



Investigating the impact of technology-supported 3E learning model in disaster education

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Abstract

This research aimed to investigate the effect of a technology-supported 3E learning model on middle school students' knowledge of disasters and their attitudes towards disaster preparedness. To this end, it used an explanatory sequential mixed methods design. Quantitative and qualitative data were used to describe how the technology-supported 3E learning model changes the learning environment. A pretest-posttest control group quasi-experimental design was used in the quantitative part of the research, and a case study was used in the qualitative part. The experimental procedure lasted for six weeks. The sample consisted of 33 fifth-grade students attending a public school. The Disaster Preparedness Attitude Scale, an achievement test, and an interview form were used as data collection tools. The analysis results showed that the experimental group achieved statistically significantly higher scores in the posttest and the retention test of the Disaster Preparedness Attitude Scale, and the achievement test compared to the control group. Additionally, according to student views, the technology-supported 3E learning model is more helpful in acquiring skills and values, provides the opportunity to learn by experiencing, increases students' motivation, and facilitates effective disaster education. These results indicate that conducting activities on a subject that concerns the whole society, such as disasters, using advancing and innovative technological devices, preparing lesson plans, and demonstrating their effectiveness in education will make a significant contribution to the literature.

Keywords Disaster · 3E learning model · Digital game · Virtual reality

1 Introduction

Disasters are a critical problem for societies. Especially today, there is and there will be a serious increase in natural disasters due to global warming and climate change (Van Aalst, 2006). According to Emergency Disaster Database data in the report of the Centre for Research on the Epidemiology of Disasters (2021), a total of 432 disasters (174 in Asia, 129 in the Americas, 57 in Africa, 56 in Europe, and 16 in Oceania) occurred in 2021, killing 10,492 people and affecting 101.8 million people. According to the report, the average annual economic loss caused by disasters between 2001 and 2020 was 153.8 billion dollars. The Centre for Research on the Epidemiology of Disaster revealed in its report that there were 387 natural disasters in 2023, and 185 million people were affected by these disasters. When the statistics in the published report are analyzed in detail, it is seen that the natural disasters that occurred in 2022 caused 30,704 people to lose their lives and caused 223.8 billion dollars of economic damage.

Apart from statistical damages, it may be useful to mention the negative effects of disasters. Lee and Zhang (2023) state that disasters have an impact on the economies of states and are a major obstacle to trade and growth. Akao and Sakamoto (2018) stated that natural disasters will affect agriculture, and production opportunities may be destroyed. Lopez-Ibor (2006) stated that natural disasters negatively affect social life and cause psychological damage to individuals, while Newnham et al. (2020) said that children may need rehabilitation services after disasters. Kousky (2016) stated that children are vulnerable, and the natural disasters they will experience will affect them and cause problems that may last for years in terms of education and health. Kharb et al. (2022) stated the most important dimension of losses and mentioned human losses that cannot be solved or returned. All the statistics and negativities mentioned reveal the seriousness of the issue of natural disasters and the necessity of disaster education.

Sumarmi et al. (2020) and Johnson et al. (2016) stated that disaster preparedness is necessary to reduce material and moral losses caused by disasters. To minimize the negative effects of past and future disasters on human life over a long time, individuals should be made aware from an early age (Fuhrmann et al., 2008). The potential of natural disasters and the fact that children are the most vulnerable group when a disaster occurs make disaster education in schools mandatory for children (Khaerudin & Suharto, 2022). As Rabe et al. (2022) state, children's preparedness for disasters can be improved in schools. However, it should be noted that there are some problems. For example, Cerulli et al. (2020) noted that disaster education is insufficient in countries with low disaster risk. According to the questions prepared by the United Nations Office for Disaster Risk Reduction to determine the quality of disaster education, primary and middle school curricula for developing countries are inadequate in terms of disaster education (İnal et al., 2018). Thus, it seems that educational institutions do not take the responsibility to ensure that student develop knowledge and awareness of disasters (Shiwaku et al., 2007; Apronti et al., 2015). In this context, disaster education should be given due importance in schools as soon as possible to reduce the negative effects of disasters and ensure disaster preparedness (Saregar et al., 2022).

Arıkan and Aladağ (2021) and Aladağ et al. (2021) emphasised that educational environments should be designed to attract students' interest. Zhang and Wang (2022) stated that disaster education is not only knowledge-oriented but also skill-oriented. In this context, one of the most important aims of disaster education is to develop various skills in individuals and reduce the risk of disaster (Mangione et al., 2013). In this context, it is obvious that the active participation of students is necessary in disaster education. One of the most important elements in disaster education is to ensure continuity in disaster preparedness (Seddighi et al., 2022). In order to ensure continuity and active participation, disaster education should be carried out comprehensively and should not be limited to the level of knowledge but should also cover skills and application levels (Çakır, 2017). For this purpose, the use of digital technologies and technological devices in disaster education can offer students experiences close to real life with the repetition of different scenarios and the effect of visual stimuli (Stefan et al., 2023; Khanal et al., 2022; Shu et al., 2019). For example, the most important feature of virtual reality technologies used in disaster education is to create different scenarios and prepare individuals for disaster in a safe environment by exposing them to the risks closest to reality in these scenarios (Xu & Dai, 2022). As a matter of fact, students should be provided with different learning environments to gain various experiences from disasters (Avcı, 2019). In this context, learning environment in disaster education should be supported by various technological devices and learning models to attract students' attention and promote their active participation. A technology-supported 3E learning model can be effective in this sense.

Natural disasters are among the most dangerous problems of our time, and every society faces natural disasters, albeit differently. In this context, reducing and preventing natural disasters has become one of the most important issues (Zhang & Wang, 2022). Reducing and preventing natural disasters and minimizing risks and material and moral losses are only possible through effective disaster education. When disaster education is carried out in a long-term and sustainable manner, a correct culture towards disasters can be formed in society (Shiwaku & Fernandez, 2011). It is important to provide disaster education to individuals from an early age in order to create a culture towards disasters in society and to make the right behaviours towards disasters a habit (Khaerudin & Suharto, 2022). For this reason, an effective and interesting disaster education suitable for today's conditions should be realized. As a matter of fact, the transition to digitalization in education has accelerated, and digital technology has been included in the teaching process (Kuncoro et al., 2023). In this context, in order to make disaster education more effective, technological devices and different teaching models should be included in the teaching process, and digital technology should be utilized. Disaster education, which will be realized by utilizing technological devices and digital technology, is important for creating a disaster-sensitive and prepared society. For this reason, this research aimed to investigate the effect of a technology-supported 3E learning model on middle school students' knowledge levels about natural disasters and their attitudes towards disaster preparedness and to determine students' opinions.

When the literature is examined, Ronan et al. (2015) state that disaster education programs reveal positive results in terms of reducing risks related to disasters

and increasing resilience. Mızrak (2018) stated that providing disaster education is important in creating a resilient society against disasters; Özmen and İnce (2017) stated that teachers, students, and parents gave positive feedback to school-based disaster education programs. Shiwaku et al. (2007) revealed that students should take an active role in disaster training.

It may be useful to examine worldwide social and technology trends to address the question of how disaster education should be. Among these trends, the concepts “Society 5.0” and “Industry 4.0” have been frequently used in recent years to refer to the transformation caused by technological innovations in the social and industrial fields (Sakurai & Shaw, 2022). Society 5.0 can be defined as a human-centred but technology-based society in which technology is integrated into the flow of normal life (Yacan, 2021). Industry 4.0 can be defined, in general terms, as the ability of machines to communicate with each other, faster and cheaper production, and digitalization in line with advancing technology. However, it is argued that the impact of these paradigms will spread not only to the field of production but also to many other areas (Soylu, 2018). Indeed, the effects of Industry 4.0 and Society 5.0 will spread to the field of education and lead to differences. In this context, it is essential to provide today’s students with digital skills such as software and coding, data science, artificial intelligence, and digital literacy. With the effect of digitalization in education and the emergence of digital skills, it is necessary to use digital opportunities, especially in disaster education. Taking into account Industry 4.0, Society 5.0, digitalization, and other concomitants, this research intensively supported the 3E learning model using innovative technologies in the learning process.

With an innovative approach, the 3E learning model was supported by technologies such a virtual reality headset, a 360-degree 4 K action camera, a live-streaming drone, and digital games. Tsai et al. (2015) found that digital game-based disaster education had a positive effect on students’ motivation and learning. As a matter of fact, the power of games to appeal to individuals of all ages is important for ensuring active participation in disaster education, generating solutions, developing cooperation, and creating a discussion environment (Gampell et al., 2017). Simulations, digital games, and video games can be used in disaster education. Toyoda (2018) developed a methodology for the use of simulation in disaster education and showed the use of simulations in disaster education to be a successful method for society and students. Tsai et al. (2019) developed a game-based learning package for flooding protection using the learning cycle. They observed a significant increase in students’ disaster prevention skills and interest in learning. Considering all these results, the use of technology in disaster education seems to be effective.

A scientific study on a subject that concerns the whole society, such as disasters, using technological devices, which are developing but new for educational environments, will make a significant contribution to the literature and future studies. It is hoped that the use of digital games together with the 3E learning model in this research will serve as a guide for innovative teachers. The use of digital games and technological devices in the study will create a resource for scientists working on this subject and teachers working as practitioners and will pave the way for the production of innovative ideas.

This research aimed to investigate the effect of the technology-supported 3E learning model on middle school students' knowledge of natural disasters and attitudes towards disaster preparedness, and to explore their relevant views. To this end, the effect of this learning model on the variables of knowledge and attitude was examined. Disasters have negative economic, social, physical, and psychological effects on individuals (Altun, 2018). These negative effects of disasters can be reduced by informing individuals and the active use of this information before, during and after the disaster. Therefore, it is of critical importance to find out how to improve students' knowledge about disasters. Attitude is another variable examined in this research because students' attitudes towards what needs to be done for disaster preparedness and not to be helpless in the face of disasters is important in disaster education.

1.1 Literature review

Learning cycles were developed within the framework of Piaget's mental development theory and constructivism for use in science subjects (Demir & Maskan, 2014). The learning cycle is based on an approach that ensures students' active participation in the teaching process (Marfilinda et al., 2019). The learning circle ensures that learning takes place through experiences and can be used in the teaching process (Adesoji & Idika, 2015). Classes taught using the learning cycle are stated to have advantages over the traditional approach (Ören & Tezcan, 2008). Nuhoğlu and Yalçın (2006) also emphasised that the learning circle improves research skills and creative thinking and provides opportunities to apply new concepts to new situations. Musanni et al. (2015) also highlighted the prominent feature of learning circles in encouraging students to explore.

The first model of learning circles is the 3E learning model. The 3E learning model was introduced by Robert Karplus at the University of California in the 1960s. After the popular 3E learning model, the 5E and 7E learning models were also introduced. The learning circles of the 3E learning model are named as exploration, concept development (explanation), and concept application (expansion/elaboration).

At the exploration stage, students draw on their own experiences and prior knowledge (Haliqah et al., 2022). They communicate with their classmates and make predictions (Türkmen, 2006). The purpose of this stage is to help students systematically and critically observe and construct new ideas and theories (Mahendra et al., 2020).

The concept development stage is also referred to as explanation. At this stage, students learn and explain concepts through group discussions (Türkmen, 2006). Various activities such as discussions can be conducted at this stage to ensure that students connect new learning with prior knowledge (Haliqah et al., 2022). As a result of this stage, valid hypotheses are put forward by students (Musanni et al., 2015).

The concept application or elaboration phase is the stage where students demonstrate and apply the knowledge and skills that they have learned. At this stage, experiments, reading, films, and discussions can be used. Concepts are expanded through various sources. In this way, students try to establish a relationship between their daily life and concepts (Türkmen, 2006). This last stage of the 3E learning model involves doing practices and activities regarding the subject that students have conceptualised (Haliqah et al., 2022). The purpose of these activities is that students

adapt and apply their new learning in new situations and use new concepts (Kristiana et al., 2020; Küçükyılmaz, 2003).

This research aimed to investigate the effect of the technology-supported 3E learning model on middle school students' knowledge of natural disasters and attitudes towards disaster preparedness, and to explore their relevant views. Regarding the effect of learning cycles on disaster education, no study on the 3E learning model was found. The effect of 5E learning model on disaster education has been investigated in very few studies (Güven & Özünel, 2023; Carignan & Hussain, 2016; Goh & Sun, 2015; İltir & Ünal, 2014). On the other hand, it has been determined that digital games (Çoban & Göktaş, 2022; Hu et al., 2022; Winarni et al., 2021; Gampell et al., 2020; Caroca et al., 2019; Sudarmilah et al., 2019; Tanes & Cho, 2013) and virtual reality (Rajabi et al., 2022; Krnjic & Cvetkovic, 2021; Liang et al., 2018; Li et al., 2017; Caroca et al., 2016) have been increasingly studied in disaster education. In addition, there are no studies on the use of drones and 360-degree videos in disaster education. This study differs from other studies in terms of examining how the 3E learning cycle will affect the learning environment in disaster education by supporting it with technological materials and platforms such as digital games, virtual reality, drone, 360-degree videos.

The research conducted for this purpose will contribute to the studies on disasters, which is one of the most important problems of societies from past to present, the effect of technological devices, which are newly included in the education and training process, on disaster education will be examined and it will shed light on researchers and teachers in both material and intellectual sense. As a matter of fact, there is no definite judgement about the materials that can be used in disaster education in the literature, and the benefits that many materials will provide to the teaching process are also a matter of discussion. The study will show how today's digital generation affects the learning process by using devices and applications such as virtual reality goggles, 360-degree 4 K action camera, instant image transferring drone and digital game that emerged as a result of technological developments as materials in disaster education. This situation will clarify the ideas of the students, who are the data source of the research, about the technology-supported teaching process, and will help to create new ideas about the disaster education process by revealing their knowledge levels and attitudes towards disaster preparedness. In line with the contributions of the research to the literature, research questions were determined, and answers were sought to improve disaster education.

The research questions of this study are as follows:

What is the effect of using technology-supported 3E learning model activities compared to traditional social studies textbook activities on students' academic achievement scores?

What is the effect of using technology-supported 3E learning model activities compared to traditional social studies textbook activities on students' Disaster Preparedness Attitude scores?

What are the students' views on the effect of technology-supported 3E learning model activities on their academic achievement and disaster preparedness attitudes?

2 Methods

2.1 Research design

This research used both quantitative and qualitative data to explain how the technology-supported 3E learning model changes the learning environment. To this end, it used an explanatory sequential mixed methods design. A pretest-posttest control group quasi-experimental design was used in the quantitative part of the research, and a case study was used in the qualitative part.

The experimental group was taught using the technology-supported 3E learning model, while the control group was taught using the activities in the social studies textbook. The independent variable of the research was the technology-supported 3E learning model, and the dependent variables included students' knowledge of disasters and their attitudes towards disasters.

2.2 Sample

The 5th grade students selected by a simple random sampling method from two branches of a public school in the Aydın district of Efeler province were included in the study. The academic achievement and socioeconomic level of the school are similar to the city average. There are six 5th grade classes in the school. The disaster preparedness attitude scale and achievement test were applied to all of these classes as a pretest. According to the pre-test results, the two branches that were at the closest level to each other were randomly assigned as experimental and control groups. Thus, cognitive and affective differences between the branches were tried to be minimised. In addition, the social studies teacher in the branches included in the study was the same person. The age range was within 10 to 12 years. 17 students (9 girls and 8 boys) took part in the experimental group, and 16 students (10 girls and 6 boys) took part in the control group. In the qualitative part of the research, semi-structured interviews were held with 8 students (5 girls and 3 boys) in the experimental group. Demographic information about the students in the study group is presented in Table 1.

Table 1 Demographic information about the students in the study group

	Age	Girls	Boys	General
Experiment	10	2	2	17
	11	6	5	
	12	1	1	
Control	10	2	1	16
	11	6	5	
	12	2		
Interview group	10	1	1	8
	11	3	2	
	12	1		

2.3 Data collection tools

The data were collected using an achievement test and semi-structured interview questions developed by the researchers, and the Disaster Preparedness Attitude Scale developed by Çakır and Kılcan (2022).

2.3.1 Achievement test

The achievement test was developed by the researchers. The researchers prepared 43 questions considering the learning outcomes related to disasters in the 5th-grade social studies curriculum. The appropriateness of the questions in the question pool created by the researchers to the students' level of comprehension and understanding was examined through focus group interviews. At the end of focus group interviews, two questions were revised. Then, expert opinion was sought to check the appropriateness of the questions in terms of their scope, language, level, measurement, and evaluation. In this context, support was received from two social studies education experts, two social studies teachers, two measurement and evaluation experts, and one Turkish education expert. As suggested by the experts, three questions were deleted from the test, and two questions were revised.

After the focus group interviews and expert opinions, the four-choice 40-item question pool was piloted with a group 113 students attending the 6th grade in the same school to check the validity and reliability of the test. Standard deviation (S_j), variance (S_j^2), index of discrimination (r_{jx}), index of difficulty for the upper and lower groups (P_{ul}) and for the total sample (P), pointed-biserial correlations (r_{Pbis}), and corrected item-total correlations were computed to analyse the pilot test data. Items 2, 5, 7, 9, 10, 14, 15, 17, 18, 24, 26, 27, 32, 35, 38, and 40 were found to decrease validity and reliability; thus, they were removed from the test. The final version of the achievement test consisted of 24 items in total. Table 2 shows the data about the final test.

As seen in Tables 2 and 24 items remained in the test as a result of the item analysis. According to the analysis results, the KR-20 value was 0.819, the mean was 12.84, the variance was 28.85, and the standard deviation was 5.08 for the entire test. According to the literature, the lower limit of the reliability value was 0.70 (Büyükoztürk, 2007). Accordingly, the achievement test can produce valid and reliable results.

2.3.2 Disaster preparedness attitude scale

Disaster Preparedness Attitude Scale was developed by Çakır and Kılcan (2022) in 5-point Likert type. The scale was developed by collecting data from 465 students studying in the 5th, 6th, and 7th grades. The scale is a one-factor scale consisting of 20 items in total, including 12 negative and 8 positive items. An example of negative statements in the scale is "It is unnecessary to take individual precautions against disasters". An example of positive statements is "Risks that may cause disasters should be identified in advance". The lowest score that can be obtained from the scale is 20, while the highest score is 100. The total variance explained by the scale

Table 2 Final item analysis

Upper-Lower groups					Total sample		
Item no.	Standard deviation (Sj)	Variance (Sj ²)	Discrimination index (rjx)	Item difficulty (p _{ul})	Item difficulty (p)	Point-Biserial correlation (rPbis)	Corrected item-Total correlation
1	0.48	0.23	0.61	0.63	0.64	0.42	0.34
3	0.49	0.24	0.45	0.39	0.41	0.40	0.32
4	0.41	0.17	0.42	0.79	0.79	0.43	0.36
6	0.48	0.23	0.58	0.65	0.70	0.52	0.45
8	0.49	0.24	0.35	0.60	0.63	0.36	0.28
11	0.49	0.24	0.35	0.60	0.65	0.33	0.25
12	0.50	0.25	0.65	0.48	0.54	0.48	0.40
13	0.41	0.17	0.42	0.79	0.83	0.46	0.40
16	0.48	0.23	0.71	0.65	0.71	0.54	0.47
19	0.50	0.25	0.48	0.47	0.42	0.38	0.29
20	0.49	0.24	0.39	0.42	0.43	0.38	0.29
21	0.50	0.25	0.68	0.56	0.63	0.49	0.41
22	0.49	0.24	0.42	0.40	0.39	0.39	0.31
23	0.47	0.22	0.39	0.32	0.27	0.36	0.28
25	0.50	0.25	0.77	0.52	0.51	0.60	0.53
28	0.50	0.25	0.68	0.53	0.51	0.49	0.41
29	0.50	0.25	0.45	0.55	0.49	0.37	0.28
30	0.50	0.25	0.71	0.55	0.55	0.57	0.50
31	0.50	0.25	0.55	0.50	0.46	0.47	0.39
33	0.50	0.25	0.52	0.48	0.44	0.44	0.36
34	0.50	0.25	0.45	0.55	0.53	0.45	0.37
36	0.49	0.24	0.48	0.40	0.42	0.37	0.29
37	0.50	0.25	0.48	0.53	0.57	0.40	0.32
39	0.49	0.24	0.48	0.40	0.33	0.44	0.37

was found to be 31.89%. The Cronbach's alpha coefficient of the scale was found to be 0.88.

2.3.3 Interview questions

The researchers formulated 11 interview questions. In general terms, the questions were focused on determining students' level of prior knowledge and awareness about disasters, enabling them to evaluate the teaching activities used, revealing the acquired knowledge and skills, and receiving suggestions for the teaching process. Care was taken to prepare the questions for both cognitive and affective domains. Expert opinion was sought from two social studies education experts, two social studies teachers, one measurement and evaluation expert, and one Turkish education expert. In line with expert opinions, one question was revised.

2.4 Experimental procedure

A 6-week experimental procedure was planned to examine the effect of the technology-supported 3E learning model on disaster education. Lesson plans and learning materials were prepared in line with the literature and expert opinions.

Then, a meeting was held at the school where the experimental procedure was conducted in the presence of the research team, the school principal, the vice principal, and two social studies teachers who had classes in the 5th-grade sections. The research team made a presentation about the research at the meeting. The opinions of the school administration and teachers about the research were taken. Social studies teachers were also asked for opinions about measurement tools, lesson plans, and materials.

The school had six 5th-grade sections. The Disaster Preparedness Attitude Scale and the achievement test were administered as a pretest to all the sections. Two sections that had the closest scores on the pretests were selected as the experimental and control groups.

One week before the experimental procedure, the experimental and control group students were informed about the procedure. After all the students confirmed their voluntary participation in the research, they were given a participant consent form and asked to return the forms one week later.

The experimental procedure lasted for six weeks. Predetermined lesson plans were followed in the experimental and control groups throughout the experimental procedure. During the experimental procedure, the planning and implementation of classes in both groups were managed by the research team.

The lessons were planned in the experimental group using technology-support content and following the 3E learning stages (i.e., exploration, concept development, and concept application). The lessons were taught in the control group following the activities and processes defined in the social studies textbook.

The 5th-grade People, Places and Environments unit has five learning outcomes. Four of them are directly related to disasters. These four learning outcomes were taught in the experimental group using the technology-supported 3E learning model. Table 3 shows the content of the lesson plan.

2.5 Data collection and data analysis

The research procedure was conducted within the scope of the People, Places and Environments unit of the social studies class. The experimental procedure lasted for six weeks. Pretests were administered before the experimental procedure, and post-tests and interviews were conducted after the experimental procedure. Retention tests were administered six weeks after the experimental procedure.

Within the scope of the research, a number of methodological strategies were used to ensure the validity and reliability of the qualitative data. The interviews were conducted by the researchers. The interviews were conducted in an empty classroom at the school in a quiet environment. Each interview session was conducted separately with the student alone, so that the students could express their thoughts freely without the potential influence of their peers. Before the interviews, the students were

Table 3 Information about the activities

Title of the activity	Description of the activity	Duration	Materials	Methods and techniques
Climate and people	VR glasses were introduced, and information was given about their use. Videos about the natural disasters, i.e., floods and storms, were watched using VR glasses. The web-based game was played with students.	4 class hours	VR glasses, web-based game	3E learning model, Q&A, group learning
Places to live	A drone was introduced. The students were taken to the garden, and the place where they were living was filmed using a drone. The effect of natural and human features on the population and settlement was examined through drone videos. The natural disaster risks of their place of residence were examined. A web-based game about a forest fire and avalanche was played. The impact of these natural disasters on the population and settlement was analysed using the web-based game.	5 class hours	Drone, VR glasses, web-based game	3E learning model, discussion, Q&A, brainstorming, group learning
Natural disasters, environmental problems and their impacts	Earthquake videos were watched using VR glasses. Together with the students, a drone was flown, and shooting were done using a 360-degree 4 K action camera. Through the images taken with the 360-degree 4 K action camera, the earthquake preparedness level of their place of residence was examined. and brainstorming was done about potential problems in the event of an earthquake. A web-based game about earthquakes was played.	5 class hours	Drone, 360-degree 4 K action camera, web-based game	3E learning model, discussion, Q&A, brainstorming, group learning
The impact of natural disasters on our lives	Videos about drought, landslides, and erosion in our country were watched using VR glasses. Arid areas, landslide-prone areas, and eroded areas in their place of residence were examined. Brainstorming was done about the effects of these disasters on social life. A web-based game was played.	4 class hours	VR glasses, web-based game	3E learning model, discussion, Q&A, brainstorming, group learning

given the necessary information about the interview, and they were asked to sign an informed consent form about taking audio recordings and voluntarily participating in the interviews. After the interview, these voice recordings were played to the students, and their approval was obtained. They were then asked whether there was anything they wanted to add or not. Those who wanted to add were taken into consideration. The interviews lasted approximately 55 min. The interviews were transcribed by the researchers. As a result of this transcript, it was determined that the interviews were 12 pages long. The interviews were independently content-analysed by two researchers using MAXQDA 2020 software. Analyses and data visualisation were carried out in a systematic and organised manner through MAXQDA 2020 software. In the content analysis, codes, categories, and themes were first created by following an inductive approach that would provide a comprehensive understanding of students' learning experiences through an iterative process. The Kappa coefficient was used for inter-coder reliability. In this framework, a ratio of 0.87 was obtained, and it was

seen that a strong agreement was achieved. Inconsistencies were resolved through discussion and reference to the original transcripts, with extensive discussions until consensus was reached. In reporting the qualitative analyses, direct quotations from the interviewees were used for interpretation. The consistency of the findings was examined by comparing the results between the qualitative and quantitative data sources as well as the participant interviews. SPSS and Microsoft Excel programmes were used to analyse the quantitative data of the study. In the analysis of quantitative data, analyses were carried out with a double coder.

ANCOVA and Repeated Measures ANOVA analyses were used to analyse the quantitative data within the scope of the research. For the validity and reliability of the findings of our research, it was checked whether some basic assumptions were met before the analyses. For ANCOVA, firstly, it was determined that the data were normally distributed by looking at the skewness and kurtosis values and histogram graphs. Then, Levene's test was performed to determine the equality of the variances of the scores of the dependent variable for each of the groups. By examining the scatter diagrams, it was determined that there was a linear relationship between the pretest and posttest scores of the groups. Finally, the homogeneity of regression trends was analysed.

Repeated Measures ANOVA has three main assumptions: normality, independence, and sphericity. In this context, firstly, it was determined that the data were normally distributed by looking at the skewness and kurtosis values and histogram graphs. Secondly, Levene's test was used for equality of error variances. Levene's test showed that homogeneity of variances can be assumed since variances are equal between groups and time points. Thirdly, Mauchly's test of sphericity was used to test sphericity. Mauchly's test of sphericity showed that the assumption of sphericity was met for the two-way interaction. The results showed that the assumption of sphericity was met as the observed significance value was greater than 0.05.

3 Results

3.1 Achievement

A repeated measures ANOVA was used to examine the statistical difference between the achievement pretest, posttest, and retention test scores of the experimental group students. The analysis results are shown in Table 4.

Table 4 Results of the repeated measures ANOVA

Sources of variation	Sum of squares	df	Mean square	F	<i>p</i>	Significant difference	η^2
Between-subjects	433.412	16	27.088				
Pre-Post-Retention	352.588	1.104	319.249	13.138	0.002*	1–2	0.451
Error	429.412	17.671	24.301			1–3	
Total	1.215.412	18.791	370.638				

* $p < .05$

Table 5 Results of the repeated measures ANOVA

Sources of variation	Sum of squares	df	Mean square	F	<i>p</i>	Significant difference	η^2
Between-subjects	915.000	15	61.000				
Pre-Post-Retention	28.792	1.303	22.099	1.367	0.267	-	0.084
Error	315.875	19.542	16.164				
Total	1.259.667	20.860	99.263				

* $p < .05$ **Table 6** ANCOVA results

Source of variance	Sum of squares	df	Mean square	F	<i>p</i>	η^2
Pre-test	39.193	1	39.193	1.472	0.234	0.047
Group	131.148	1	131.148	4.926	0.034*	0.141
Error	798.686	30	26.623			
Total	969.027	32	196.964			

* $p < .05$

Because Mauchly's sphericity test did not validate the repeated measures ANOVA ($W(2)=189$; $p=.000$), the Greenhouse-Geisser correction was used. Accordingly, there was a statistically significant difference with a large effect size between the pretest, posttest, and retention test scores ($F(1.104, 17.671)=13.138$; $p=.002$; $\eta^2=0.451$). The results of the Bonferroni multiple-comparison test showed that there was a difference between the pretest ($\bar{X}=11.12$) and the posttest ($\bar{X}=16.94$) in favour of the posttest scores, and between the pretest ($\bar{X}=11.12$) and retention test ($\bar{X}=16.41$) in favour of the retention test scores. There was no statistically significant difference between the posttest ($\bar{X}=16.94$) and retention test ($\bar{X}=16.41$) scores.

A repeated measures ANOVA was used to examine the statistical difference between the achievement pretest, posttest, and retention test scores of the control group students. The analysis results are shown in Table 5.

Mauchly's sphericity test did not validate the repeated measures ANOVA ($W(2)=0.465$; $p=.0005$). According to the Greenhouse-Geisser correction results, there was no statistically significant difference between the pretest, posttest, and retention test scores of the control group students ($F(1.303, 19.542)=1.367$; $p=.267$; $\eta^2=0.084$).

An analysis of covariance (ANCOVA) was performed to examine the statistical difference between the experimental group and control group in their adjusted mean scores on the achievement posttest. The results are shown in Table 6.

According to the results of ANCOVA, there was a statistically significant difference with a large effect size between the experimental group ($\bar{X}=16.93$) and control group ($\bar{X}=12.95$) in their adjusted posttest means in favour of the experimental group [$F(1, 30)=4.926$; $p<.05$; $\eta^2=0.141$].

ANCOVA was performed to examine the statistical difference between the experimental group and control group in their adjusted mean scores on the achievement retention test. The results are shown in Table 7.

According to the results of ANCOVA, there was a statistically significant difference with a large effect size between the experimental group ($\bar{X}=16.40$) and control

Table 7 ANCOVA results

Source of variance	Sum of squares	df	Mean square	F	<i>p</i>	η^2
Pre-test	31.969	1	31.969	1.429	0.241	0.045
Group	141.846	1	141.846	6.340	0.017	0.174
Error	671.148	30	22.372			
Total	844.963	32	196.187			

p* < .05Table 8** Results of the repeated measures ANOVA

Sources of variation	Sum of squares	df	Mean square	F	<i>p</i>	Significant difference	η^2
Between-subjects	7792.510	16	487.032				
Pre-Post-Retention	5122.392	1.362	3761.015	10.104	0.002*	1–2	0.387
Error	8111.608	21.792	372.237			1–3	
Total	21.026.510	23.170	4.620.284				

p* < .05Table 9** Results of the repeated measures ANOVA

Sources of variation	Sum of squares	df	Mean square	F	<i>p</i>	Significant difference	η^2
Between-subjects	1793.979	15	119.599				
Pre-Post-Retention	481.292	2	240.646	3.130	0.058	-	-
Error	2306.708	30	76.890				
Total	4581.979	47	437.135				

**p* < .05

group ($\bar{X}$ = 12.26) in their adjusted retention test mean scores in favour of the experimental group [$F(1, 30) = 6.340$; $p < .05$; $\eta^2 = 0.174$].

3.2 Disaster preparedness attitude

A repeated measures ANOVA was used to examine the statistical difference between the pretest, posttest, and retention test scores of the experimental group students on the Disaster Preparedness Attitude Scale. The analysis results are shown in Table 8.

Mauchly's sphericity test did not validate the repeated measures ANOVA ($W(2) = 532$; $p = .009$). Thus, the Greenhouse-Geisser correction was used. Accordingly, there was a statistically significant difference with a large effect size between the pretest, posttest, and retention test scores ($F(1.362, 21.792) = 10.104$; $p = .002$; $\eta^2 = 0.387$). The results of the Bonferroni multiple-comparison test showed that there was a difference between the pretest ($\bar{X} = 46.94$) and the posttest ($\bar{X} = 67.59$) in favour of the posttest scores, and between the pretest ($\bar{X} = 46.94$) and retention test ($\bar{X} = 68.76$) in favour of the retention test scores. There was no statistically significant difference between the posttest ($\bar{X} = 67.59$) and retention test ($\bar{X} = 68.76$) scores.

A repeated measures ANOVA was used to examine the statistical difference between the pretest, posttest, and retention test scores of the control group students on the Disaster Preparedness Attitude Scale. The analysis results are shown in Table 9.

Table 10 ANCOVA results

Source of variance	Sum of squares	df	Mean square	F	<i>p</i>	η^2
Pre-test	653.252	1	653.252	2.520	0.123	0.077
Group	1313.967	1	1313.967	5.069	0.032*	0.145
Error	7776.615	30	259.221			
Total	9.743.834	32	2.226.440			

* $p < .05$ **Table 11** ANCOVA results

Source of variance	Sum of squares	df	Mean square	F	<i>p</i>	η^2
Pre-test	401.117	1	401.117	1.397	0.247	0.044
Group	1.219.224	1	1.219.224	4.245	0.048*	0.124
Error	8.616.879	30	287.229			
Total	10.237.220	32	1.907.570			

* $p < .05$

Mauchly's sphericity test validated the repeated measures ANOVA ($W(2)=0.879$; $p=.0406$). Accordingly, there was no statistically significant difference between the pretest, posttest, and retention test scores ($F(2, 30)=3.130$; $p=.058$).

ANCOVA was performed to examine the statistical difference between the experimental group and control group in their adjusted posttest mean scores on the Disaster Preparedness Attitude Scale. The results are shown in Table 10.

According to the results of ANCOVA, there was a statistically significant difference with a large effect size between the experimental group ($\bar{X}=67.21$) and control group ($\bar{X}=54.53$) in their adjusted posttest mean scores in favour of the experimental group [$F(1, 30)=5.069$; $p < .05$; $\eta^2=0.145$].

ANCOVA was performed to examine the statistical difference between the experimental group and control group in their adjusted retention test mean scores on the Disaster Preparedness Attitude Scale. The results are shown in Table 11.

According to the results of ANCOVA, there was a statistically significant difference with a medium effect size between the experimental group ($\bar{X}=68.47$) and control group ($\bar{X}=56.26$) in their adjusted retention test mean scores in favour of the experimental group [$F(1, 30)=4.245$; $p < .05$; $\eta^2=0.124$].

3.3 Student views

Students' views on disaster education conducted using the technology-supported 3E learning model were subsumed under two themes: beneficial aspects and limitations. The theme of beneficial aspects is divided into the following categories: value acquisition, skill learning, experiencing, student motivation, academic achievement, and disaster education. The theme of limitations, on the other hand, includes three codes: feeling anxiety and fear, challenges to reality, and challenges in terms of expanding the target audience. Figure 1 shows the results of the content analysis.

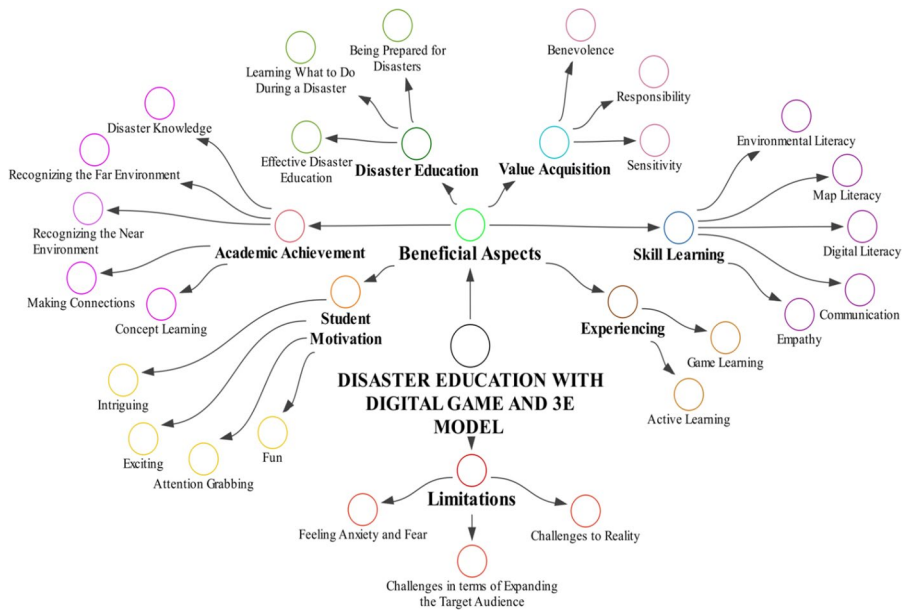


Fig. 1 The hierarchical code-subcodes model of disaster education with technology-supported 3E learning model

3.3.1 Values and skills

The codes in the ‘value acquisition’ category include benevolence, sensitivity, and responsibility. The codes in the ‘skill learning’ category include environmental literacy, map literacy, digital literacy, communication, and empathy.

During disaster education, students’ willingness to actively participate in activities, to help others under possible conditions, to take action against disaster situations, to be prepared and conscious of disasters might be effective in the development of these values and skills. For example, AE: “*We built sturdy houses and schools, we planted moist trees in places where there were fires, we located schools and hospitals in safe places.*” EL: “*When I see people experiencing disasters, I realise it could happen to me, so I empathise. In the event of an earthquake or fire, I have to be patient and give blankets to whoever needs.*” ER: “*I have to help those who are damaged in the earthquake and fire. Disasters can happen all over our country, so we must take measures to protect our country.*” SE: “*I learned to be patient in disasters, and I learned how to be a responsible and benevolent person.*” Although the students’ statements reveal that they have acquired many values and skills, it is seen that their sensitivity has developed, especially within the framework of values, and their empathy skills have developed within the framework of skills.

The students knew that they need to inform relevant institutions and organizations in case of emergencies, and they do this in possible scenarios. This shows that they have developed responsibility. For example, AE: “*I tell my relatives what I learn about disasters. I tell them to stay calm during the earthquake and call AFAD for help.*” YA: “*I learned that I have to help the Turkish Red Crescent at the time of*

the incident.” YU: “When disaster strikes, you should stay calm and call for help. When there is flooding in the house, we unplug electrical devices and move to higher ground and wait for help to arrive.” RB: “If there is a fire in the house or in our neighbourhood, I immediately unplug all electrical appliances and then call AFAD.” SE: “If there is an earthquake at school, I rescue those who are trapped and call AFAD.” These expressions, which show the importance of cooperation, solidarity, and communication during and after disasters, reveal that students are able to look at emergencies such as disasters from a broader perspective.

3.3.2 Experiencing

The experiencing category includes two codes: game learning and active learning. During disaster education, students played games to learn what to do in the disaster preparation phase and in the face of disasters and took an active part in the process. Thus, it apparently promoted their learning by experiencing. For example, NS: “In this class, we read wrote about disasters, and learned what we need to do in disasters through games.” SE: “In the game, we saved trees and moved the school and hospital to safe places. This game is necessary to save people. If houses are resistant, people will be saved.” YU: “This game showed me how important it is to build solid buildings and help people.” EL: “We played games, I learned about disasters through VR glasses.” RB: “The game allowed me to learn disaster preparedness.” It can be concluded from these statements that students both practiced and learned by experiencing thanks to the materials used in the classed. As a matter of fact, while the 3E learning model supports learning by experience and active learning and ensures student participation in the lesson; it allows the process to be student-centred.

3.3.3 Student motivation

The following codes are included in the student motivation category: intriguing, exciting, attention grabbing, and fun. The students stated that they were curious and had fun during the disaster education conducted using the technology-supported 3E learning model because the activities called their attention. For example, AE: “In this lesson, our teachers showed us some tools. Of course, I was curious about them. They brought virtual goggles and drones to our classes.” NS: “The game was a lot of fun. In the game, we played erosion, earthquakes, fires, avalanches. In the fire, we cut down dry trees and planted moist trees. We demolished the damaged houses and moved the hospital and school to safety. With this game, I learned more about how to protect from natural disasters and what I need to do.” RB: “In this class, I saw materials that caught my attention. When I saw these, my excitement for classes rose a lot. Our teachers taught us about disasters, we flew drones, wrote, and played games.” YU: “I enjoyed playing games about the disaster.” The students’ expressions show that their motivation and willingness towards the lesson are at very high levels. In addition, it can be concluded from these statements that the students are willing to learn the subjects and learn by having fun, thanks to the remarkable effect of technological devices and the effect of the 3E learning model that allows practice.

3.3.4 Academic achievement

The codes in the academic achievement category are as follows: disaster knowledge, recognizing the far environment, recognizing the near environment, making connections, and concept learning. It can be said that students have information about disasters, learn about disasters that may occur in their environment and other regions, and make connections with disaster concepts. For example, YA: *“Before this education, I only knew about earthquakes, floods, and fires. I feel prepared for disasters because when there is an earthquake, I drop, cover, and hold on. When there is a fire, I leave the area, and when there is a flood, I get to higher ground. I know about disasters; I know what to do and who to call in the event of an earthquake and.”* YU: *“I learned which disasters are seen in which regions in Turkey. For example, there is much drought in Central Anatolia and vegetables dry out in the fields. There is also drought in Southern Anatolia and here too, vegetables dry out and this damages the economy. An earthquake may hit the Aegean region, and many houses are destroyed. In the Black Sea, when it rains a lot, there are floods.”* ER: *“In the classes, regions were shown on maps. We flew drones and watched our surroundings. They talked about the game’s relevance to disasters. I realized that we do not know much about disasters. Our teachers always gave us examples of disasters. For example, there are a lot of earthquakes in the Aegean region where we live, and they told us to be prepared.”* EL: *“In this education, I learned about the geographical regions.”* NS: *“With this game, I learned how to protect myself from natural disasters and what we need to do. I learned how to drop, cover, and hold on in an earthquake.”* In the interviews, the students emphasised not only the effects of disasters on people but also the effects on the environment and mentioned the necessity of protecting the environment from disasters. They also stated that they learned what they should do before and during disasters.

3.3.5 Disaster education

The codes in the disaster education category are as follows: being prepared for disasters, learning what to do during a disaster, and effective disaster education. It seems that the students learned what to do before and during disasters, and the disaster education was effective. For example, ER: *“This disaster education was good. I would do the same.”* AE: *“We install sensors in places where there will be floods, and when the water comes in, the sensor works immediately. We also install smoke sensors on the tops of trees so that there are no fires in the forests. When there is a flood, we have to be calm and patient.”* EL: *“If there is an earthquake at school, I have to stay calm and go outside slowly. If there is a flood in the house, I will unplug electrical appliances and get to higher ground with my family.”* RB: *“I do not want anything to be change about this education. Because I learned all the information.”* YU: *“I did not know anything about disasters, I did not know what to do if something happened to me. I feel prepared for disasters now. I prepared an earthquake bag at home. This bag contains water, medicines, money, phone, and food. Yes, I feel knowledgeable about disaster. When disaster strikes, we should be calm and call for help. When there is flooding in the house, we unplug electrical devices and move to higher ground and*

wait for help to arrive.” As a matter of fact, according to the students, the disaster education was instructive, comprehensive, beautiful, and made them feel prepared. This situation may have resulted from the cyclic structure of the 3E learning model. In this context, it can be stated that the use of technology-supported 3E learning models in the process of disaster education makes students more prepared for disasters.

3.3.6 Limitations

The codes under the theme of limitations are as follows: feeling anxiety and fear, challenges to reality, and challenges in terms of expanding the target audience. Regarding the limitations, the students stated that they were afraid of the anxiety and fear caused by disasters, drills could be more realistic, and disaster education should be given to wider masses. For example, NS: *“In these disasters, a more realistic earthquake drill could have been done.”* YA: *“I want all people to be knowledgeable about it.”* AE: *“All students should receive disaster education. We have to watch videos about disasters and tell people.”* NS: *“One day I went shopping with my mother. On the way out of the grocery store, we got caught in a storm, I was very scared, and my mom said it was a natural disaster. I do not feel very prepared for disasters because I am still scared.”* SE: *“All people should be given disaster education. They should have information about the disaster. I would inform the society. I would like to see more education activities about earthquakes.”* When the students’ statements about limitations are analyzed, especially the fear and anxiety they feel in the face of disasters, they come to the fore. These statements reflect the psychological effects of disasters on students.

4 Discussion, conclusion and recommendations

The research aimed to investigate the effect of the technology-supported 3E learning model on students’ knowledge about disasters and their attitudes towards disaster preparedness attitudes and to explore students’ opinions. According to the results of the analyses conducted to determine whether there was a significant difference between the pretest, posttest and retention test means of the experimental group students, it was determined that the achievement test scores of the experimental group increased significantly, and the effect size was large. The retention test means of the experimental group were statistically higher than the pretest means; however, there was no difference between the posttest and retention test means. This result shows that the technology-supported 3E learning model is effective and beneficial and promotes retention. Similarly, in the study conducted by Tsai et al. (2019), it was observed that students’ learning and awareness increased as a result of teaching using a digital game for flood protection and Kolb’s experiential learning cycle. The reason for this is the contribution of the digital game used in the study to motivation and the active use of the experiential learning cycle. In the study conducted by Tokaç et al. (2019), it was observed that using video games was more effective than traditional teaching methods in the classroom. According to the study, the factors that are effective in this case are game mechanics, knowledge and skills transferred through

the game, and the ease of skill transfer through the game. Gampell et al. (2020) stated that games can facilitate the learning process by providing active and experiential participation. Similarly, the digital game used in this study positively improved students' level of knowledge about disaster education and retention of learning and facilitated learning by allowing reinforcement through different scenarios. As a matter of fact, as Sudarmilah et al. (2019) stated, technology-assisted instruction using devices such as VR, digital games, and drones can be effective in disaster education because it provides fun learning opportunities and is attractive to students. In addition, in the study conducted by İltir and Ünal (2014), it is seen that the 5E learning cycle increases motivation and retention in individuals. In this study, in which the 3E model was used, the learning cycle was effective thanks to its features of arousing curiosity and excitement and being interesting.

According to the results of the analysis to determine whether there was a significant difference between the pretest, posttest and retention test means of the control group students, it was determined that there was no statistically significant difference between the pretest, posttest and retention test means of the control group. This finding suggests that textbook activities are not sufficient to increase students' level of knowledge about disasters. Musacchio et al. (2016) stated that audiovisual materials are one of the best ways of encouragement. However, the traditional methods and course contents that continue to be used today are far from encouraging, ordinary and inadequate. Değirmenci et al. (2019) stated that subjects related to disaster and disaster education are included in 4th, 5th, 6th and 7th grade social studies textbooks, but the content is limited to press sources; Kısı (2019) stated that when the Social Studies Course Curriculum is examined, the subjects and achievements related to disaster and disaster education are insufficient and not sufficiently associated with skills and values. The reason for the result of the study may be that the activities in the textbook cannot provide active participation in the lessons and are not innovative and interesting.

According to the results of the analyses performed to determine whether there was a significant difference between the adjusted mean scores of the experimental and control groups in the achievement posttest, it was determined that the experimental group students were statistically significantly more successful than the control group students. The effect size of the difference was large in favour of the experimental group. This finding indicates that the technology-supported 3E learning model is effective and leads to a grater increase in students' level of achievement in disaster education compared to textbook activities. Indeed, it seems that students' active participation in classes and their first-hand experiencing of the exploration, concept development, and concept application stages of the 3E learning model were influential in increasing their level of achievement. In the study conducted by Toyoda (2018), a game simulation was used in the scope of disaster education, and it was observed that the simulation facilitated the connection with reality, which resulted in more success compared to traditional disaster education. In the study conducted by Winarni et al. (2021), games were used for disaster education, and it was revealed that individuals were more successful than students who used presentations, thanks to the increase in their willingness to learn and motivation. Bhuiyan and Mahmud (2015) stated that digital game-based teaching is more informative and improves

subject-related skills compared to traditional teaching. The reason for this result is that the subject matter is appropriately integrated into the games used, and the reality, which is difficult and costly to experience, can be experienced by abstracting it. Güven and Özünel (2023) stated that students' academic achievement and attitudes towards technology increased in the study in which digital materials and the 5E learning model were used. Thus, in this study, the application of the discovery-concept definition-concept application stages of the 3E learning model in the teaching process and providing students with experience with digital games may have been effective in increasing their achievement levels about disasters. As a matter of fact, Hu et al. (2022) also revealed in their study that games offer a pleasant and effective learning process and make the lesson fun for similar reasons.

When the adjusted mean scores of the experimental and control groups from the achievement retention test were examined, according to the results of the analysis, the retention test scores of the students differed significantly in favour of the experimental group. This result shows that the technology-supported 3E learning model makes students' learning more permanent compared to the teaching based on textbook activities. In parallel with this result, Liang et al. (2018) revealed in their study that the use of VR makes teaching more effective than traditional methods thanks to the experiential advantage it provides. Telli and Deniz (2022) revealed in their study that the use of information technologies in teaching contributes positively to student achievement due to their benefits such as reinforcement, exemplification, and ease of access to information. In the study conducted by Şahin (2019), teachers stated that information technologies make teaching more effective due to their features such as enriching the teaching process, motivating students, and making the lesson fun. In another study, it was observed that individuals developed higher-level skills as a result of using their knowledge about disasters in different scenarios in the virtual environment (Caroca et al., 2016). Carignan and Hussain (2016) stated that students' motivation and learning increased in his study, in which he included the 5E teaching model. Similar to the results of other studies, materials such as VR, digital games, and drones used in this study within the framework of the 3E learning model enabled students to use their knowledge and skills in different scenarios, helped them learn by reinforcing them, contributed to their interest and motivation, made the lesson fun, and increased the retention of knowledge acquired through experiences. As Memiş and Babaoğlu (2020) stated, technological developments are very effective in disaster management and disaster risk reduction.

According to the results of the analysis conducted to determine whether there was a significant difference between the pretest, posttest and retention test means of the experimental group students, it was determined that the Disaster Preparedness Attitude Scale scores of the experimental group increased significantly, and the effect size was large. Their retention test scores were higher than their pretest scores; however, there was no statistically significant difference between their posttest and retention test scores. In fact, the technology-supported 3E learning model led to a significant increase in students' attitudes towards disaster preparedness. It is thus evident that the technology-supported 3E learning model enriches the learning process and makes students more aware of disaster preparedness. Similarly, in the study conducted by Tsai et al. (2015), a game was used in teaching where students could

face real-world flood disaster problems, and 98% of the participants of the game stated that they would pay more attention to disaster prevention issues. The most important factor affecting this result is that the students had the chance to learn about the flood disaster that they could not experience in the real world by experiencing it in a different and non-hazardous environment. The results of Tsai et al. (2015) and this study are similar. The digital game used in this study enabled students to learn by experiencing disasters during the teaching process. In this way, it can be stated that students became more conscious in terms of disaster preparedness attitudes. As Çoban and Göktaş (2022) stated, digital games offer an effective learning experience to raise awareness about natural disasters. While games help to overcome the lack of information about disasters faster, they also provide information about the equipment to be used during or after the disaster (Caroca et al., 2019). Goh and Sun (2015) showed that the 5E learning cycle increases creative and critical thinking in individuals through practical experiences and positively affects their learning. Underneath all these benefits, it can be said that the technology-supported 3E teaching model provides benefits such as experiencing, reinforcing, and using skills through different scenarios and facilitating access to information.

According to the results of the analysis to determine whether there was a significant difference between the Disaster Preparedness Attitude Scale pretest, posttest, and retention test means of the control group, no statistically significant difference was found between the pretest, posttest, and retention test means. This result indicates that textbook activities fail to ensure that students are prepared for disasters. A different study qualifying this result was conducted by Mani et al. (2016). When the study was examined, teaching about the volcanic eruption disaster was carried out only with a presentation to one group, while it was carried out with a video game for the other group. It was determined that the presentation method was less effective because it was ordinary and appealed only to a certain group. The reason for the inadequacy of the activities in the textbook can be expressed as the lack of diversification of the process, as in the teaching process carried out with the presentation, its mediocrity, and the inability to fully motivate the students. One of the most important elements in increasing the quality of education offered in the learning environment is to accept that each individual may have different learning styles and methods and to act accordingly. In this context, enriching the learning environment as much as possible with the materials and methods offered to students within the scope of this new paradigm, which is also referred to as differentiated instruction, is an important step for every student in the classroom environment to learn. In this context, it can be stated that the technology-supported 3E learning model can contribute to the cognitive and affective development of students through different materials and platforms during the experimental intervention process and has important potential.

When the adjusted posttest means of the Disaster Preparedness Attitude Scale of the experimental group and the control group were compared, the scores of the experimental group differed statistically significantly compared to the control group and the effect size was large. This indicates the technology-supported 3E learning model is more effective in helping students acquire essential knowledge, skills, values, and learning outcomes to be prepared for disasters compared to teaching with textbook activities. In the study conducted by Thangagiri and Naganathan (2016),

it was observed that students who received digital game-based disaster education were more open to learning. This was attributed to the fact that digital game-based teaching is interactive, engaging, and effective for cognitive learning. Krnjic and Cvetkovic (2021) revealed in their study that technology-supported teaching is very effective because it provides correct behavior and practical experience, especially simulations, which have an excellent effect on disaster education. In another study, a 3E-like model consisting of various stages that provide individuals with opportunities such as flexibility, exploration, and reinforcement was used, and it was observed that students improved in terms of skills to reduce the damages of disasters (Atmojo et al., 2017). Thus, the higher scores and effect size of the experimental group students on the Disaster Preparedness Attitude Scale may be based on the fact that the technology-supported 3E teaching model similarly makes the lesson interactive and experience-oriented, making students more interested and more open to learning.

When the adjusted retention means of the Disaster Preparedness Attitude Scale of the experimental group and the control group were compared, the scores of the experimental group differed statistically significantly compared to the control group and the effect size was medium in favour of the experimental group. It can be stated that teaching using the technology-supported 3E learning model is more effective in ensuring the retention of disaster preparedness attitudes. Mani et al. (2016) stated that games are effective for students in terms of hazard awareness and disaster preparedness thanks to their realism and communicative features. Li et al. (2017) revealed that technology-supported teaching using tools such as virtual reality and digital games is more successful by providing immersive experiences to individuals. In this study, the reason why the teaching carried out with the technology-supported 3E teaching model in the experimental group was more successful in the disaster preparedness attitude scale compared to the control group may be that the technology-supported 3E learning model in the experimental group helped to increase the knowledge and attitude required for pre-earthquake preparation, during, and after earthquake interventions by providing realistic and interactive experiences. In addition, it can be said that the games continue their development in terms of disaster education by giving individuals the opportunity to make reinforcement with the advantage of replaying (Tanes & Cho, 2013). In the study conducted by Çakır and Kılcan (2022), scenario-based disaster education was carried out, and factors such as active participation, motivation, effective teaching, and suitability to real life positively affected students' academic achievement and attitudes compared to traditional teaching methods. As a result, reinforcing the experiences of individuals through different and new scenarios and reusing the acquired skills through the technology-supported 3E teaching model may have made disaster education more permanent.

According to the results of the content analysis, which analysed students' views on the effect of technology-supported 3E learning model activities on their academic achievement and disaster preparedness attitudes, the technology-supported 3E learning model helped develop skills such as environmental literacy, map literacy, digital literacy, communication, and empathy, as well as values such as responsibility, sensitivity, and benevolence. Bhuiyan and Mahmud (2015) stated in their study that digital game-based teaching improves student skills related to the targeted subject, with the advantage of gaining experience. This is in parallel with the result of the study.

The technology-supported 3E teaching model, which is also effective in increasing students' attitudes towards disaster preparedness, increases their motivation towards the course and increases their academic achievement and retention of the acquired knowledge. In addition, it shows that it helps students learn by experiencing and that effective disaster education is realized by learning what to do before and during the disaster. Rajabi et al. (2022) also stated that training through VR will be effective and will allow experiencing and reinforcing by using different scenarios. In their study, Moradian and Nazdik (2019) revealed that games are more effective than traditional methods in terms of both students' knowledge level and disaster risk management (preparation, what to do in case of disaster, etc.) thanks to their motivating and interactive nature. It can be stated that these qualitative results that emerged with the use of the technology-supported 3E teaching model used in this study and the use of technological devices in the teaching process are due to the reasons such as active participation, reinforcement, experimentation, student motivation and motivation mentioned in previous research results.

Considering the loss of life and property and the environmental damage caused by disasters, it is critical for societies to always be prepared for and conscious of disasters. Thus, it is of utmost important to ensure that individuals living in places with high disaster risk are prepared for disasters and develop necessary knowledge and attitudes through education at an early age. Taken together, the results of the research show that the technology-supported 3E learning model is more effective in disaster education than traditional teaching with textbook activities, promotes the acquisition of knowledge and attitudes, positively affects academic achievement, increases learning motivation, offers opportunities for learning by experiencing, and enables students to be prepared for disasters.

Limitations and suggestions within the scope of the research are as follows:

In this research, achievement tests, attitude scales, and interview questions were used as data collection tools. In addition to these tools, alternative data collection tools such as performance-based measurements and disaster scenario simulations can be used. This approach will enrich the interpretation of the findings and provide valuable insights for a more comprehensive understanding of the effectiveness of disaster education interventions.

The technology-supported intervention carried out within the scope of the research requires a hardware cost that may not be available in all educational environments. At this point, public and private sector-supported projects can be utilised for the procurement of devices. In order to increase feasibility, it may be useful to make lower-cost adaptations by making cost analyses. For example, 360-degree videos watched during disaster training can be watched on devices such as a TV or smart board. In addition, videos and games on disaster education do not have sufficient diversity yet. In this context, designing projects focusing on developing materials and resources for disaster education can be useful in terms of ensuring the long-term sustainability of these interventions.

In order to use these technological devices and digital platforms as an effective teaching environment and material, it would be useful to develop teachers' professional competences on this subject during the undergraduate period. For example, during the undergraduate period, it may be useful to inform teachers in field edu-

cation courses such as Social Studies Learning and Teaching Approaches, Material Design in Social Studies Teaching, Information Technologies in Social Studies, Science, Technology, and Society, Social Studies Teaching, Disasters and Disaster Management, professional knowledge courses such as Teaching Principles and Methods, Instructional Technologies, and general culture courses such as Information Technologies.

When using 360-degree videos or ready-made videos in disaster training, whether the content is suitable for the age and mental health of the target audience should be handled with a pedagogical approach. In addition to adapting the content according to the students and their cognitive abilities, content that can potentially elicit negative psychological reactions such as anxiety and stress should be avoided. In addition, VR technology is known to cause headaches, a loss of sense of reality, and nausea in some individuals from time to time. In addition, it may be useful to investigate potential mitigating factors such as user training protocols for its use in educational environments, taking into account the charging time and its weight of approximately 500 grammes.

In order to increase the effectiveness of games, videos, and platforms prepared for disaster education, it may be useful to translate them into different languages. It may also be useful to make the game graphics more visually engaging to enhance the user experience and the realism of the scenarios. It would be very useful to develop adaptive game mechanics that scale difficulty based on individual player performance and allow students of different skill levels to work collaboratively.

The activities carried out within the scope of this research included joint problem solving, focusing on cooperation in disaster situations. During the activities, solutions against disasters were produced together, especially in cooperation, and it was emphasised to the students that it was necessary to take precautions against disasters together and to be in solidarity together after disasters. Post-training discussions were organised to encourage students to think about the importance of social solidarity and community support after disasters. In this context, it may be useful to prepare the platforms prepared for disaster education in a structure that allows common games or cooperation.

The digital game used in the last stage of the learning process enabled students to practice their theoretical knowledge and have experience. Thus, the use of digital games seems to be especially useful for students to apply what they have learned.

The use of VR glasses, a 360-degree 4 K action camera, and a live-streaming drone through an innovative approach attracted students' attention and motivated them to learning. It would be a fruitful area for further work to examine the impact of immersive experiences through the long-term use of such innovative technologies.

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Data availability The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Conflict of interest Not applicable.

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