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Which training method is more effective in earthquake training: Digital game, drill, or traditional training?

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Abstract

One of the most important reasons for deaths and injuries caused by earthquakes is that society does not have sufficient knowledge of appropriate protective behaviors during an earthquake. The purpose of this study is to evaluate the effectiveness of different educational practices in providing primary school students with the knowledge of earthquake preparedness and protection from potential hazards of an earthquake. Considering the quasi-experimental research, the pretest–posttest control/comparison group design was used, and a total of 401 students from the fourth grade in four different schools constituted the sampling of the study. Within the study, three types of educational activities were applied: digital games evaluating smart learning environments, earthquake drills, and traditional education. Findings show that the most effective way to teach students what to do during an earthquake is the earthquake drill. This study also indicates that the design elements in the three-dimensional earthquake game developed in the scope of the research played an effective role in earthquake education. This study is of importance as it provides significant results on how to determine the most appropriate educational method for primary school students and how digital games can be used more effectively in the learning process.

Keywords: Earthquake education, Digital games, Game-based learning, Earthquake drill, Earthquake protective behaviour

Introduction

Turkey is one of the countries which are vulnerable to earthquakes because of its geographical structure (Soyluk & Harmankaya, 2012). For this reason, it is extremely important to take appropriate measures and raise awareness of society to reduce the hazards of a potential earthquake (Zhou et al., 2018). However, the preparation process for natural disasters has been negatively affected by people who think that natural disasters such as earthquakes are their destiny and punishment from God due to their sins (Adiyoso & Kanegae, 2012). Furthermore, being unprepared and the lack of knowledge about natural disasters leave people without a solution in case of a natural disaster (Baytiyeh & Naja, 2015; McClure et al., 2016). It is known that the role of education is highly important in creating social awareness and providing information for earthquake preparedness and protective measures (Hoffmann & Muttarak, 2017; Maio et al., 2017). It has been argued that earthquake education especially for children is an effective strategy to create social awareness and inform society about risks to safety (Izadkhah & Hosseini, 2007; Oda, 2016). In the South Asian earthquake in 2004, a 10-year-old British student who studied tsunami in geography recognized the signs of a tsunami, warned others, and helped the survival of 100 people on average. As can be seen, the importance of raising the awareness of children about natural disasters is vital (Altay, 2008).

Traditional methods, digital games evaluating smart learning environments (Agbo et al., 2021), drills, and printed materials such as brochures and posters, are intensely utilized in earthquake education for children (Izadkhah & Hosseini, 2007). In this regard, Clerveaux and Spence (2009) tried to educate children on natural disasters through the game technique. Relevant researchers have concluded that their design model developed yields successful results in increasing children's awareness. Haferkamp and Krämer (2010) have developed the *Dread ED Game* to provide successful crisis management during a natural disaster. The results show that the game process in a virtual environment can be beneficial during crisis management. Tanes and Cho (2013) have benefited from a digital game developed for earthquake preparedness and education on natural disasters. According to the results of the study applied to university students, it is concluded that the digital game accelerates the learning process of earthquake preparedness. Barreto (2014) has developed a game known as *Treme-Treme* to teach primary school students earthquake preparedness. Though it has been emphasized that the game motivates the students and increases their awareness of earthquake preparedness, it is concluded that there are some design deficiencies pedagogically. Chen (2015) has developed a digital earthquake game called *Defying Disaster* and stated that the developed game has contributed to the achievement of better results in learning about earthquake preparedness. However, Chen has emphasized that different research is needed because game scenes cannot fully reflect a real earthquake scene. Hilyard et al. (2011) utilized web technologies to help children with the process of disaster preparation. However, they found that web technologies are not available for students.

It has been emphasized that natural disaster drills are an important educational method in the determination of the strategies for earthquake preparedness, development of children's resistance to natural disasters, and the creation of awareness in the society (Hull, 2011; Johnson, Johnston, et al., 2014a, Johnson, Ronan, et al., 2014b; Mitchell, 2009). Furthermore, it has been argued that repetitive feedback provided for children's skills during the disaster drills helps to improve their self-confidence and resistance to natural disasters (Ronan & Johnston, 2005). However, some researchers state that there are some limitations of drills in earthquake education. For instance, it is stated that the school drills consist of repetitive educational activities instead of activities that provide the students with an opportunity to acquire practical skills and that this situation does not improve the learning process against new scenarios (Mayer, 2002; Lovreglio et al., 2018). In this regard, it is emphasized that poorly designed practices, which are not beneficial for the development of individuals' skills for giving appropriate reactions in case of a natural disaster, cannot help them during an earthquake (Gebbie et al., 2006). From a pedagogical point of view, it is thought that the drills are not an effective training method in earthquake education (Lovreglio et al., 2018).

Traditional methods, which include some printed materials such as books, journals, newspapers, and brochures, are also utilized in earthquake education (Bandrova et al., 2015; Parsizadeh & Ghafory-Ashtiany, 2010; Tanaka, 2005; Tekeli-Yesil et al., 2019). A teacher-centered approach is usually adopted in the traditional education process (Aydın, 2010). It is stated that the media materials such as brochures, posters, and written documents used together with the traditional methods are effective in earthquake education (Izadkhah & Hosseini, 2013; Mileti & Fitzpatrick, 1992; Tanaka, 2005). However, it is emphasized that the traditional methods are not effective in the learning process, education with books and other printed materials deprives students of interaction, they have limited features (Hake, 1998; Tekeli-Yesil et al., 2019) and cannot motivate students in disaster education (Tsai et al., 2015). Furthermore, it is stated that the traditional methods cannot be effective in the learning process of today's students called the digital generation (Presnky, 2010).

Considering these facts, it can be said that it is quite difficult to predict which educational method is more beneficial in terms of earthquake preparedness and get protective measures. Unfortunately, various methods and techniques have been used without considering their effectiveness and accuracy in many countries for creating awareness and educating children on natural disasters (Izadkhah & Heshmati, 2007). Furthermore, it is stated that the process of earthquake preparedness should be improved through different methods instead of a single activity (Tanaka, 2005). Izadkhah and Heshmati (2007) have informed kindergarten students about earthquakes through the use of six different educational methods and argued that the factor of entertainment is effective in the learning process and that the students who are taught through puppets are more successful in earthquake education. Soffer et al. (2010) inform the students, who are between 10 and 12 years old, about earthquakes through three different methods as drills, traditional education, and a combination of the two. In the relevant study, it was found that the traditional education method combined with the drills is more effective.

In the light of the studies in the literature, it is emphasized that the studies, which can determine the effectiveness of different educational methods, are highly limited (Becker et al., 2012; Johnson, Johnston, et al., 2014; Johnson, Ronan, et al., 2014; Ronan & Towers, 2014; Soffer et al., 2010; Tatebe & Mutch, 2015). Furthermore, it is argued that the potential of different practices in earthquake education should be evaluated (Izadkhah & Heshmati, 2007; Johnson, Johnston, et al., 2014; Johnson, Ronan, et al., 2014; Ronan et al., 2007; Tekeli-Yesil et al., 2019) because the question on the appropriate way of earthquake education should be answered (Lai & Tang, 2018). The aim of this study, which discusses earthquake education from a holistic perspective, is to evaluate the effectiveness of different educational practices (digital games, earthquake drills, and traditional education) conducted to inform primary school students about earthquake preparedness and protective measures to be taken. In this regard, the research question can be stated as follows:

What is the effect of different educational practices on the students' academic success to teach primary school students the preparedness for earthquake and earthquake protection?.

Methodology

Research model

Generally, it is more appropriate to use experimental research designs in different teaching environments, while examining the effect of teaching methods or teaching elements. Quasi-experimental, however, is highly preferable because it is difficult to determine unbiased sampling in education research (McMillan & Schumaher, 2014). Therefore, in this study, the pretest–posttest control/comparison group design under the quasi-experimental research was used as the sampling is not randomly determined contrary to the true experimental design. For this reason, it was paid attention to the average pre-test scores of the groups in terms of academic achievement which is the dependent variable of the study. A pre-test was administered to the groups initially, and after the implementation process, the average post-test scores are compared. Three different educational methods, which are to be administered to three experimental groups and one control group, were examined in terms of the students' academic achievement.

Participants

Information on earthquake preparedness and protective measures was provided to the primary school fourth-grade students by the curriculum. For this reason, the participants consist of students from the fourth grade in four different primary schools located in one of the cities in the eastern part of Turkey. In the selection of participants for sufficient sample size, the schools with a high number of students were taken into consideration. It was randomly determined which of the selected schools would be experiment or control groups. The participants approximately between 9 and 10 years voluntarily took part in this study academic performance levels of most of the participants were low. It is stated that low academic performance caused by individual differences or environmental factors can complicate the learning process (Lamas, 2015; Lodge et al., 2018). Furthermore, the participants were educated in the ideal laboratories and classrooms with the capacity of 30–35 students on average. The participants in the study consisted of three experimental groups and one control group selected from four different primary schools as shown in Table 1.

Table 1 Information on participants

Groups	Group definition	Gender	n
Experimental Group-A	The group trained by playing the three-dimensional (3D) earthquake game developed by the researcher	Girl	48
		Boy	46
Experimental Group-B	The group trained by playing the earthquake games already established in the field	Girl	60
		Boy	38
Experimental Group-C	The group participated in the earthquake drill which includes the relevant activities	Girl	53
		Boy	49
Control Group	The group participated in traditional teaching activities	Girl	48
		Boy	59
Total			401

Learning content

To the curriculum determined by the Ministry of National Education (MoNE), the learning unit titled *The Place We Live* within the third section of the course of social studies (three hours a week) given for the fourth-grade students based on the educational content of the curriculum (MoNE Content, 2017). One of the educational acquirements in the relevant learning domain is the acquirement titled *Disaster Prevention and Safe Life*. A comparison of the sub-achievements and the contents provided by the educational methods applied is presented in Table 2.

Table 2 Content-based comparison of different educational practices according to the achievements

	Experimental Group-A	Experimental Group-B		Experimental Group-C	Control Group
Disaster Prevention and Safe Life Achievements	**Earthquake Game developed in the study**	**Earthquake Master Game**	**Earthquake Game**	**Education with drills**	**Traditional education**
Realizes the people's needs to stay alive	✓				✓
Distinguish necessary and unnecessary materials during an earthquake	✓				✓
Gets an idea of necessary materials after an earthquake	✓	✓	✓		✓
Lists the materials that may be needed and used in an emergency in various places	✓	✓	✓	✓	✓
Takes an active role in preparing an earthquake emergency bag for the classroom and providing necessary materials	✓			✓	
Discusses necessary actions to be taken during an earthquake in various places	✓		✓	✓	✓
Knows the ways of evacuation from the building after an earthquake				✓	
8. Be aware of the hazards they may encounter during the evacuation of the building	✓	✓	✓	✓	
9. Explains the actions they can take against all potential hazards during the evacuation of the building		✓		✓	

Procedure

Planning, implementation, and evaluation (PIE) processes were followed in this study (Newby et al., 2000). At the planning stage, necessary tools and infrastructure preparations were made by the educational method to be applied to the study groups, and appropriate time intervals related to the practices were determined. As a pre-test, an academic achievement test (AAT) presented in Appendix was applied to all the working groups before the implementation process. A week after the implementation process, the same AAT was applied as a post-test to the students in each study group. The tests lasted for 30 min on average. The PIE processes in each study group are summarized in Fig. 1.

When digital games related to disaster education were examined, it was found that a great majority of the games are 2D, they were not sufficient in terms of the instructional content based on the curriculum, the entertainment factor was not taken into consideration, and informative items related to the playing process were not included in some plays. Furthermore, there was no research in the academic context related to many games, and there were very few specific games about earthquake education in the field. While developing the earthquake game in this study, these deficiencies in the existing earthquake games in the literature were tried to be completed.

As a result of the examination of these games, the Disaster and Emergency Management Presidency of Turkey (DEMP) officials and some specialists in teaching technology and earthquakes were interviewed by the researchers. As a result of the interviews, the target group was determined in line with the information obtained through the MoNE curriculum, and the development of the 3D earthquake game was planned. While the 3D earthquake game was developed in the scope of the study, the game stages were considered by the target achievements. In this respect, the achievements to be obtained in the relevant stages through the educational content are shown in Table 3.

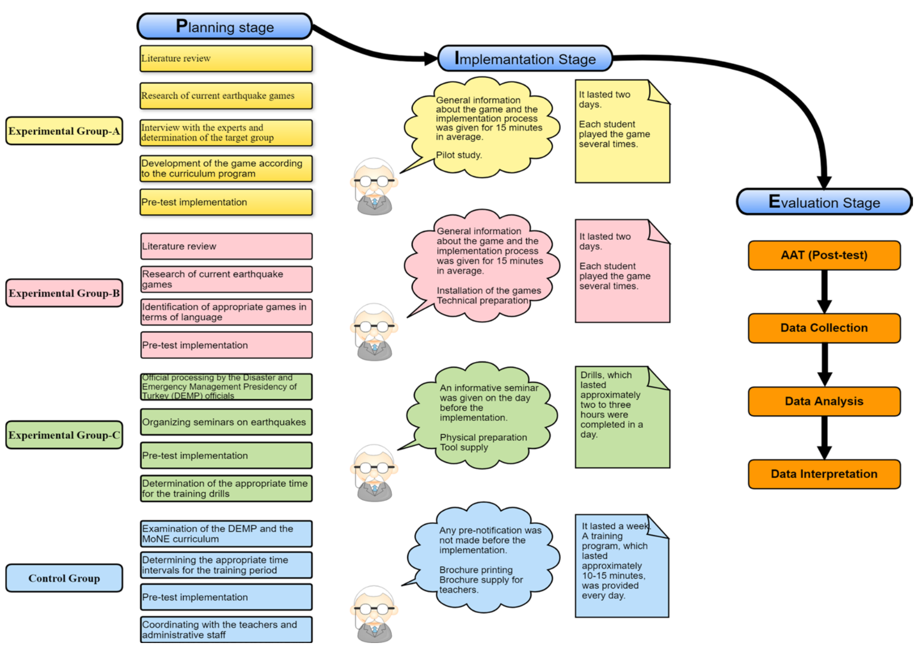


Fig. 1 Study process based on PIE model Experimental Group A—Study process

Table 3 Information on the game stage with the achievements

Event	Achievements	Stages
Before earthquake	Realizes the people's needs to stay alive Takes an active role in preparing an earthquake emergency bag for the classroom and providing necessary materials	First stage
During earthquake	Distinguishes necessary and unnecessary materials during an earthquake Lists the materials that may be needed and used in an emergency in various places Discusses necessary actions to be taken during an earthquake in various places	Second stage
After earthquake	Gets an idea of necessary materials after an earthquake Knows the ways of evacuation from the building after an earthquake Be aware of the hazards they may encounter during the evacuation of the building Explains the actions they can take against all potential hazards during the evacuation of the building	Second stage

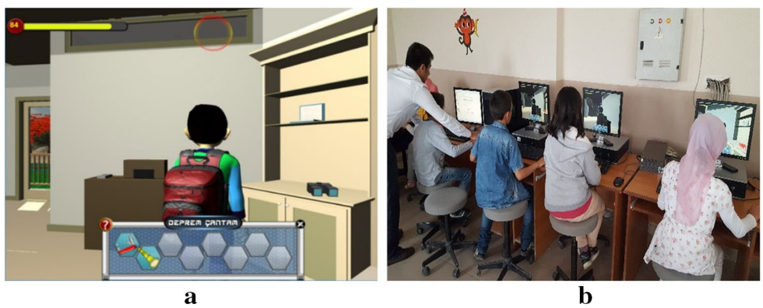


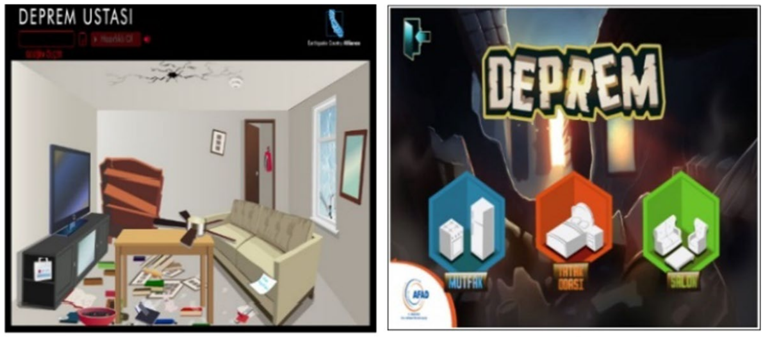
Fig. 2 **a** A photograph of the earthquake game. **b** A photograph of the implementation process

Audio and visual elements were included in the game developed to provide students with entertainment and motivation in the learning process. Furthermore, the game was designed in 3D, and the educational content was expected to be presented with realistic physical simulations to provide more interactivity. There were also informative items related to the instructions which state what students would do at what stage of the game. Researchers, who developed the earthquake game by using the Unity 3D game engine platform, benefited from ready models and codes (Unity3D, 2018). Photographs of the implementation process and the developed game over a year are shown in Fig. 2.

Before the implementation stage, a pilot study was conducted to prevent potential user errors and make necessary corrections. After arrangements were made again, the game was completed by considering the feedback taken and observation made at the end of the pilot study, which was performed with five students for an hour. The real implementation process was administered after the accomplishment period lasted a month on average. The students played the game several times during the two-day.

Experimental group B—study process

Two digital games, suitable for the Turkish language, were found as a result of the examination of the current earthquake games. These are the *Earthquake Master* game shown in Fig. 3a and the *Earthquake* game shown in Fig. 3b. The game called *Earthquake Master* was developed by the *Southern California Earthquake Center* (Earthquake



a b

Fig. 3 (**a**) Earthquake Master game, (**b**) Earthquake game

Master Game, 2019). The game was designed to teach the protective measures to be taken before an earthquake. The second game, which is on the official website of the DEMP, was designed to inform the students on the actions for earthquake protection (Earthquake Game, 2015). The game aims to teach the students how to protect themselves in three places (kitchen, bedroom, living room) during a possible earthquake.

During the implementation process, a general introduction was made about the games and the students in the study group played the games. The implementation process lasted two days. Each student played the games several times.

Experimental group C—study process

In this study group, the DEMP provided the students with practical training on the protective measures for earthquake protection. Informative seminars on earthquake protection were organized by the DEMP authorities on the day before the implementation process, and the students were informed of the implementation methods. The implementation process lasted one day. The students in the working group participated in practical activities related to earthquake protection, rescue, and evacuation. Photographs of the implementation process are shown in Fig. 4.

Control group—study process

This group was trained through the use of brochures on the official website of the DEMP and the use of the resources on earthquake protection. These brochures (Brochures, 2019) and resources (Resources, 2019) were prepared in print and delivered to the relevant branch teachers. A training program was conducted by six teachers who provided the students with the theoretical information in the last lesson of the day through the use of traditional methods that took approximately 10–15 min. The implementation process lasted a week, and the students in the group took part in the training process in which the traditional methods of earthquake protection, rescue, and evacuation were used.

Data collection tool

AAT shown in Appendix, which was used as a data collection tool, was prepared by the researchers. In this process, firstly learning objectives were prepared by the official information and experts' opinions on the curriculum found on the DEMP website. Then AAT was prepared based on these learning objectives as shown in Table 7. *Kuder Richardson*

Fig. 4 Photographs from the process of practical training

(KR-20) was used to determine the reliability of the achievement test. The test was applied to the seventy-two students from the fourth grade in the primary school, and the value of the KR-20 reliability analysis was found as 0.718. In this regard, it can be said that the test is reliable (Field, 2013). Under the guidance of an expert in the DEMP and four primary school teachers, a table of specifications was prepared for the validity of the AAT.

Data analysis

O*ne-way ANOVA* was used to analyze the data obtained through the pre-test applied to the study groups. *ANCOVA* and the Post-Hoc statistical methods were utilized to analyze the obtained data through the post-test. Furthermore, descriptive statistical methods were used to describe the obtained data through the pre-test and the post-test.

Results

By *Levene's test* results, it was found that the distribution of the data obtained through the pre-test ($p = 0.052$; $p > 0.05$) and the post-test ($p = 0.533$; $p > 0.05$) applied to the groups is homogeneous. It was observed that the pre-test and post-test data showed normal distribution. Accordingly, the ratio of kurtosis (0.25) and skewness (0.258) values for the pre-test was found to be (0.96 < 1.96). For the post-test, the ratio of kurtosis (0.195) and skewness (0.322) values was found to be (0.60 < 1.96) (Field, 2013). In addition, histogram graphics of the data support that the data is normally distributed. In this context, it was determined that there was not any significant difference [$F_{(3-397)} = 0.261$; $p = 0.854 > 0.05$] between the groups according to the *ANOVA* results related to the pre-test values and that the groups showed a similar level in terms of achievement. The obtained pre-test and post-test results through the descriptive statistics methods are shown in Table 4.

Table 4 Mean and standard deviation for pre-test and post-test scores of the AAT

	Study Group	n	M	SD	SE	Min	Max
Pre-test	Experimental Group-A	94	49.19	14.076	1.452	8	76
	Experimental Group-B	98	49.31	13.070	1.320	20	80
	Experimental Group-C	102	48.25	10.913	1.081	20	76
	Control Group	107	49.78	12.650	1.223	12	68
Post-test	Experimental Group-A	94	51.87	13.970	1.441	20	84
	Experimental Group-B	98	45.27	13.852	1.399	16	84
	Experimental Group-C	102	61.24	14.450	1.431	28	96
	Control Group	107	39.72	12.385	1.197	12	72

[*] The highest score you can get from the AAT is 100

Table 5 The ANCOVA results

Source	Sum of Squares	df	Mean Square	*F*	*P*	μ^2
Corrected Model	32,088.911[a]	4	8022.228	46.319	< .001	.319
Intercept	30,604.546	1	30,604.546	176.706	< .001	.309
Pre-test	5524.468	1	5524.468	31.897	< .001	.075
Method	27,571.094	3	9190.365	53.064	< .001	.287
Error	68,585.044	396	173.195			
Total	1,079,120.000	401				
Corrected Total	100,673.955	400				

a. R-Squared = .319 (Adjusted R-Squared = .312)

According to post-test results shown in Table 4, the mean of AAT (M = 61.24, SS = 14.450) was found as the highest value in the Experimental Group-C in which the students participated in the practical activities. On the other hand, the Experimental Group-A, in which the students played the digital game developed by the researcher, took second place in terms of the means of the AAT (M = 51.87, SS = 13.970).

It was found that the hypothesis of the *ANCOVA* test related to the post-test data is [$F_{Method{*}pre\text{-}test\ (1-400)} = 1.138$; $p = 0.334 > 0.05$]. In this regard, it is seen that the condition for the equation of regression tendencies was fulfilled. The *ANCOVA* results, which indicate that there is a significant difference between different educational methods provided when the pre-test scores are kept under control, are shown in Table 5 [$F_{(3-396)} = 53.064$; $p < 0.001$; $\mu^2 = 0.287$].

To determine whether there is a significant difference between which groups and in which group's favor, *Benforonni's posthoc test* results presented in Table 6 were utilized. (Field, 2013). When the relevant table was examined, it can be seen that the difference between the post-test scores of the students in the Experimental Group-C and the post-test scores of the students in other groups is high. In this regard, it was determined that the educational method with drills applied to the Experimental Group-C is more successful than the other methods used. Furthermore, it was seen that the educational method with the digital game applied to the Experimental Group-A is more effective than the educational method with the other digital game applied to the Experimental Group-B. Finally, it can be concluded that the traditional education method applied to the Control Group is less effective in learning than the other educational methods.

Table 6 Bonferroni posthoc test results

Dependent variable: post-test						
G1	**G2**	**Mean Difference (G1-G2)**	**SE**	***p***	**95% confidence interval for the difference**	
					Lower Bound	**Upper Bound**
Experimental Group-A	Experimental Group-B	6.641*	1.900	.003	1.603	11.679
	Experimental Group-C	−9.638*	1.882	< .001	−14.629	−4.647
	Control Group	12.324*	1.861	< .001	7.391	17.258
Experimental Group-B	Experimental Group-A	−6.641*	1.900	.003	−11.679	−1.603
	Experimental Group-C	−16.279*	1.862	< .001	−21.217	−11.341
	Control Group	5.684*	1.840	.013	.804	10.563
Experimental Group-C	Experimental Group-A	9.638*	1.882	< .001	4.647	14.629
	Experimental Group-B	16.279*	1.862	< .001	11.341	21.217
	Control Group	21.963*	1.823	< .001	17.129	26.796
Control Group	Experimental Group-A	−12.324*	1.861	< .001	−17.258	-7.391
	Experimental Group-B	-5.684*	1.840	.013	−10.563	−.804
	Experimental Group-C	−21.963*	1.823	< .001	−26.796	−17.129

* The mean difference is significant at the .05 level

b. Adjustment for multiple comparisons: Bonferroni

Participant answers to the questions in the AAT test (all questions except questions 1, 5, 7, 13, and 23) corresponding to the common achievements numbered 3, 4, and 6 in Table 2 were considered and a new calculation was made. According to the achievements in Table 2, the averages of the in-group and intergroup answers of the study groups for each question in the AAT were compared and presented in Table 7.

The average values highlighted in bold in Table 7 represent the average values for the questions that students answered most correctly in the group, taking into account the average academic achievement of the students in the relevant group. For example, when the overall success average of the students in Experimental Group-A after the educational intervention (M = 51.87 and SD = 13.97) is taken into account, it was determined that the students answered the questions about the average values highlighted in bold more correctly. In the light of these results, it was observed that while the students in all study groups answered some questions corresponding to the achievements in Table 2 correctly above the average within the group, they answered the questions corresponding to some achievements correctly below the average. It should not be forgotten that some of the questions in the AAT are for more than one of the objectives in Table 2 or only for one outcome.

It is seen that there is a significant difference between the answers given to some questions in the AAT (except for the questions numbered 3, 7, 8, 18, and 25) between the study groups. Post-hoc results were used to determine the significant difference between which questions and in favor of which group according to the study groups. Table 8 presents the post-hoc results of the groups with significant differences according to the questions in the AAT.

Considering the answers to the questions (questions numbered 1, 5, 7, 13, and 23) in Table 2 that do not address the common achievements, the following results were obtained:

Table 7 Results on answers to questions on the AAT test between and within groups

Question number	Learning objectives*	Achievement number related to disaster protection in Table 2	Mean and standard deviation values of study groups								Analysis results between the groups		
			Group A		Group B		Group C		Control Group				
			M	SD	M	SD	M	SD	M	SD	*F*	p^{***}	μ^2
1**	Knows the first precaution to be taken before an earthquake	4, 5, 6, 7, 9	.61	.49	.47	.50	.48	.50	.32	.46	5.85	.001	1.40
2	Knows that an earthquake emergency bag should be prepared during the preparation process before an earthquake	1, 2, 3, 4, 5	.45	.50	.26	.43	.54	.50	.22	.41	10.83	< .001	2.34
3	Knows which materials should be found in the earthquake bag	1, 2, 3, 4, 5	.56	.49	.40	.49	.51	.50	.42	.49	2.37	.070	.58
4	Knows what kinds of food can be kept in the earthquake bag	1, 2, 3, 4, 5	.66	.47	.52	.50	.66	.47	.46	.50	4.32	.005	1.03
5**	Knows which protective measures should be taken before an earthquake	6	.53	.50	.31	.46	.56	.49	.26	.44	10.38	< .001	2.35
6	Knows which items can be hazardous during an earthquake if they have not been fixed before the earthquake	6	.50	.50	.34	.47	.72	.45	.51	.50	10.31	< .001	2.41
7**	Knows which educational activities can be arranged before an earthquake	1–9	.56	.49	.70	.45	.72	.45	.55	.50	.785	.071	3.433
8	Knows the appropriate behaviors which can be shown during an earthquake	6	.63	.48	.53	.50	.63	.48	.48	.50	2.34	.072	.572
9	Knows the safe places to take shelter during an earthquake	6	.48	.50	.36	.48	.64	.48	.29	.45	10.40	< .001	2.40
10	Knows the correct way to act for evacuation of the building during an earthquake	6, 7, 8, 9	.61	.49	.61	.49	.76	.42	.38	.48	11.49	< .001	2.58
11	Knows that the items which have not been fixed may cause a loss during an earthquake	6	.55	.50	.42	.49	.68	.47	.43	.49	6.20	< .001	1.49
12	Knows what kind of items can be the most hazardous during an earthquake	6, 7, 8, 9	.51	.50	.36	.48	.70	.46	.43	.49	9.11	< .001	2.15
13**	Knows which equipments should be utilized in case of being trapped under the rubble after an earthquake	3, 4, 5	.54	.50	.44	.49	.66	.47	.31	.46	9.74	< .001	2.29
14	Knows what actions should be avoided for safety after an earthquake	7, 8, 9	.49	.50	.40	.49	.69	.46	.40	.49	7.80	< .001	1.86
15	Knows the appropriate behaviors which should be acted while being trapped under the rubble after an earthquake	3, 4, 5	.62	.48	.47	.50	.73	.44	.42	.49	8.50	< .001	1.99
16	Knows which equipments should be utilized for any water or gas leakage which may occur after an earthquake	6, 7, 8, 9	.47	.50	.38	.48	.64	.48	.33	.47	8.11	< .001	1.530
17	Knows phone numbers of the institutions which can be contacted for help after an earthquake	4, 9	.51	.50	.46	.50	.70	.46	.42	.49	6.36	< .001	1.53

Table 7 (continued)

Question number	Learning objectives*	Achievement number related to disaster protection in Table 2	Mean and standard deviation values of study groups								Analysis results between the groups		
			Group A		Group B		Group C		Control Group				
			M	SD	M	SD	M	SD	M	SD	*F*	*p****	μ^2
18	Knows about the first institution which will help the people who have been trapped under the rubble after an earthquake	8, 9	.55	.50	.53	.50	.66	.47	.47	.50	2.63	.051	.645
19	Knows the minimum number of people required to hear those who have been trapped under the rubble after an earthquake	4, 7, 8, 9	.46	.50	.43	.49	.67	.47	.36	.48	7.73	< .001	1.84
20	Knows what behavior is safer during an earthquake	6	.44	.49	.31	.46	.56	.49	.36	.48	5.05	.002	1.19
21	Knows the appropriate behavior to be shown when an earthquake occurs during sleeping	6	.45	.50	.39	.49	.58	.49	.45	.50	2.64	.049	.652
22	Knows the kind of items that may be hazardous during an earthquake	6	.52	.50	.67	.47	.52	.50	.49	.50	2.86	.037	.070
23**	Knows the reasons for earthquakes	1–9	.37	.48	.55	.50	.37	.48	.29	.45	5.27	.001	1.22
24	Knows the importance of the measures to be taken for protection from earthquakes	1–9	.35	.48	.48	.50	.60	.49	.50	.50	4.09	.007	1.01
25	Knows what kinds of food can be included in the earthquake emergency bag	1, 2, 3, 4, 5	.54	.50	.57	.49	.46	.50	.40	.49	2.45	.063	.061

*Each question may contain more than one achievement in Table 2

**Except for these questions, all questions are included in the common achievements in all groups

***The mean difference is significant at the 0.05 level

The questions (questions 3, 7, 8, 18, and 25) to which the *p* values highlighted in bold in the table belong, indicate that there is no significant difference between the groups regarding the averages of the questions answered in the academic achievement test

Table 8 Comparison results between groups regarding the answers to the questions in the AAT test

Question Number	Group 1	Group 2	Mean difference (I-J)	*p**	95% Confidence Interval	
					Lower bound	Upper bound
s1	Experimental Group-A	Control Group	.289	< .001	.10	.47
s2	Experimental Group-A	Experimental Group-B	.192	.027	.01	.37
		Control Group	.223	.005	.05	.40
	Experimental Group-B	Experimental Group-C	−.284	< .001	−.46	−.11
	Experimental Group-C	Control Group	.315	< .001	.14	.49
s4	Experimental Group-A	Control Group	.202	.023	.02	.39
	Experimental Group-C	Control Group	.199	.021	.02	.38
s5	Experimental Group-A	Experimental Group-B	.226	.007	.04	.41
		Control Group	.270	< .001	.09	.45
	Experimental Group-C	Experimental Group-B	.253	.001	.07	.43
		Control Group	.297	< .001	.12	.47
s6	Experimental Group-A	Experimental Group-C	−.216	.012	−.40	−.03
		Experimental Group-C	−.379	< .001	−.56	−.20
	Experimental Group-C	Experimental Group-A	.216	.012	.03	.40
		Experimental Group-B	.379	< .001	.20	.56
		Control Group	.202	.017	.02	.38
s9	Experimental Group-A	Control Group	.189	.034	.01	.37
	Experimental Group-B	Experimental Group-C	−.280	< .001	−.46	−.10
	Experimental Group-C	Control Group	.348	< .001	.17	.52
s10	Experimental Group-A	Control Group	.223	.006	.05	.40
	Experimental Group-B	Control Group	.229	.004	.05	.40
	Experimental Group-C	Control Group	.382	< .001	.21	.56
S11	Experimental Group-B	Experimental Group-C	−.258	.001	−.44	−.07
	Experimental Group-C	Control Group	.247	.002	.07	.43
s12	Experimental Group-A	Experimental Group-C	−.185	.048	−.37	.00
	Experimental Group-B	Experimental Group-C	−.339	< .001	−.52	−.16
	Experimental Group-C	Control Group	.266	.001	.09	.44
s13	Experimental Group-A	Control Group	.234	.004	.05	.42
	Experimental Group-B	Experimental Group-C	−.218	.010	−.40	−.04
	Experimental Group-C	Control Group	.348	< .001	.17	.53
s14	Experimental Group-A	Experimental Group-C	−.197	.030	−.38	−.01
	Experimental Group-B	Experimental Group-C	−.288	< .001	−.47	−.11
	Experimental Group-C	Control Group	.284	< .001	.11	.46
s15	Experimental Group-A	Control Group	.196	.026	.02	.38
	Experimental Group-B	Experimental Group-C	−.256	.001	−.44	−.07
	Experimental Group-C	Control Group	.305	< .001	.13	.48
s16	Experimental Group-B	Experimental Group-C	−.260	.001	−.44	−.08
	Experimental Group-C	Experimental Group-B	.260	.001	.08	.44
		Control Group	.310	< .001	.13	.49
s17	Experimental Group-B	Experimental Group-C	−.237	.004	−.42	−.05
	Experimental Group-C	Control Group	.276	< .001	.10	.46
s19	Experimental Group-A	Experimental Group-C	−.209	.017	−.39	−.02
	Experimental Group-B	Experimental Group-C	−.238	.004	−.42	−.06
	Experimental Group-C	Control Group	.312	< .001	.13	.49
s20	Experimental Group-B	Experimental Group-C	−.253	.002	−.44	−.07
	Experimental Group-C	Control Group	.194	.025	.02	.37
s21	Experimental Group-B	Experimental Group-C	−.191	.041	−.38	.00

Table 8 (continued)

Question Number	Group 1	Group 2	Mean difference (I-J)	*p**	95% Confidence Interval	
					Lower bound	Upper bound
s22	Experimental Group-B	Control Group	.187	.042	.00	.37
s23	Control Group	Experimental Group-B	−.261	.001	−.44	−.08
s24	Experimental Group-A	Experimental Group-C	−.247	.003	−.43	−.06

*The mean difference is significant at the 0.05 level

Negative values regarding the differences between the means indicate that there is a significant difference in favor of the group under the heading "Group 2"

- According to the answers to question 1, there is a significant difference between Experimental Group-A and Control Group in favor of Experimental Group-A.
- According to the answers to question number 5, there is a significant difference between Experimental Group-A and Experimental Group-C and Experimental Group-B and Control Group in favor of Experimental Group-A and Experimental Group-C.
- There is no significant difference between the groups regarding question number 7.
- According to the answers to question number 13, there is a significant difference between Experimental Group-A, Experimental Group-B, Experimental Group-C, and Control Group in favor of the experimental groups. In addition, there is a significant difference between Experimental Group-B and Experimental Group-C in favor of Experimental Group-C.
- According to the answers to question number 23, there is a significant difference between Experimental Group-B and Control Group in favor of Experimental Group-B.

Considering the questions addressing the common achievements (all questions except the questions numbered 1, 5, 7, 13, and 23), it was observed that the students in Experimental Group-C were more successful than the students in other groups. According to the significance level of $p<0.001$ shown in Table 8, it was determined that the students in Experimental Group-C answered the questions in the AAT more correctly than the students in the other groups. It was observed that there was no significant difference between the groups regarding questions 3, 8, 18, and 25 in the AAT. In addition, it was observed that the students in Experimental Group-B answered question number 22 in the AAT better than the students in the Control group.

Discussion

The findings of this study suggest that the students who participated in practical activities (Experimental Group-C) were more successful in their education on earthquake preparation and protective measures. These findings coincided with some research in the literature (Oda, 2016; Soffer et al., 2010). Students in this group participated actively in practical activities and learned the ways of protection against a potential earthquake with the support of an experienced team. It was argued that individuals perceived, or thought-through information and learned by applying knowledge according to the perception in the learning process (Kolb, 2014). According to this learning approach supported by the experimental learning model, it was stated that learning was a process in which knowledge could be continuously changed with the accumulated experience (Kolb, 2014). In terms of academic success, it was thought that the reason for the higher success of the students in this study group than in the other study groups resulted from the characteristics stated in the experiential learning model.

Another reason for the higher academic achievement of the students in Experimental Group-C than in the other groups could also be attributed to the social learning theory. According to the relevant theory (Bandura, 1986), it was emphasized that primary school students could model and learn the majority of emotional, cognitive, social, and psychomotor learning skills more effectively through observation. Moreover, it was argued that the student's interaction with the teacher during the observation process would contribute to the development of their mental functions (Bandura, 1986). It can be said that the students, who participated in practical activities based on these learning approaches, were more successful than the students in other groups to gain experience through observation, implementation, and use of knowledge. In this regard, it was emphasized that practical activities in earthquake education could yield more effective results in terms of learning. Heath et al. (2007) and Soffer et al. (2010) argued that practical activities give more effective outcomes in learning.

Many researchers argued that digital games had positive effects on learning (Bachen et al., 2016; Beckmann & Mahanty, 2016; Bulut, et al., 2022; Connolly et al., 2012; Edmonds & Smith, 2017; Hardy & Totman, 2017; Kim & Chang, 2010; Pilegard & Mayer, 2016; Waiyakoon et al., 2015). However, some studies proposed that digital games had no effect on learning or might have a negative effect (Annetta et al., 2009; Huizenga et al., 2007; Tuzun et al., 2009). In this study, it was found that the academic achievement of the students, who had been trained on earthquake preparedness and protection by playing the 3D earthquake game developed by the researcher, was positively affected by the relevant education. Especially when compared to the students who were educated by the traditional education method, it was seen that the students who were trained by playing the 3D earthquake game were more successful. The reason for the positive impact on the students' academic achievement may be the fact that the education on protection from natural disasters such as earthquakes can be provided through a digital game (Tsai et al., 2015). In addition, creating an awareness of the relevant information, which will enable the students to use it in their future life, is also helpful for them (Barreto, 2014; Keller, 1987). Chen (2015) found that digital games developed for earthquake preparedness might have a positive contribution to the achievement of better results in learning.

According to the findings, it was found that the students did not show the expected performance in terms of academic achievement. Especially, the problems arising from the structure of the design elements in the game may be a reason for the underperformance. When systematic analysis studies on digital games are examined, it is seen that the design elements are important for digital games which have great importance in the learning process (Clark et al., 2016). There may be another reason why the design elements in the development process of the games are not efficiently designed and user responses are not fully compatible with the relevant process. This is because the pleasure received from the game while playing and the response given to the game as a result of such pleasure also affect the process of feedback received from the user. In this regard, the process of feedback affects the duration of the users' focus on the activities in the game which can also be reflected in the learning outcomes of the game (Garris et al., 2002).

When the academic achievement results obtained from the students who were trained by playing digital games are evaluated, it is seen that the results are different but close to each other. The results show that the academic achievement of the students in the Experimental Group-B is lower than the academic achievement of the students in the Experimental Group-A trained through the 3D earthquake game developed by the researchers. Furthermore, another reason for this difference may result from the incompatibility of the educational content of the games and the curriculum (Garris et al., 2002).

For instance, in the game called *Earthquake Master*, we focus only on information about how things should be fixed before the earthquake. On the other hand, the *Earthquake Game* on the official website of the DEMP focuses on teaching how to fix the pre-earthquake materials and how to be safe during an earthquake. However, these games do not include any information about which preparation materials should be kept before an earthquake.

When the pre-test and post-test results are compared, it is found that there is a partial decrease in the achievement grades of the students in the Experimental Group-B and the control group. The game activities presented to the students in the Experimental Group-B provide different acquirements in terms of the learning content. It is thought that the achievement grades of the students may be affected by this change as their achievements may vary depending on the content of the game activity preferred by them. Furthermore, various technical and hardware difficulties encountered by the students during the application process may hurt the students' motivation levels. These experiences may also have an indirect impact on the students' achievement grades. It is seen that the post-test scores of the students in the control group show a higher decrease when compared to the students in the Experimental Group-B. The existence of some limitations of the printed materials especially in creating awareness of earthquake education and earthquake preparedness (Tekeli-Yesil et al., 2019) may be considered a reason for this decrease. Most importantly, the learners need the tools, resources, and opportunities to practice and transfer the knowledge, skills, and achievements they have learned (Morrison et al., 2019). The fact that the traditional teaching method is insufficient for the process of acquirement and transfer of the students' achievements and does not provide the opportunity required to apply the knowledge learned by the students may be another reason for the decrease in the average success of the students. The students in the control group being trained by different teachers may be considered as another reason for the differences in their achievement grades. In addition, students' cognitive awareness may have changed after the application, or the results may have been affected by the individual characteristics of the students. Finally, the partial incompatibility of the achievements that the applied AAT aims to measure, and the learning contents offered with traditional education may be the reason for this decrease. In terms of instructional content, the content in the game must be compatible with the characteristics of the game (Garris et al., 2002). For this reason, it is stated that the design elements in the game may affect the learning process (Clark et al., 2016). It has also been argued that the process of instructional design, which includes the components of the game and the content to be taught through the game, is very important for a game to be developed for a learning process that will yield more successful results (Becker, 2010). Such reasons may result in academic failure.

In this study, the technical and hardware difficulties experienced during the use of digital games in the teaching process may be another reason which affects the academic achievement of the students participating in practical activities (Kozma, 1991) because of the process of integrating media forms into teaching is not effective enough. Furthermore, it is emphasized that schools, where practical activities can be conducted, are important in education on the prevention of natural disasters, community-based disaster preparedness, and the need for an emergency shelter during a disaster (Oda, 2015, 2016). Therefore, it can be argued that education programs in schools and in-service training activities should be arranged appropriately in disaster education.

Considering the answers given by the study groups to the questions in the group, it can be said that there is a parallelism between the learning content presented, the training method applied and the answers answered. For example, in Experimental Group-A, more answers are seen from the students in the group to the questions about the learning content presented with the game. The fact that the students in Experimental Group-B gave similar answers in parallel with the learning content in the related games supports this situation. In addition, considering the answers of the students in Experimental Group-C to the questions about evacuation from the building and the methods of protection in case of earthquakes further strengthens the importance of the learning contents in the effectiveness of the applied methods. The fact that the students in the control group answered fewer questions about practical behaviors and gave more answers to questions in which cognitive competencies came to the fore supports this situation.

Considering the results in Table 8, it can be said that the compatibility of the methods applied with the learning content increased the students' answers to the questions. Considering the questions addressing common achievements (all questions except the questions numbered 1, 5, 7, 13, and 23), the fact that the students in Experimental Group-C are more successful than the students in other groups supports this situation. Therefore, it can be said that students learn better in learning environments based on practice and supported by real-life examples. On the other hand, although the number of questions is low, there is no significant difference between the groups regarding questions 3, 8, 18, and 25 in the AAT. The reason for this situation may be due to the similarity of the learning content in the applied education methods and the individual characteristics of the students.

There are many limitations to this study. First of all, there are some differences in the provided educational content although the learning achievements are the same. These differences are compared according to the achievements in Table 2. Furthermore, even though the education was given in the same content for the students in the control group, the education was given by different teachers. However, the sample size and the random determination of the educational activities applied to the groups may have minimized the effects of such limitations.

Conclusion

In this study, earthquake education was discussed from a holistic perspective, and the effect of different educational practices on the students' academic achievement was examined. Within the scope of the study, three different educational methods were compared in terms of academic achievement, and the results show that the students in the experimental group are more successful than the students in the control group. The most successful group among the experimental groups in terms of academic success was the group consisting of the students who participated in the practical activities. In this context, it was seen that the method in which the practical activities are used is a more successful educational method in terms of academic achievement. In addition, it could be argued that digital games were considered a platform that allows individuals to have an effective learning experience for providing the K-12 students with earthquake education and creating an awareness of natural disasters.

Furthermore, it was found that the planning of the design items in the game, the users' characteristics, and the process of adopting the game were important factors that allow the 3D earthquake game to provide the students with an effective learning process. So that a game that will be developed can yield successful results in learning, the design of the game and the teaching process should be integrated. Furthermore, it can be said that the traditional methods cannot completely meet the learning needs of today's students called the digital generation.

Since this study covers a limited content and duration of earthquake education, more comprehensive and longer-term applications can be made in the future. In this regard, the following recommendations can be taken into consideration:

- Learning activities, which allow the students to have real experiences in the learning process, can increase the success of earthquake education. In this context, the reality experience offered by virtual reality technologies can be tested in terms of academic success (Oyelere et al., 2020).
- Use of digital games can be preferred as a supportive factor in earthquake education.
- Detailed planning of the variables such as time, cost, individual characteristics of the groups, technological infrastructure, and detailed pilot studies can be useful to obtain more valid and reliable results.
- According to the experiences acquired through this research, it has been foreseen that teamwork with a specialist for each of the design elements used in the game (graphics, sound, video, animation, code, and programming) can yield more successful results.
- This study is based on comparative research. However, a research approach based on a design-based research model may be more beneficial in the achievement of positive results.

Appendix

1. What is the first measure to be taken before an earthquake?

A. To make a plan on earthquakes | B. To fix the things at home | C. To learn about the damages caused by an earthquake | D. To remove the breakable items from the environment

2. What kind of preparation can be made before an earthquake?

A. A device which measures the intensity of earthquake can be bought | B. A device which helps to predict the time of earthquake can be bought | C. An earthquake emergency bag can be prepared | D. Necessary measures can be taken according to the intensity of earthquake

3. Which of the following items is not one of the primary equipments that must be included in an earthquake emergency bag?

A. Pocket knife

B. Radio

C. Wrench

D. Clock

4. Which of the following food can be stored in an earthquake emergency bag?

A. Milk | B. Packaged tuna fish | C. Boiled egg | D. Banana

5. Which of the following is one of the measures that should be taken before an earthquake?

A. To place the breakable items next to the bed | B. To fix the items such as chandelier and flowerpot | C. To carry all the breakable items to the kitchen | D. To fix carpets and breakable items

6. Which of the following items may be more hazardous if it is not fixed before an earthquake?

A. Furniture | B. Chandelier | C. Washing machine | D. Dishwasher

7. Which of the following is not included in the educational activities to be arranged before an earthquake?

A. To receive education on earthquakes and their effects | B. To learn the causes of earthquakes | C. To receive education to predict the time of earthquakes | D. To be informed of earthquake preparedness

8. Which of the following should be done during an earthquake?

To stay in a safe place | B. To drop-cover-hold on | C. To stay away from breakable items | D. All

9. Which of the following is one of the safe places to shelter in case of an earthquake?

A. Staircase | B. Balcony | C. Elevator | D. None

10. Which of the following can be done for safety during an earthquake?

To evacuate the building within 10–15 s | B. To evacuate the building within a minute | C. To find the earthquake emergency bag even if it causes a loss of time | D. To wait for the earthquake to pass without panic

11. What kind of damages may be caused by non-fixed items during an earthquake?

A. They pose no threat if we hold them during an earthquake | B. They only cause injuries | C. They may fall on us and injure or kill us | D. They do not pose any threat

12. Which of the following is one of the items that may cause the highest damage during an earthquake?

A. Non-fixed white appliances | B. Non-fixed breakable goods | C. Non-fixed furniture group | D. Propane cylinder

13. Which of the following items can be utilized when you have been trapped under the rubble after an earthquake?

Match for light | B. Screwdriver and seismometer | C. Whistle | D. None

14. Which of the following should not be done for safety after an earthquake?

A. We should breathe deeply if we are in a dark place | B. We should check if someone is injured | C. We should use a hand lamp if we are in a dark place | D. We should evacuate the building if we are in a building

15. Which of the following is a more appropriate behaviour when we have been trapped under the rubble after an earthquake?

A. We should use a match or lighter to have some light | B. We should continually scream for help | C. We should shout to call people | D. We should drop-cover-hold and wait in a proper place

16. Which of the following equipments can be used to prevent gas or water leakage after an earthquake?

A. Wrench	B. Pocket knife	C. Screwdriver	D. Gas measuring device
			

17. Which of the following phone numbers can be called for help to the injured after an earthquake?

A. 11,880	B. 118	C. 112	D. 154

18. What is the first institution that can help people who have been trapped under the rubble after an earthquake?

A. DEMP	B. Kızılay (Red Crescent)	C. Local Authority	D. Gendarme

19. What is the minimum number of people required to hear those who have been trapped under the rubble after an earthquake?

A. Two	B. Three	C. Four	D. Five

20. Which of the following behaviours is safer than the others during an earthquake?

A. To wait near the window to escape	B. To get inside the toilet and lock the door	C. To get inside the bathroom and lock the door	D. To lie down near the washing machine

21. Which of the following behaviours is more appropriate when an earthquake occurs during sleeping?

A. To open the window and to call for help	B. To wait for the earthquake to pass without panic	C. To evacuate the building within 10–15 s	D. To wait for other individuals at home to wake up

22. Which of the following may be more hazardous than the others during an earthquake?

A. A non-fixed washing machine	B. A non-fixed bookshelf	C. A non-fixed picture frame	D. A non-fixed heater

23. Which of the following is the cause of earthquakes?

A. A punishment from god	B. It is caused by the rotation of the earth	C. It is as a result of overtemperature caused by the sun	D. It is caused by the movement of the earth's crust

24. Why is it important to learn the protective measures against an earthquake?

A. It completely saves the buildings from being destroyed	B. It always saves our lives	C. It eliminates all the reasons that may cause us injury	D. It can minimize the loss of life and property

25. Which of the following food goes bad quicker than the others when included in an earthquake emergency bag?

A. Bread	B. Canned food	C. Yoghurt	D. Biscuit

The application and evaluation process of the test was done in Turkish

Abbreviations

DEMP	Disaster and emergency management presidency
3D	Three-dimensional
MoNE	Ministry of National Education
PIE	Planning, implementation, and evaluation PIE
AAT	Academic Achievement Test
2D	Two-dimensional
KR-20	Kuder Richardson

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Author contributions
Both authors designed, developed, and implemented the digital game in designated schools. The first author collected and analyzed the data. The second author supported the data review gateway and reporting process. In addition, the second author organized the schools and held the necessary meetings. All authors read and approved the final manuscript.

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Declarations

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