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The Effect of Digital Game-based Learning on Gifted and Talented Students' Learning of Hooke's Law: Try and See!

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ABSTRACT

In this study, in which the effect of developing an educational digital game on gifted and talented students' attitudes towards physics was investigated, a quasi-experimental design with pretest/posttest control group design was used. While the control group conducted the experiment using PhET: Interactive simulations programme, the experimental group conducted the experiment in an educational digital game-based learning environment developed by the researcher. The study group of the research consisted of 46 11th grade students selected voluntarily. 'Attitude towards physics scale' was used in the study. When the findings of the study were examined, it was found that there was no significant difference between the pretest scores of the experimental and control groups, while there was a significant difference between the posttest scores in favour of the experimental group as a result of independent t test analysis. As a result, in this study, it was revealed that it is important to intensify the interest of students who spend most of their free time playing games in front of the computer to educational games with activities related to the courses.

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1. Introduction

Gifted individuals are those who demonstrate high performance in one or more areas such as academic and intellectual ability, creativity, leadership, and visual arts (Gubbins et al., 2012). In Turkey, gifted students are identified during primary school through a two-stage intelligence test (WISC-R), and those who score 130 or above are classified as gifted (MoNE, 2018). In addition to their regular school education, these students receive at least six

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hours of supplementary education per week at Science and Art Centers (BİLSEM) (MoNE, 2020). BİLSEM institutions are state-run schools that provide advanced education for gifted individuals, allowing students to take courses in mathematics, science, and social sciences based on their interests. Physics is one of the fields in which gifted students show the most interest (Höffler et al., 2019).

Physics, one of the courses taught in the education process of students, makes students uneasy because most of its concepts are abstract and students have prejudices against this course (Yıldırım & Baran, 2021). For example, Hooke's law is a well-known topic in introductory physics courses and is often taught using loaded springs to illustrate the linear relationship between force and strain (Euler, 2008). Students still have difficulty in relating Hooke's law concepts to daily life, because so far students have studied physics that is less relevant to life (Hidayatulloh, 2020). Students still have difficulties in relating Hooke's law concepts to daily life, because so far students have studied physics that is less relevant to life (Hidayatulloh, 2020). Due to their high learning capacities, gifted and talented students may find the traditional school curriculum inadequate or uninteresting for them, which may lead to a loss of interest (Morris et al., 2021). Therefore, enriched content and appropriate learning environments are essential to improve their academic achievement, motivation, imagination, positive attitudes, and higher-order skills such as problem solving, critical thinking, and creativity (Sak, 2010). The main problem in this process is not whether students learn physics or not, but whether a teaching process that will enable them to learn effectively can be designed (Korsacılar & Çalışkan, 2015). The game teaching method, which will enable teaching abstract concepts by concretising them, is an effective teaching tool (Gençer & Karamustafaoğlu, 2014). Games can be used to reinforce and complement the knowledge to be taught in physics (Yıldırım & Baran, 2021). In order to ensure effective and permanent learning in physics, students should be offered a teaching process that includes new teaching methods, and among these methods, game-based instructional design should be included to help students embody the physics course content that they encounter in every aspect of their daily lives in the games they play (Yıldırım & Baran, 2021). Game-based learning, which refers to the use of digital games to enhance learning in formal education (Talamo et al., 2016), has been advocated in the last decade according to Fu et al. (2022). There are two orientations in game-based learning applications; one uses commercial video games for learning and the other uses custom designed games to help students learn (Fu et al., 2022). However, in general, commercial video games are designed for entertainment, while educational games are designed for learning in a specific knowledge domain and are normally used in the classroom (de Sousa et al., 2018). Many students may have a wealth of knowledge that can be demonstrated and utilised through appropriate tools such as digital games (Haladyna & Downing, 2004). Thanks to the adaptation of digital games to the educational process, students can learn in an enthusiastic and fun way, which leads to permanent learning (Yıldırım & Baran, 2021). According to some studies, digital educational games have a positive effect on learners and therefore should be used in physics education (Anderson & Barnett 2013; Croxton & Kortemeyer 2018; Nada et al. 2019). Many researchers have argued that digital games have the potential to help students learn (Young et al., 2012; Young & Slota, 2017) and recent meta-analyses have shown that digital games have positive effects under certain teaching conditions compared to non-game conditions (Clark et al., 2016; Wouters et al., 2013). However, most of the research on educational games has focussed on how game design relates to learning (Callies et al., 2017; Clark et al., 2016; Law & Chen, 2016; Sun et al., 2018; Young & Slota, 2017). There are many studies revealing the positive effects of educational games on learning (Budak et al. 2006; İnal et al. 2005; Karamustafaoğlu et al., 2018; Foster et al. 2006; Korkusuz 2012). Thanks to the adaptation of digital games to the educational process, students can learn with enthusiasm and fun, which leads to permanent learning (Yıldırım & Baran, 2021). In this respect, digital games can provide an excellent environment for learning (Hostetter 2002). By utilising the affordances of digital gaming traditions, educators can potentially increase engagement and promote deeper learning as students engage in recursive and critical games in which hypotheses about the game system are generated, plans and strategies are developed, observations are made, and ultimately hypotheses are adapted to the game (Cordova & Lepper 1996; Squire, 2006, 2008). Games also have the potential to support students to integrate their implicit conceptual knowledge with the knowledge taught (NRC 2011). According to Anderson & Barnett (2013), this is achieved through specific game design that allows students to make choices that affect the state of the simulated models. Complex scientific content represented through concrete, experienced, non-text-mediated representations, games and simulations can serve to engage reluctant students in science studies (Anderson & Barnett, 2013).

Hooke's law experiment, which is based on finding the spring constant, is an experiment that can be easily applied in laboratory courses at many different levels because it does not require complex and special experimental materials. Students encounter some problems during the Hooke's Law experiment (Çoramık & Özdemir, 2021). According to Çoramık & Özdemir (2021), one of the main problems is that students cannot accurately or precisely measure the amount of elongation of the spring using a ruler. For this reason, the measurements are repeated more than once and the average value is taken and the amount of elongation is recorded. For this reason, it should be planned to design a more entertaining process in the teaching of Hooke's law experiment for finding the spring constant, which is encountered with difficulties during its application in the literature, and to eliminate the application difficulties of the students. From this point of view, there was a need to develop a digital game for Hooke's law, which is the subject of physics. In this study, it is aimed to look at the effect of the digital game developed for teaching Hooke's law on students' attitudes towards physics. In line with this purpose, it was tried to find a solution to the following problem situation.

RQ: Is there a significant difference between the experimental and control groups in the attitudes of gifted and talented students towards physics before and after the application?

2. Method

2.1. Research Design

In this study, a quasi-experimental design (Campbell & Stanley, 1966) with pretest/posttest control group was used. While the experimental group carried out the experiment using the PhET: Interactive simulations programme, the control group carried out the experiment in a digital game-based learning environment developed by the researchers.

2.2. Study Group

The study group consisted of 46 (22 experimental group, 24 control group) 11th grade students studying in a high school located in the Eastern Black Sea Region of Turkey in the 2022-2023 academic year. All of the students participated in the study voluntarily. Since the students were admitted to this school through a central exam, it is known that their levels are the same.

2.3. Digital-based Game Development Process

In this study, a digital game was developed with Unity, a cross-platform game engine developed by Unity Technologies, which is used to develop video games and simulations for computers and mobile devices. The design of the game adopted the following elements that encourage student engagement in an educational game environment (Malone, 1980; Prensky, 2003): (a) rules, (b) clear but challenging objectives, (c) an event linked to student activity, (d) progressive levels of difficulty, (e) interactivity and a high degree of student control, (f) ambiguous outcomes, and (g) immediate and constructive feedback. Furthermore, in order to arouse curiosity and motivation, the game was intended to be neither too complex nor too simple for the students' existing knowledge (Malone, 1980). In the developed digital game, 'progressive difficulty levels' were not used to ensure that the learning environments of the experimental and control groups were equivalent. Violence and gender bias, traditional disadvantages of games, were avoided. (For example, the player character is not gender specific in order to appeal to both boys and girls and the student does not use any avatar in the game). However, the following practical limitations were also considered: (a) the game should be runnable on older computer hardware in school computer labs, (b) the game should be easy to learn, (c) the game should not be time-consuming as it is undertaken by a single person (student) with limited time. PHET: In the interactive simulation environment, spring constant was tried to be found with the help of weights. In the digital-based game environment, objects of various weights are placed on the spring tray and calculations are made on the electronic board. Here, students perform the experiment interactively as in the PHET environment. Table 1 shows the applications made during the five-week implementation process.

Table 1. Planning the application process

Time	Experimental Group	Control Group
Week 1	The students were informed about the application and the measurement tool was applied.	The students were informed about the application and the measurement tool was applied.
Week 2	Introducing the students to the way of playing and rules of the game developed on the Unity game development platform.	Informing students about PhET interactive simulation and introducing the platform
	Students are asked to play the educational digital game and record data in the process.	Students practice the PhET interactive simulation and in the process students are asked to record data.
Week 3	Drawing graphs using the recorded data (drawn on graph paper).	Drawing a graph using recorded data (performed digitally).
Week 4	Replaying the game to eliminate problematic data.	Re-implementation of the PhET interactive simulation to eliminate problematic data.
Week 5	After a general evaluation of the implementation, post-tests were administered.	After a general evaluation of the implementation, post-tests were administered.

2.4. Data Collection Tools

Physics attitude scale: The scale developed by Tekbıyık & Akdeniz (2010) consists of thirty-five-point Likert-type items. Factor analysis was conducted to reveal the evidence for the construct validity of the scale. In the factor analysis, the Kaiser-Meyer-Olkin (KMO) coefficient and Barlett's test were used to check whether the data were suitable for factor analysis. A KMO coefficient of at least 0.60 and a significant level of Barlett's test indicate that the data are suitable for factor analysis (Büyüköztürk, 2007; Kalaycı, 2005). In the study, KMO coefficient was calculated as 0.697 and Barlett's test value was calculated as 2310.112 ($p<0.001$). Accordingly, it can be said that the data are suitable for factor analysis. As a result of the analyses, it was determined that the scale had 4 factors named as importance, comprehension, need and interest. The Cronbach Alpha coefficients calculated for these factors are 0.83, 0.79, 0.74, 0.71 and 0.87 for the whole scale, respectively. In this study, the Cronbach Alpha coefficients calculated for the factors are 0.72, 0.81, 0.73, 0.75 and 0.74 for the whole scale, respectively.

2.4. Analysis of Data

The analyses were carried out in the SPSS 28 statistical package program based on a significance level of 0.05. Before proceeding with the data analysis, it was tested whether the data showed a normal distribution with the skewness kurtosis coefficient. In a normal data distribution, this value is expected to be between -1 and +1 (Hair et al., 2013). In the study, the skewness and kurtosis values were found to be -0.15 and 0.21, respectively. Therefore, an independent t-test was conducted to determine students' attitudes towards physics.

3. Results

The findings obtained as a result of the research are presented below.

3.1. Is there a significant difference between the experimental and control groups in the attitudes of gifted and talented students towards physics before and after the application?

According to Table 2, no statistically significant difference was found in the pretest attitude towards physics scores of the experimental and control groups before the application ($t_{0.05;44}$=-0.66). According to this result, it was seen that the experimental and control groups were equal to each other at the beginning.

Tablo 2. Experimental and control group pre-test post-test independent t-test results

Test	Group	N	Mean	Sd	t	df	p
Pre-test	Experiment	22	3.87	12.76	-0.66	44	0.51
	Control	24	3.96	13.69			
Post-test	Experiment	22	4.51	12.52	2.52	44	0.014*
	Control	24	4.13	17.46			

*p>0.05

Table 2 shows that there is a statistically significant difference between the posttest attitude scores of the students in the experimental and control groups in favour of the experimental group ($t_{0.05;44}$=2.52).

4. Discussions and Conclusion

According to the findings of the study, the attitudes towards physics of the gifted and talented students who participated in the digital-based game activity were statistically significant in favour of the experimental group. This finding is in parallel with the findings of Coşkun et al. (2012). When the literature is examined; digital games are increasingly used in the education process to facilitate teaching and learning (Hsu et al., 2015; Hsu et al., 2020; Sanchez-Mena et al., 2019; Talamo et al., 2016). Egenfeldt-Nielsen (2004) found that educational digital games positively increase students' attitudes towards their impact on the learning product and stated that educational digital games should be used in education. The benefits of digital games are listed as enabling students' hand-eye coordination, improving attention-gathering tactics, increasing mental rotation and mental integration skills, and developing visual intelligence (Smith, 2004). Well-planned digital games can provide rich, fun and interactive experiences that can encourage children's cognition, mental development, skill development, social interaction, physical activity and healthy attitudes (Lieberman et al., 2009).

Considering the reasons such as the fact that science and physics courses are among the courses with the lowest achievement, that there are many misconceptions in this field, and that students' attitudes and motivation towards these courses are lower than other courses; it is important to concentrate the interest of students who spend most of their free time playing games in front of the computer to educational games with activities related to the courses. It is thought that students' interest in games will positively affect their attitudes, motivation and achievement towards science and physics courses.

Gifted and talented students are often more motivated in environments that involve problem solving, exploration and challenge. Game-based learning can increase students' interest in physics by making physics topics fun and interactive. Gifted students often tend to be independent learners. Game-based learning environments allow them to progress at their own pace and explore different topics. This can help them develop a more positive attitude towards physics. In conclusion, digital game-based learning can be an effective method for developing positive attitudes towards physics courses. Especially for gifted and talented students, such learning environments can increase academic achievement and support motivation by providing an engaging and stimulating experience.

5. Suggestions

According to the results of the study, the digital game platform developed by the researchers had a positive effect on students' attitudes towards physics. This study, which was conducted with 11^{th} grade students, can be integrated and applied to different levels of education. The study can guide the development of different digital games and the measurement of different variables (academic achievement, motivation, etc.). In addition, researchers who will conduct research on such topics can enrich their research by taking student opinions. The study was limited to 11th grade students, Unity game platform, Hooke's law and a period of five weeks.

Declaration of Competing Interest and Ethics

The author declare that he has no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. This research study complies with research publishing ethics. The scientific and legal responsibility for manuscripts published in OPS Journal belongs to the author.

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