the percentage of compliance of the study. For this research, it can be said that coding reliability is provided at an acceptable level.

Findings

It is considered appropriate to use PhET simulation software to transform the technology and digital competencies within the perspective of the science course curriculum into gains in students. In the study, simulation experiments suitable for student gains for science courses were classified according to class levels.

I. CLASSIFICATION OF STUDENT ACHIEVEMENTS IN PhET SIMULATION SOFTWARE WITH EXPERIMENTS IN SCIENCE COURSE TEACHING PROGRAM ACCORDING TO GRADE LEVELS

A) PhET application according to the gains in a science course for the fifth grade of secondary education

Below, the classification of the student gains in the science course curriculum in Table 1 according to the unit, subject, discipline area in PhET application, and content name related to the fifth grades are given.

B) PhET application according to the gains in a science course for the sixth grade of secondary education

Below, the classification of the student gains in the science course curriculum in Table 2 according to the unit, subject, discipline area in PhET application, and content name related to the sixth grades are given.

Table 1. PhET application according to the gains in a science course for the fifth grade of secondary education

Grade	Unit Name	Subject Name	Discipline area in PhET application	Content name in PhET application
5	The Sun, Earth and Moon	Structure and Features of the Sun	-	-
		Structure and Features of the Moon	Geoscience	Moon landing
		Moon's Movements and Phases	-	-
		The Sun, Earth and Moon	Geoscience	Gravity and orbits
5	World of Living Things	Let's Get to Know the Living	Biology	Natural Selection
5	Measuring Force and Friction	Measurement of Force	Physics	Power
		Friction Force	Physics	Friction Force
5	Matter and Change	State Change of Substance	Physics	States of Matter: Basic Information
		Distinctive Properties of Matter	Physics	States of Matter: Basic Information
		Heat and Temperature		Energy Transformations - Introduction
		Affects Heat Agents		States of Matter: Basic Information Energy Transformations - Introduction
5	Spread of Light	Radiation of Light	Physics	Bending Light: Introduction
		Reflection of Light	Physics	Bending Light: Introduction
		Encounter of Light with Matter		-
		Full Shadow		-
5	Human and Environment	Biodiversity		-
		Human and Environmental Relationship	Biology	Greenhouse effect
		Destructive Natural Events		-
5	Electrical Circuits Elements	Representation of Circuit Elements with Symbols and Circuit Diagrams	Physics	Circuit setup tool: DC-Introduction
		Variables Affecting Lamp Brightness in a Simple Electrical Circuit	Physics	Circuit installation tool: DC - Experiment Circuit Structure Kit-DC-Virtual lab.

Table 2. PhET application according to the gains in a science course for the sixth grade of secondary education

Grade	Unit Name	Subject Name	Discipline area in PhET application	Content name in PhET application
6	Solar System and Eclipses	Solar System	Geoscience	Gravity and orbits
		Solar and Lunar Eclipses		Gravity and orbits
6	Systems in Our Body	Support and Movement System	Biology	-
		Digestive System		
		Circulatory system		
		Respiratory System		
		Urinary System		
6	Force and Movement	Resultant Force	Physics	Force and Movement: Basic Principles
				Rope pulling game
		Fixed Speed Motion		Force and Movement
6	Matter and Heat	Granual Structure of Matter	Physics	States of Matter: Basic Information
		Density	Chemistry	Density
		Matter and Heat	Physics	States of Matter: Basic Information
		Fuels	-	-
6	Sound and Properties	Dissemination of Sound	Physics	Sound and waves
		Sound Being Heard Differently in Different Environments		Sound and waves
		Speed of Sound		-
		The Interaction of Sound with Matter		-
6	Systems and Health in Our Bodies	Controller and Regulatory Systems	-	-
		Sensory Organs		-
		Health of Systems		-
6	Transmission of Electricity	Conductive and Insulating Substances	Physics	Circuit setup tool: DC-Introduction
		Electrical Resistance and Related Factors		Resistance of a wire

C) PhET application according to the gains in a science course for the seventh grade of secondary education

Below, the classification of the student gains in the science course curriculum in Table 3 according to the unit, subject, discipline area in PhET application, and content name related to the seventh grades are given.

D) PhET application according to the gains in a science course for the eighth grade of secondary education

Below, the classification of the student gains in the science course curriculum in Table 4 according to the unit, subject, discipline area in PhET application, and content name related to the eighth grades are given.

II. THE FIELD OF SCIENCE WITH WHICH THE EXPERIMENTS IN THE PhET SIMULATION SOFTWARE ARE RELATED ACCORDING TO STUDENTS' ACHIEVEMENTS

When the experiments in the PhET simulation program were analyzed according to the student gains in the science course curriculum, it was determined that the 21 experiments in the field of physics were most suitable for gains. In addition, 5 experiments in the field of earth science and 5 in biology were determined to be suitable for gains. In the field of chemistry, it is seen that at least 5 experiments are suitable for gains. Apart from this, it is seen that the PhET simulation program is also related to the field of Mathematics.

III. CONDITIONS IN WHICH THE EXPERIMENTS IN THE PhET SIMULATION PROGRAM ARE FEASIBLE AND LIMITED?

A) Subject Area Names where PhET Interactive Simulation Software Is Limited

It was determined that the experiments suitable for the gains related to the subjects in each unit according to the grade level in the science course curriculum were not in the PhET simulation software. In the PhET simulation software, each experiment has its limitations. It is necessary for teachers to examine the application before the lesson and to prepare for what they can and cannot do according to the gains of the course to prevent waste of time.

In PhET simulation software, there are no experiments on the subjects in some units in the science curriculum. These are topics such as "Systems and health in our body" and "Reproduction, growth, and development in living things" in the field of biology. In particular, it is thought that the presence of simulation applications can be effective for students to perform their learning by questioning the working principles of the systems in our bodies. In the "radiation of light" unit, it was determined that there was no application in the application of non-transparent substances and translucent substances when it came to the encounter of light with matter. While PhET contains various examples of transparent substances, it is noticeable that there are no transparent substances or translucent substances. Again, there is no simulation application related to the subject of "full shadow" in the same unit. There are not enough simulations in PhET application related to "the sun, earth, and moon" unit. It is also significant that there is no PhET simulation application in the "cells and divisions" unit on an issue that is considered important such as cells, mitosis, and meiosis. In addition, there is no test section on

Table 3. PhET application according to the gains in a science course for the seventh grade of secondary education

Grade	Unit Name	Subject Name	Discipline area in PhET application	Content name in PhET application
7	Solar System and Beyond	Space Exploration	Geoscience	Gravity and orbits
		Solar System Beyond: Celestial Bodies		Gravity and orbits
7	Cells and Divisions	Cell	Biology	-
		Mitosis		
		Meiosis		
7	Force and Energy	Mass and Weight Relationship	Physics	Rope pulling game
		Relationship between Power, Work and Energy		Force and Movement
		Energy Transformations		
7	Pure Matter and Mixtures	Granual Structure of Matter	Physics	States of Matter: Basic Information
		Pure Substances	Chemistry	Density
		Blends	Physics	States of Matter: Basic Information
		Separation of Mixtures	-	-
		Household Waste and Recycling	-	-
7	Interaction of Light with Matter	Absorbing of Light	Physics	Light and colors
		Mirrors		Geometric Optics
		Light Refraction and Lenses		Bending Light: Introduction
7	Reproduction, Growth and Development in Living Things	Reproduction, Growth and Development in Humans	-	-
		Reproduction, Growth and Development in Plants and Animals		
7	Electrical Circuits	How Bulbs Connect	Physics	Circuit setup tool: DC-Introduction
				Resistance of a wire

Table 4. PhET application as per the gains in a science course for the eighth grade of secondary education

Grade	Unit Name	Subject Name	Discipline area in PhET application	Content name in PhET application
8	Seasons and Climate	Formation of Seasons	Geoscience	Gravity and orbits
		Climate and Weather Movements		-
8	DNA and Genetic Code	DNA and Genetic Code	-	Natural Selection
		Heritage		
		Mutation and Modification		
		Adaptation (Environmental Adaptation)		
		Biotechnology		
8	Pressure	Pressure	Physics	Pressure
8	Matter and Industry	Periodic System	Chemistry	-
		Physical and Chemical Changes		-
		Chemical Reactions		Chemical reactions
		Acids and Bases		pH ruler: Basic
				pH scale
		Interaction of Matter with Heat		States of Matter: Basic information
		Chemical Industry in Turkey		-
8	Simple Machines	Simple Machines	-	-
8	Energy Transformations and Environmental Science	Food Chain and Energy Flow	Biology	Natural Selection
		Energy Transformations		-
		Substance Cycles and Environmental Problems	Physics	Greenhouse effect
		Sustainable Development		-
8	Electricity Loads and Electrical Energy	Electrical Charges and Electrification	Physics	Balloon and stagnant electricity
		Electrically Charged Objects		Balloon and stagnant electricity
		Transformation of Electrical Energy		Types of energy and transformations - Systems

the representation of the compound of forces of different directions in the simulation application related to the subject of "Resultant Force" in the "Force and Movement" unit. It can be stated that there is a limited situation showing the combination of forces in different directions in this regard.

B) Subject Areas that Can Be Applied in PhET Interactive Simulation Program

In PhET application, simulations that can be done by considering three different units are explained in detail. In the science course, simulation applications that can be used in order according to the gains for the "Force and Movement" unit in PhET application for sixth grades have been identified. In the sixth-grade science course curriculum, experiments to be carried out to teach the concepts given in gains "F.6.3.1.1. Able to indicate the direction, direction, and size of the force affecting an object by drawing it; F.6.3.1.2. Able to observe by experimenting with multiple forces that act on an object. The combination of forces in the same direction is emphasized; F.6.3.1.3. Able to compare balanced and unbalanced forces by observing the motion states of objects (Ministry of National Education, 2018)" are as follows.

In PhET simulation application, the experimental mechanism under the heading "Force and Movement: Basic Principles" can be used in the physics topic. This experiment includes simulation experiments titled "Rope pulling game", "Motion", "Friction force" and "Acceleration".

In the "Force and Movement" unit in the PhET simulation application, the simulation test sample is included in Fig. 2a for gains related to "characteristics of force (direction, direction, and magnitude)" related to the subject of "Compound force". The direction and size of the force affecting an object can be demonstrated by a simulation experiment titled "Motion" in accordance with the gains by vector representation. In the simulation experiment, there is the possibility to change the size of the force to activate a selected object. By increasing and reducing the size of the force to be applied, how the direction and size of the force change can be demonstrated in the experimental mechanism. Various objects of different sizes are also present in the simulation experiment. In the same way, it is possible to observe movement by changing the direction and size of the force we will apply to activate objects of different sizes.

In the "Force and Movement" unit in the PhET simulation application, the simulation test sample is included in Fig. 2b for gains related to "Multiple forces acting on an object" related to the subject of "Resultant force". As shown in Fig. 2b, rope pulling is a convenient simulation to show an object the combination of opposing forces acting in the same direction. In addition, when forces of different sizes are applied to an object in this experimental mechanism, students can observe the result that the object gains momentum and accelerates depending on the different size forces applied.

Another example of a PhET simulation application is "Transmission of Electricity" unit. In the PhET simulation application, there are experiments to be performed to realize the gains in "F. 6.7.1.1 Uses the electrical circuit it designed to classify substances according to the state of electrical transmission and F. 6.7.1.2. Describes examples of what the electrical conductivity and insulation characteristics of substances are used for in everyday life (Ministry of National Education, 2018)" for "conductive and insulating substances" subject for the sixth graders. In the PhET simulation application, the test equipment can be used under the subheading "Circuit installation tool - DC demonstration" in the physics topic, in the chapter "Electrical, magnets & circuits". In this experiment assembly, there are in sequence simulation experiments called

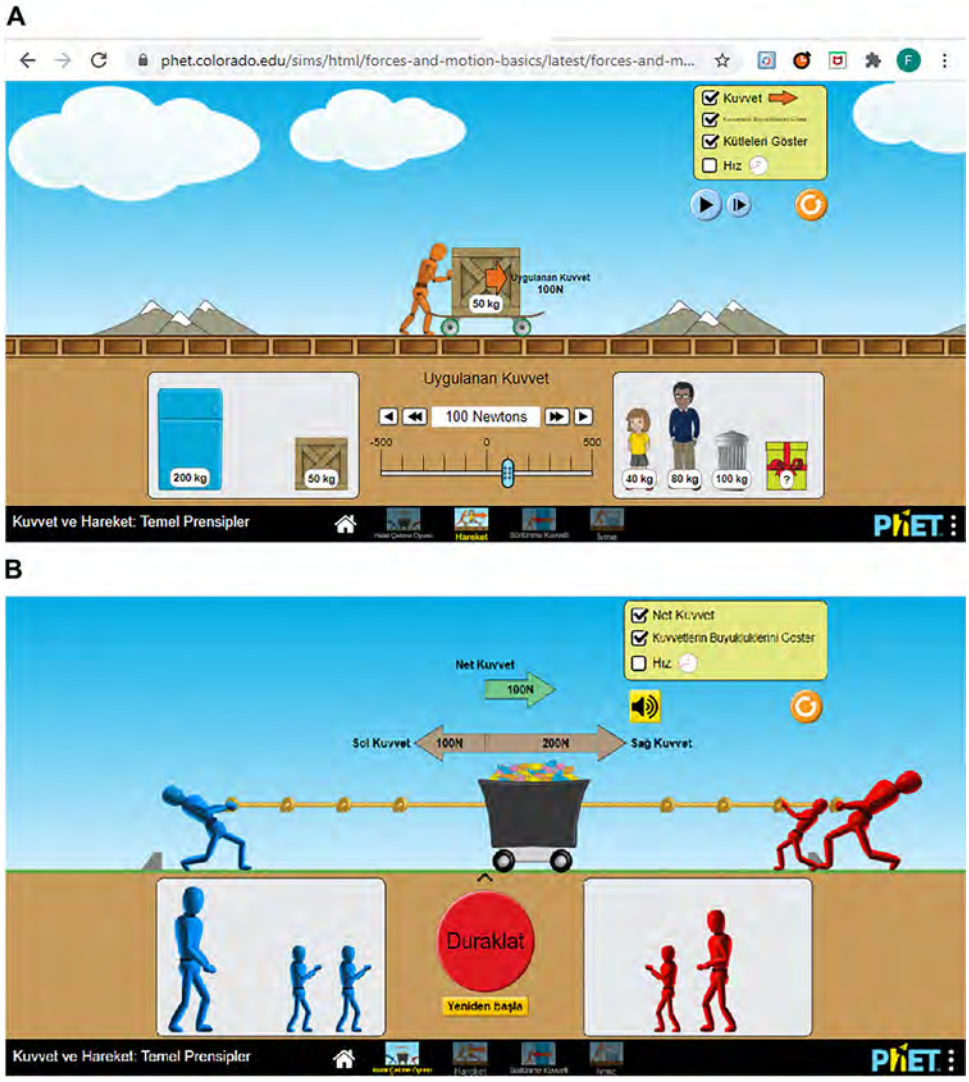

Fig. 2. a) Representation of the direction, direction, and magnitude of the force. b) Representation of forces and resultant forces acting in different directions in the same direction

"Introduction" and "Experiment". After establishing a simple electrical circuit related to the "conductive and insulative substances" in the PhET simulation application, the simulation experiment samples such as "paper money, paper-clip, metal money, eraser, pencil, human hands, dogs, fuse", where classification of various living and inanimate substances based on electricity transmission, are given in Fig. 3a and b.

Using an electrical circuit designed for "conductive and insulator" in electrical transmission, an experiment on the gain related to classification of substances in relation to the state of

electrical transmission can be carried out using a simulation example. In this experiment, students can also design simple electrical circuits. As seen in the simulation experiment in Fig. 3a and b, a simple electrical circuit will be established to determine which of pencil and eraser is conductive and which is insulated. Since simulation programs can be used by both teachers and students, they can actively take part in the courses.

As in Fig. 3a and b, when students classify live and inanimate substances according to the state of electricity transmission, they will be able to clarify their minds in what purpose the electrical conductivity and isolation characteristics of substances are used for in daily life.

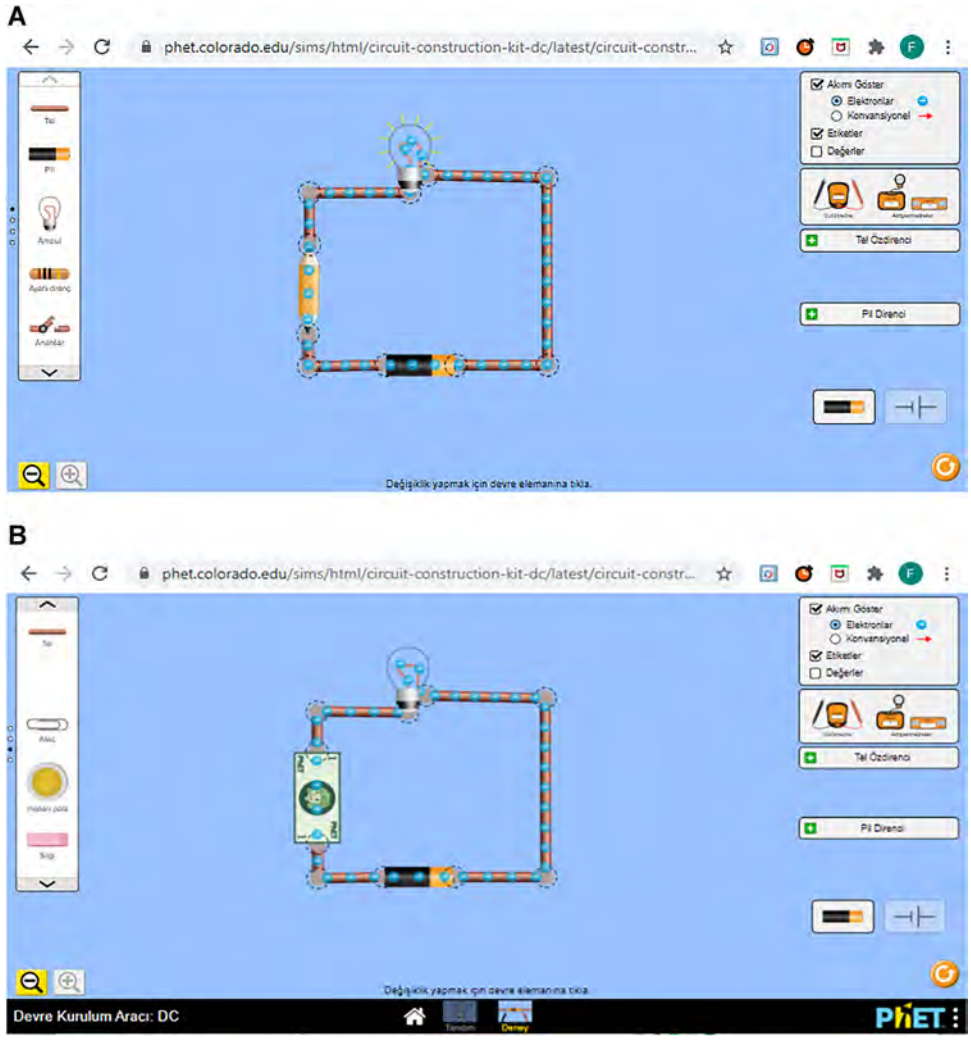

Fig. 3. a) Example of a simulation of conductive and insulator. b) Example of a simulation of conductive and insulator

Consequently, in the learning and teaching process, students are guided by their teachers, or they be able to design experiments themselves, embody scientific knowledge and perform permanent learning.

Last example of PhET simulation application for the 8 graders can be given from the "Electrical loads and Electrical Energy" unit. An experiment suitable for gain "F. 8.7.3.1 Student are able to give examples of applications where electrical energy is converted into heat, light and motion energy (Ministry of National Education, 2018)" included in Transformation of electrical energy" subject can be performed through simulation example.

When the "Energy types and Conversions" experiment is selected under the subheading "work energy and power" of physics in the PhET application, the experiment called "systems" should be run. In order to demonstrate how energy conversions are performed in this experiment, two energy sources must be identified. In addition, two energy converters (generator and solar panel) are available as options in the experimental equipment. We need to choose an energy converter that matches the first energy source we choose. The opposite is also possible, users can select the energy source that is suitable for the energy converter chosen. To see which energy the first energy source chosen turns into, another energy source must be selected on the other side of the energy converter. So it is possible to show the students the energy transformations that occur in the systems. Figure 4a-b-c provides a simulation example of applications where a selected type of energy becomes mechanical, heat, chemical, electrical and light energy.

As shown in Fig. 4a, the tap was selected as the first energy source, the generator as the energy converter and the water-filled beaker on a heater as the second source. The water flowing from the tap creates mechanical energy. Mechanical energy is converted into electrical energy through the generator (energy converter). Electrical energy will allow the water in the beaker to boil to transform into heat energy.

As shown in Fig. 4b, the first source of energy is solar, solar panel as energy converter, and bulb as the second source. The energy of light that the solar rays radiate around the environment is transformed into direct electrical energy in the solar panel. Electrical energy is seen to illuminate the bulb, illuminating the light around the bulb with light energy, but also energizing the surrounding area by heating up some bulbs.

As shown in Fig. 4c, the teapot is selected as the first source of energy, the generator as the energy converter and the propeller as the second source. The boiling water in the kettle will release both heat energy and mechanical energy. The heat and mechanical energy generated in the boiling water will become electrical energy through the generator.

In the PhET simulation application, it is possible to show the transformation of chemical energy into other types of energy (mechanical, heat, light and electricity). In the example shown in Fig. 5 below, a section of the simulation application is given to the conversion of chemical energy to mechanical energy. In the simulation application, when the student turns the bike's pedals, the chemical energy in his body will become mechanical energy. The mechanical energy generated will become electrical energy in the generator. Electrical energy will also turn the fan into a mechanical energy.

Discussion and conclusion

With the onset of an epidemic process that affects the world and Turkey, the need for digital applications has increased. In addition, the learning needs of the digital age must be organized digitally to meet the learning needs. In experimental and observation-based practical courses,

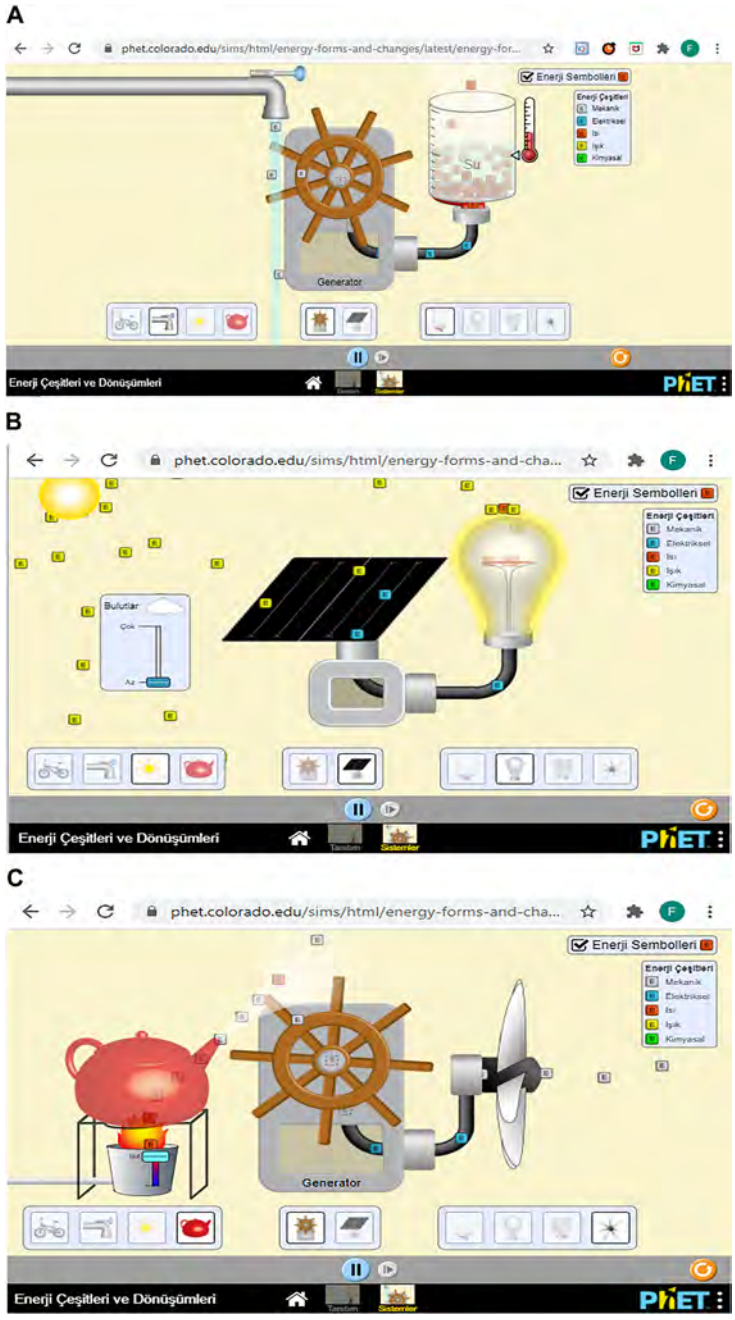

Fig. 4. a) Example of a simulation of the conversion of mechanical energy to heat energy. b) Example of a simulation of the conversion of light energy to heat and light energy. c) A simulation example of the conversion of heat and mechanical energy into mechanical energy

Fig. 5. Example of a simulation of chemical energy conversion to mechanical energy.

such as science education, there should be alternative solutions to ensure that students are not deprived of particularly experimental activities. The use of activities in science education has become more important as a result of the spread of context-based and interrogation-based teaching, according to current research in science education. It is known that laboratory use and flexible use of experimental materials in teaching environments have a lot of impact on conceptual understanding, especially for experimental activities. In this context, due to the introduction of digital applications in education applications, our teachers need to be aware of simulation practices in science education and to be informed about the application.

In this study, the content of the PhET interactive simulation program was examined secondary education according to the fifth, sixth, seventh, and eighth-grade levels. It was determined that the experiments in the content of the PhET simulation program matched with which student gains according to the grade levels. Subject areas where experiments in the PhET interactive simulation program are limited and feasible are given. It has been determined that the PhET simulation application is limited in the fields of biology such as "Systems and health in our body" and "Reproduction, growth, and development in living things". Similarly, in the light unit, it was determined that there are deficiencies in the applications related to the encounter of light with non-transparent materials and translucent materials. It is seen that the simulations about "The sun, earth, and moon" unit are not sufficient. In the unit "Cells and divisions"; It has been determined that there is no PhET simulation application for an important subject such as cell, mitosis, and meiosis. It has been determined that the PhET simulation application is sufficient in the field of physics at most. In the field of physics, it is thought that both mechanical and electrical experiments are quite sufficient in terms of content. It can be stated that the experiments in the other fields of chemistry, biology, and earth science are also sufficient for the gains.

I acknowledge that there are several limitations to my study. Firstly, although the document analysis research was comprehensive, it is still possible that some experiments or student gains were missed. Secondly, while determining the matches of student gains according to the grade

levels in the science curriculum with the experiments in the PhET simulation software, some experiments are still likely to be overlooked.

According to the findings obtained within the scope of the research, it has been determined that the student achievements according to the grade levels in the science course curriculum match the majority of the experiments in the PhET simulation program. In the PhET simulation program, it is seen that there are no experiments to meet the gains related to issues such as human and environment, systems in our body, cells and divisions, reproduction, growth and development in living things. It has been determined that the experiments that match the students' achievements in the PhET simulation program are mostly in the field of physics. The experiments included in the PhET simulation program have limitations in themselves. Since access to the PhET website is easy, each educator can later improve the structure and characteristics of the experiments included in the simulation program.

The first attempt on the development of the technological infrastructure for the use of information technologies in the education system in Turkey started with the Fatih project. The Education Information Network (EIN) has been developed by the Ministry of National Education to provide electronic content in addition to the training program within the scope of the Fatih project. Students are able to access course resources through the system in EBA. In EBA, mathematics, social information and science are rich in content. Although EBA has effective applications to contribute to science teaching, the only downside is that these applications are not interactive. In EBA, the experimental mechanisms related to science education do not allow the student to design independent experiments. The majority of applications in PhET are in the form that students can design the experimental system themselves.

Experiments using virtual experimental materials in the PhET simulation application are exactly the same as experiments using laboratory experimental materials. The simulation realizes the gain that should be given in the field with experiments. It also allows students to experience, interact and gain meaningful learning similar to real-life experiences. Performing experiments with simulation applications allows students to take an interest by observing the results of the experiment. It also helps them to see the relationships between the stages of the experiment and to make scientific comments. In this context, simulation applications should not be preferred only when hazardous experiments are not performed. It should be preferred because students will be actively involved in simulation applications. These practices will help students to better understand concepts and to carry out conceptual learning, as they will enable them to achieve the results of the experiment themselves (Liu et al., 2021; Moore et al., 2014). In addition, the PhET simulation application will make the course more enjoyable as it is both visual and interactive (Sandoval, 2011).

Since all activities are required in the remote training process, it is necessary to encourage both teachers and students to use alternative simulation applications. These simulation applications enhance different skills in students and encourage interest in science (Nafidi et al., 2018; Perkins et al., 2006). These applications also increase students' interest and motivation in the courses (Nafidi et al., 2018; Pinto et al., 2014). Therefore, teachers should demonstrate interactive simulations of experiments that may be alternative in science courses in a practical way to students, and then students should be encouraged to use these simulation applications independently. Students can also perform this application using mobile tools in non-school environments. The availability of the PhET app in mobile applications will help students learn independently of time and space. According to Bozkurt (2015), it facilitates individualized

learning. In addition, it is stated that it allows uninterrupted learning in learning environments such as formal education, informal education and non-formal.

RECOMMENDATIONS

In the course of science, simulation applications such as PhET are included in computer-assisted science. These studies are often used by teachers who are studying postgraduate. More teachers are expected to know and implement the PhET simulation application in the Ministry of Education. When PhET simulation application reaches more teachers and students in terms of use, it is thought to be positive feedback for science teaching. In courses where students are struggling, such as science, students will perform learning by living and exploring by doing. At the same time, students will have digital capabilities such as the evaluation of information and the development of their basic skills.

In science education, it is stated that PhET simulation application can be used in the field of physics, chemistry, biology and earth sciences and those that are suitable for gains. In this respect, the PhET simulation application is considered to be a content-rich application. Although only physics mentioned in application's name, it is advantageous to have simulations in chemistry, biology, geology and mathematics.

It is predicted that gifted students in the field of special education can contribute to the development of their thinking skills with the PhET simulation application. It is thought that the use of the PhET simulation application in instructional planning designed by instructors to improve the thinking skills of gifted students will be much more effective in these students' understanding and learning on their own.

In line with these results, the following recommendations for the PhET simulation application can be made.

- In science courses in education faculties, teacher candidates should be encouraged to use PhET and similar simulation programs in computer-assisted science education.
- After experiments have been conducted in the laboratory in formal training, experiments must also be supported with PhET simulation experiments.
- To use simulation applications such as PhET in science, physics, chemistry, biology and mathematics, more teachers should be informed through in-service training.
- Students should be directed to use the PhET simulation app on their mobile devices in non-school environments. In this context, it is thought that the study of the impact of mobile learning on academic achievements by using simulation applications in science education will contribute to the field of research and will be a new subject.
- Gifted students in the field of special education should be encouraged to use the PhET simulation application.

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Appendix 1

PhET simulation program review form

Grade	Unit Name	Subject Name	Discipline area in PhET application	Content name in PhET application