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AI-based Digital Mobile Technology Game-Based Learning as an Innovative Learning Strategy for Children in Disaster Education

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Abstract

Indonesia is a disaster-prone country, with children among the most vulnerable groups. This study developed and examined an integrated AI-supported digital mobile game-based learning intervention for disaster education. A mixed-methods approach was employed, combining research and development using the ADDIE model, a quasi-experimental pretest-posttest control group design, and descriptive analysis of affective and psychomotor outcomes. Quantitative data were analyzed using normality, homogeneity, and independent-samples t-tests, while qualitative and observational data were analyzed using MAXQDA and Gephi. The results showed that students receiving the integrated intervention achieved significantly higher cognitive learning outcomes than those in the control group, with a large effect size (Cohen's $d = 1.19$). Descriptive and observational findings also indicated more favorable patterns of learning activity, motivation, and psychomotor performance in the experimental group. These findings suggest that integrating digital mobile technology, game-based learning, multimedia resources, teacher facilitation, and selected AI-supported tools has potential to support disaster education among elementary school students.

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INTRODUCTION

Education is a learning activity that involves various parties. In learning, there are several things that must be fulfilled and done, one of which is learning strategies, namely, the art of carrying out plans or strategies (Hemmler & Ifenthaler, 2024; Ramdani et al., 2023). Teaching strategies in learning are methods used by educators during the process of teaching and learning activities aimed at influencing students in achieving effective and efficient learning goals (Sudjana, 2008). So, a learning strategy is a series of activities designed to deliver lessons and achieve learning objectives.

Not only students but also teachers must use this strategy because learning quality needs improvement. Thus, educators need an understanding of learning strategies, such as the use of technology in learning (Indriawati et al., 2021; W. Zhou et al., 2026). The adoption of information technology not only in teachers' pedagogical practice but also in their professional learning (Flores & Swennen, 2020; Schriever, 2021). Therefore, an innovative learning strategy is needed to improve learning quality. Learning that is strategic and self-organized to meet needs and goals is considered a key competency in continuing education (Gu & Liu, 2025; Hemmler & Ifenthaler, 2024; Zhang et al., 2026). Therefore, learning reform must include changes to the pattern of learning activities to make the learning atmosphere more engaging and better align the learning process with the times.

Learning reform is indispensable in disaster education. Disaster education requires learning reform. The implementation of disaster management activities must be carried out in a planned, integrated, coordinated, and comprehensive manner, as stipulated in Undang-undang (UU) Number 24 of 2007 concerning Disaster Management (Pemerintah Indonesia, 2007). Regulation of the Minister of Education and Culture Number 33 of 2019 concerning the Implementation of the Disaster Safe Education Unit Program strengthens the law (Kementerian Pendidikan dan Kebudayaan, 2019). Thus, disaster education must be taken seriously.

Given that Indonesia is in a disaster-prone area, disaster education must be effective in achieving its goals. Indonesia is prone to geological disasters such as tsunamis, eruptions, and landslides because of its location within the world's three active earthquake zones (Khusna, Sumarmi, Bachri, Astina, & Aristin, 2023; Suhardono et al., 2025). Indonesia is also vulnerable to climatic disasters because the tropical climate has an impact on climate change, such as forest fires, flash floods, and tornadoes (Legionosuko et al., 2019; Wu et al., 2026). In addition, socioculturally, Indonesia is a multicultural, multiethnic country with several legal beliefs that allow disputes between individuals or groups to arise (Khusna, Sumarmi, Bachri, Astina, Susilo, et al., 2023). In addition, international disasters have increased awareness of the importance of disaster preparedness among the general public and health workers, who are directly involved in disaster response (Labrague et al., 2018; Smith et al., 2026; Spencer & Thompson, 2024).

In response to this vulnerability, the Indonesian government organizes a preventive disaster education program, namely the Satuan Pendidikan Aman Bencana (SPAB). Disaster learning materials at each education level are self-contained and integrated with other subjects (Global Alliance for Disaster Risk Reduction and Resilience in the Education Sector, 2022). Of course, in its implementation, it must have the right strategy, as it will affect students' knowledge, attitudes, and skills in responding to disasters that may occur at any time, anywhere (Amri et al., 2022; Global

Alliance for Disaster Risk Reduction and Resilience in the Education Sector, 2022). This is due to the fact that disaster-prone areas are spread throughout the region, which can cause large-scale losses such as casualties, damage to the environment, loss of property, and psychological consequences (Aguirre, 2020; Graveline & Germain, 2022; Pemerintah Indonesia, 2007).

The condition of education, the social order of the community, the behavior of children, and the emotional state of the affected human can be quickly affected by disasters (Perfect et al., 2016). One way to change the learning model in disaster education is to adopt innovative learning strategies. This must be done immediately because disasters can have serious consequences. In this case, schools are very important to restore mental health to children who are traumatized by disasters (Rolfesnes & Idsoe, 2011). Thus, an educational institution or school can play a significant role in disaster reduction activities, especially in terms of human resources.

Disaster education focuses not only on adult students but also on children. After all, children are a vulnerable group and are at risk of experiencing adverse effects from disasters, which will have a major impact on mental conditions, including post-traumatic stress disorder, depression and anxiety (Sanson et al., 2019; Taylor & Peace, 2015). Disaster education focuses not only on adult students but also on children. After all, children are a vulnerable group and are at risk of experiencing adverse effects from disasters, which will have a major impact on mental conditions, including post-traumatic stress disorder, depression and anxiety (Spencer & Thompson, 2024; Taylor & Peace, 2015). Therefore, disaster education is very important and should be delivered appropriately to children, especially those in disaster-prone areas. Disaster education can impact not only individuals who are trained and have the right knowledge about responding to disasters, but also help others when responding to disasters and help prevent life-threatening events (Tsai et al., 2020).

Disaster education for children, when delivered with the right strategies, will be more effective in achieving learning goals. Basically, children like fun learning activities, such as games. Digital technology-based games need to be developed to meet the demands of globalization in the era from Industry 4.0 to Society 5.0. The Society 5.0 era combines humanism and technology. In this era, technology is expected to be used to solve environmental and social problems and improve human well-being (Castañeda & Selwyn, 2018; Sharma & Gupta, 2024; Vidak et al., 2024). In this era, machines and humans are expected to work together to create greater value. Using technology in learning strategies is an innovative and adaptive effort. Currently, digitalization is inseparable from life, so learning activities need to incorporate it.

Digital mobile technology, e.g., game-based learning, is a learning strategy that combines game-based learning methods and media supported by the sophistication of AI-based digital mobile technology. So, this research is very important because it integrates game-based learning defence strategies into technology. Games in disaster learning can provide an easy, fun way to understand critical concepts (Khusna & Anjani, 2025; Wang et al., 2024). Through this research, they will create a disaster simulation game in which children must work together to respond quickly and effectively to disasters. The game teaches children to be heroes in their neighbourhood by equipping them with disaster mitigation knowledge. This technology not only makes learning more interesting but also teaches practical skills such as decision-making, problem-solving, and teamwork. Through this technology, children can observe and simulate natural disasters in their

environment or visualize safety measures. This technology provides children with the opportunity to learn through hands-on experience without engaging in dangerous situations.

Based on this, this study aims to develop a digital learning strategy for game-based learning on mobile devices and measure its influence on learning in the field of disaster education among children in primary education. This research has contributed to community resilience to disasters. Improving disaster management capacity can help raise a younger generation that is more prepared and aware of disaster risks. Moreover, disaster education could promote scientific concepts in students by learning about natural phenomena, e.g., the physical concepts behind floods and earthquakes, or the chemical concepts behind acid rain. Therefore, it is hoped that the findings of this study will make a significant contribution to efforts to improve community preparedness and resilience to disasters through the education sector. In the context of disaster education for children, this innovative learning strategy develops children's cognitive abilities, attitudes, and skills for dealing with disasters in a fun, engaging, and easy-to-understand way.

METHODS

This study uses a mixed-methods approach. The development of digital mobile technology follows the model proposed by Robert Maribe Branch, which uses the ADDIE (Analysis, Design, Development, Implementation, and Evaluation) method. Furthermore, it will be tested on a large scale using a pseudo-experimental pretest-posttest control-group design to measure its effectiveness. Descriptive statistics to measure affective and psychomotor aspects. This research has limitations in the aspects measured. The cognitive aspect measures students' knowledge, the affective aspect measures students' activity and motivation, and the psychomotor aspect measures students' skills during learning.

The research was conducted with third-grade elementary school students at SDN Jepun 1 in Tulungagung, Indonesia, a disaster-prone area in South Java. The control class consisted of 21 students in class 3B, and the experimental class consisted of 23 students in class 3A. In the control class, conventional learning methods were used. In the experimental class, the Innovative learning strategy for AI-based game-based learning technology is used. Both classes are ensured to have equal prior knowledge based on their pretest scores, previous examination scores, or other measures, as evidenced by their homogeneity test.



Fig 1. Implementation of Experimental Class Learning (a) students sing disaster preparedness songs by demonstrating based on examples on digital mobile technology (b) students in groups do tests through gamification on digital mobile technology

An instrument to measure students' cognitive competence using an essay test. An instrument to measure affective aspects in the form of student activities and motivation using questionnaires that contain indicators of feeling happy in learning, attention in following lessons and active participation in learning activities. Instruments for measuring psychomotor aspects are observer-assessed checklists that include components of students' skills in managing learning activities.

Data analysis in this study used several methods. The independent-samples t-test was used to assess students' cognitive aspects through posttests. However, prerequisite tests were previously conducted for normality and homogeneity. The normality test used the Shapiro-Wilk test with a significance value ($p > 0.05$), and the homogeneity test used the Levene test with a significance value ($p > 0.05$). The test was carried out using SPSS version 21 for Windows. The hypothesis testing in this study was formulated to examine whether there was a statistically significant difference in students' cognitive learning outcomes between the experimental class receiving the AI-based digital mobile technology game-based learning intervention and the control class receiving conventional learning.

The hypotheses were formulated as follows:

H0: There is no statistically significant difference in students' cognitive learning outcomes between the experimental class receiving the AI-based digital mobile technology game-based learning intervention and the control class receiving conventional learning.

H1: There is a statistically significant difference in students' cognitive learning outcomes between the experimental class receiving the AI-based digital mobile technology game-based learning intervention and the control class receiving conventional learning.

The decision criterion was set at a significance level of $\alpha = 0.05$. If the p-value is greater than 0.05, H0 is not rejected. If the p-value is less than 0.05, H0 is rejected in favor of H1. Meanwhile, to obtain an overview of students' motivations, activities, and skills, quantitative descriptive techniques and MAXQDA were used to code the data. Then the entire dataset is processed using social relationship analysis techniques in MAXQDA and GEPHI.

Qualitative data analysis software is rapidly evolving to facilitate integrative analysis in mixed-methods research studies. MAXQDA has built-in statistical analysis tools that allow for simple analysis, such as descriptive statistical calculations, correlational analysis, and variance analysis (Guetterman & James, 2023). MAXQDA is a Computer-Aided Qualitative Data Analysis Software (CAQDAS) that, although data can be stored and analyzed separately in statistical and qualitative data analysis software, for integrative analysis, the two types of data can be combined and become interdependent (Consoli, 2021). Meanwhile, Gephi is a computational method and qualitative text analysis that can visualize network structures, relationships, and topic trends (Roy & DeRoche, 2025; Sanchez et al., 2021).

RESULT AND DISCUSSION

This study integrates and develops digital mobile technology and game-based learning into an innovative learning strategy for disaster education for children. To find out its effectiveness, the ADDIE model RnD method is used with the following steps:

Table 1. Summary of ADDIE Model Activities

Development Stage	Activities
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Analysis	Conducting needs analysis based on the results of observations in various educational institutions related to the implementation of Disaster Safe Education Units; Thinking about AI-based mobile digital technology products to be developed; identifying products that are suitable for children's goals with the aim of learning in disaster mitigation; identifying the content of the learning material; Identify learning environments and delivery strategies in learning
Design	Designing a new product concept on paper; Designing a new product development tool. A design is written for each unit of learning; The instructions for implementing the design are written in detail
Develop	Develop product tools (materials or materials-and-tools) needed for development based on product design results. At this stage, it begins creating its products (materials or tools) that correspond to the model's structure; Creating instruments to measure product performance
Implementation	Get started using new products in a real learning environment; Review product development goals, interaction between students and ask for feedback; The Beginning of the Evaluation Process
Evaluation	Looking back at the impact of learning in a critical way, measuring the achievement of product development goals, and measuring what the goal has been able to achieve. Finding what information can help students achieve good results

Based on the summary of ADDIE model activities above, the ADDIE model will be combined with game-based learning to form an innovative learning strategy. The learning syntax in this study has several steps, namely:

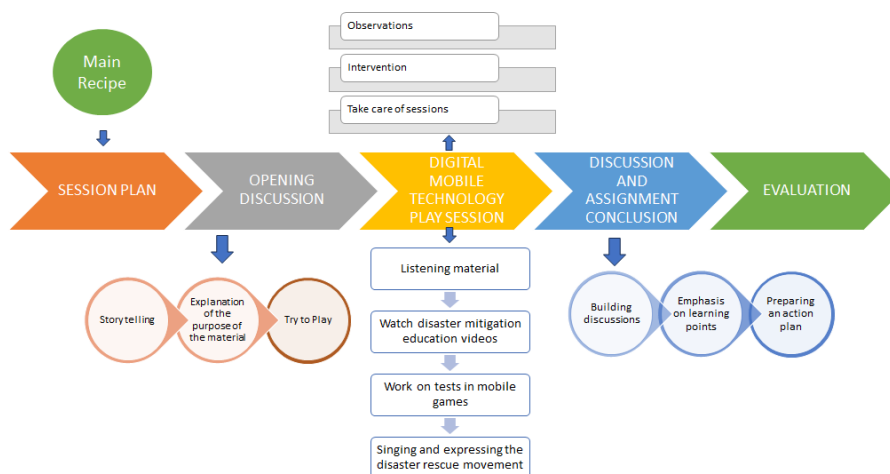


Fig 2. Steps in the Implementation of Innovation Learning Strategies through Digital Mobile Technology Game-Based Learning

The effectiveness of digital mobile technology game-based learning as an innovative learning strategy is measured by obtaining assessments from various material and media experts until the product is declared ready for use without revision. Furthermore, it is tested on a small scale and in field trials. The small-scale trial and the field trial are conducted to assess the practicality of the learning model and the media used. The trial was carried out using a three-level ordinal scale by referring to the linear interval approach and Arikunto modification which is often used to determine

the level of knowledge or attitude with a vulnerability ($< 56\%$) = Not Good (Less), ($56\% - 75\%$) = Sufficient, ($76\% - 100\%$) = Good (Susanti & Narda Meilani, 2022). The table below shows the results of the comparison between small-group trials and field trials.

Table 2. Trial Comparison Results

No.	Assessment Items	Trial		Category
		Small Scale	Large Scale	
1.	Happy with disaster mitigation learning in the use of AI-based game-based learning digital mobile technology	93%	97%	Good
2.	Not having difficulty using AI-based game-based learning digital mobile technology	90%	90%	Good
3.	Happy to answer questions by using AI-based game-based learning digital mobile technology to increase knowledge	93%	97%	Good
4.	The spirit of working on questions using AI-based game-based learning digital mobile technology	91%	96%	Good
5.	The use of AI-based game-based learning digital mobile technology is very interesting in working on problems	94%	97%	Good
6.	The use of AI-based game-based learning digital mobile technology can make it easier to work on tests	93%	95%	Good
7.	Don't feel difficulties when working on questions in using AI-based game-based learning digital mobile technology	90%	92%	Good
8.	Like the display of all content on AI-based game-based learning digital mobile technology	91%	97%	Good
9.	Can quickly work on problems using AI-based game-based learning digital mobile technology	92%	92%	Good

The student response questionnaire on innovative learning strategies using AI-based digital mobile technology games averaged 93%, meeting the product effectiveness criteria. To assess the impact of innovative learning strategies using AI-based digital mobile technology disaster-mitigation materials for children, we conducted experiments in two classes. First, we conducted normality and homogeneity tests. The results of the normality test of score gain data are shown in Table 3, and the homogeneity results are shown in Table 4.

Table 3: Normality Test

Tests of Normality				
Class		Kolmogorov-Smirnov ^a		
		Statistic	df	Sig.
Learning	Pretest Control Class	.924	21	.103
Outcomes Pretest	Pretest Experiment Class	.955	23	.372
a. Lilliefors Significance Correction				

The results of the normality test on the pretest values of the control and experimental classes indicated that the p-values were greater than 0.05. This is evidenced by the sig value in the control class pretest of $0.103 > 0.05$, while the sig value in the experimental class pretest was $0.372 > 0.05$. Based on this statement, it can be concluded that the pretest value in the control class and the experimental class is said to be normal. The next step is to conduct a hypothesis test using a T-test to determine whether there is a difference in students' comprehension abilities during learning after implementing an AI-based game-based learning digital mobile technology.

Table 4: Homogeneity Test

Levene Statistic	df1	df2	Sig.
0,089	1	42	0,767

Based on the results in Table 4 and the homogeneity test output, the Sig. Mark value of $0,767 > 0,05$; it is homogeneous. The research data used for the normality test are the same as those used for the homogeneity test, namely, pretest scores for elementary school students: class 3A (experimental class) with 23 students and class 3B (control class) with 21 students. The normality test in this study was conducted using SPSS 21 for Windows.

Table 5: Welch-adjusted independent-samples t-test

Group	N	Mean	Std. Deviation	Mean Difference	T	df	Sig. (2-tailed)	Cohen's d
Experimental	23	87.43	5.02	8.67	3.846	30.395	< 0.001	1.19
Control	21	78.76	9.15					

Because the group variances were unequal, the Welch-adjusted independent-samples t-test was used. Cohen's d was calculated using the pooled standard deviation to estimate the magnitude of the between-group difference. The significance level was set at $\alpha = 0.05$. Thus, H1 is accepted and H0 is rejected. These table show a difference in learning outcomes between the experimental and control classes. The average score for the experimental class was 87.43, and for the control class, 78.76. The findings indicate that the implementation of an AI-based digital mobile technology game-based learning strategy significantly improved students' learning outcomes compared with conventional learning, with a large practical effect (Cohen's $d = 1.19$).

In addition to influencing cognitive learning outcomes in the form of test scores, implementing innovative learning strategies, such as AI-based digital mobile game-based learning,

also affects student activities, motivation, and skills. The table below presents a comparison of the criteria for grades, activities, motivation, and skills of students in the control and experimental classes during the research. The score was obtained by categorizing posttest scores according to the curriculum applicable at the research site.

After testing the hypothesis, to illustrate a clear relationship among the indicators studied, it is necessary to code the data. The table below contains the results of the research in the form of cognitive aspects in the form of grades, aspects of student learning activities (the ability to ask, answer, propose ideas), learning motivation (students' willingness to take notes, follow rules and not be sleepy during learning), and student skills (ability to imitate, arrange, do work with procedures, do work well and appropriately, perform actions naturally).

Table 6. The Result of Data Coding

No	Code System	Experimental Class		Control Class	
		Segments	Percentage	Segments	Percentage
1	Value				
	96-100 (A)	4	17.39	0	0
	91-95 (A-)	5	21.74	4	19.5
	86-90 (B+)	14	69.87	4	19.5
	81-85 (B)	0	0	5	23.81
	76-80 (B-)	0	0	5	23.81
	71-75 (C)	0	0	2	9.52
	under 71 (D)	0	0	1	4.76
	TOTAL	23	100.00	21	100.00
2	Questioning Ability				
	The students are willing and dare to ask	16	69.57	6	28.57
	The students are shy to ask	5	21.74	5	23.81
	The students do not want to ask	2	8.70	10	47.62
	TOTAL	23	100.00	21	100.00
3	Answering Ability				
	The students give answers quickly	17	73.91	8	38.10
	The students give answers slowly	6	26.09	13	61.90
	TOTAL	23	100.00	21	100.00
4	Ability to Propose Ideas				
	The students are able to convey ideas	18	78.26	8	38.10
	The students are shy to convey ideas	3	13.04	6	28.57
	The students are afraid to convey ideas	2	8.70	7	33.33
	TOTAL	23	100.00	21	100.00
5	Taking notes ability				
	The students take notes	21	91.30	13	61.90
	The students are too lazy to take notes	2	8.70	8	38.10
	TOTAL	23	100.00	21	100.00
6.	Rules				

	The students obey the rules	23	100.00	13	61.90
	The students sometimes disobey the rules	0	0.00	5	23.81
	The students often disobey the rules	0	0.00	3	14.29
	TOTAL	23	100.00	21	100.00
7	Concentration				
	The students are not sleepy while learning	23	100.00	13	61.90
	The students are sleepy while learning	0	0.00	8	38.10
	TOTAL	23	100.00	21	100.00
8	Perception				
	The students are able to do the work as exemplified by the lecturer	20	86.96	12	57.14
	The students are less able to do the work as exemplified by the lecturer	3	13.04	7	33.33
	The students are unable to work as exemplified by the lecturer	0	0.00	2	9.52
	TOTAL	23	100.00	21	100.00
9.	Manipulating				
	The students are able to repeat activities	17	73.91	11	52.38
	The students are less able to repeat activities	6	26.09	7	33.33
	The students are unable to repeat activities	0	0.00	3	14.29
	TOTAL	23	100.00	21	100.00
10	Precision				
	Learning activities are carried out properly	18	78.26	10	47.52
	Learning activities are carried out improperly	5	21.74	11	52.38
	TOTAL	23	100.00	21	100.00
11	Articulation				
	The students show their learning results quickly and correctly	17	73.91	7	33.33
	The students show their learning results slowly and correctly	3	13.04	5	28.31
	The students show their learning results quickly and incorrectly	2	8.70	5	28.31
	The students show their learning results slowly and incorrectly	1	4.35	4	19.05
	TOTAL	23	100.00	21	100.00
12	Naturalization				
	The students give spontaneous responses	18	78.26	9	42.86
	The students give slow responses	5	21.74	12	57.14
	TOTAL	23	100.00	21	100.00

Sources: primary data analysis using MAXQDA

The data coding results above show the percentage of responses for each assessment indicator. Numerically, the difference between the two classes can be seen. To provide a clear picture of the relationship, further analysis is conducted using social relationship analysis.



Fig 3. Preview Social Relationship Analysis Control Class

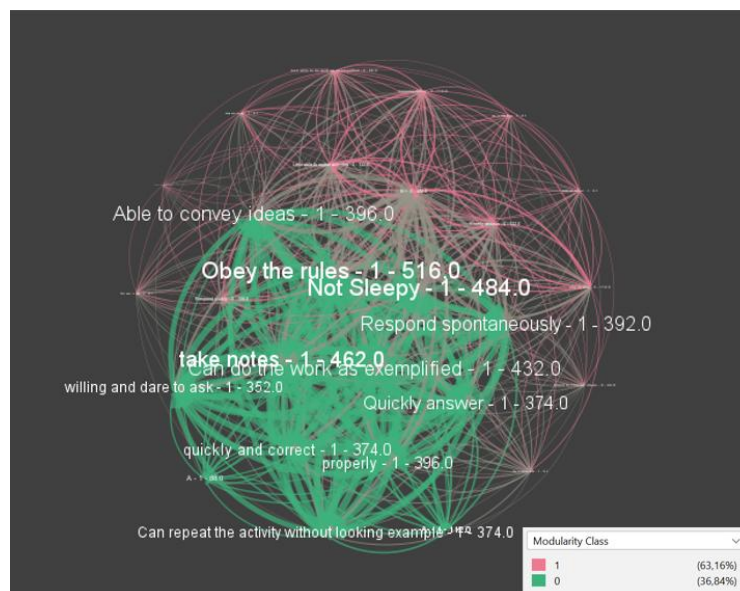


Fig 4. Preview Social Relationship Analysis Experimental Class

The picture above explains the situation of each class. Each line in Gephi represents a relationship between indicators that influence one another (Lutfiani, 2020). The thickness of the line indicates the strength of the influence. The direction of the arrow indicates the relationship of cause and effect. The numbers in the image above show the class groupings and the weights of the results

from the analysis of the relationships between statements. The results of processing modularity class and weighted degree data in Gephi 0.10.0 show differences in the relationships between the two classes. Modularity class is an algorithm to detect communities, clusters, or dense groups in a network (Lutfiani, 2020; Sanchez et al., 2021). Meanwhile, the weighted degree is used to measure the total strength or intensity of the connections (edges) connected to a node by taking into account the weight value of each of these connections (Grandjean, n.d.).

Although they both belong to two modularity classes (0 and 1), they show different counts. The control class has a modularity class 0 of 63.16% and class 1 of 36.84. Meanwhile, in the experimental class, class 0 accounted for 51.85% and class 1 for 48.15%. If we look at the three weight-degree data ratings in the control class, the highest scores are in the students' statements: "slowly answering" (286.0), "responding slowly" (264.0), and "inappropriately" (242.0). Meanwhile, in the experimental class, the highest weighted degree scores were observed among students who obeyed the rules (516.0), were not sleepy (484.0), and took notes (462.0).

In general, the control class showed a poor relationship with score acquisition, accompanied by low levels of activity, motivation, and skills, all of which were interconnected and influential. In the control class, it can be seen that the use of conventional models in learning affects many aspects, such as the number of students who are sleepy, who are shy about asking questions, and who are lazy about taking notes. This is inversely proportional to the experimental class, indicating a strong relationship between good grades and strong activity, motivation, and skills. The use of innovative learning strategies of digital mobile technology game-based learning based on AI makes students able to convey ideas, able to answer questions quickly and correctly, not sleepy, willing to take notes, able to imitate work as exemplified, willing to follow applicable rules, willing and not ashamed to ask, quick in answering questions, able to do the stages of learning well and able to repeat activities without looking Examples. So, based on this, H₀ was rejected, and H₁ was accepted because it showed the influence of AI-based mobile game learning technology on innovative learning strategies for disaster mitigation materials for children.

The use of AI-based mobile game-based learning digital technology helps students understand problems during the learning process in a fun and responsible way. To facilitate technology-based learning, teachers follow several stages. At the first meeting, after compiling a learning plan, the teacher gave an introduction through storytelling and game explanations, and demonstrated AI-based digital mobile technology game-based learning applications to students. An introduction from the teacher is very necessary for students before starting learning, and it is recommended to relate it to the local conditions of the region (Sumarmi et al., 2020).

Furthermore, teachers form groups and instruct each group to open a learning application for AI-based digital mobile technology developed by researchers. On this occasion, the teacher made observations, intervened and maintained the session. The developed learning product integrates several digital platforms and artificial intelligence (AI)-supported tools within a mobile and game-based learning environment. Each technology was selected and utilized according to its specific function in the development, presentation, and delivery of the learning materials. Therefore, the technologies used in the intervention should not be regarded as having identical technological functions.

D-ID was used to transform digital avatars or character images into talking video presenters. Through AI-based avatar generation, text-to-speech, voice generation or voice input, and lip-

synchronization, D-ID supported the development of instructional videos in which digital characters could deliver learning messages in a human-like manner. This function was particularly useful for presenting disaster education content through visually engaging digital characters.

HeyGen was also used to develop digital avatar-based instructional content. Its AI-supported avatar and voice-generation functions were utilized to create digital presenters and spoken instructional materials. The use of AI-generated avatars and voices enabled the learning materials to present information through a more interactive and visually engaging format.

Canva was used as a visual design and multimedia production platform. In addition to conventional design and editing functions, the researchers utilized Canva's AI-supported features to generate or modify visual materials based on text prompts and to facilitate the development of learning designs and multimedia content (Sari et al., 2026). Thus, Canva contributed both to the general visual design process and to selected AI-assisted content-production processes.

Wordwall was used to develop interactive game-based learning and assessment activities. In this study, Wordwall was incorporated as part of the game-based component of the intervention. Its AI-supported functions were also considered in the development of interactive learning activities. Previous research has specifically examined the development and use of Wordwall AI as an interactive learning medium and reported its potential for supporting children's cognitive development (Virgie Sekar Aulia & Mulya, 2025). Thus, Wordwall in this study was not merely used as a conventional digital quiz platform but formed part of the interactive and AI-supported learning environment.

Digital illustration and image-generation tools were also used to develop child-oriented visual characters and illustrations. These tools supported the creation of animated-style characters and visual representations that were integrated into the learning materials. The visual materials were designed to make disaster preparedness concepts more accessible and engaging for children.

Google Sites functioned primarily as the digital delivery environment for organizing and presenting the learning materials. It provided the main access point through which students could navigate the different learning resources, including instructional videos, written materials, audio, interactive activities, and game-based assessments. Therefore, Google Sites should be understood as the digital platform that organized and delivered the learning resources rather than as the primary AI component of the intervention.

Overall, the product combined digital mobile technology, game-based learning, multimedia resources, teacher facilitation, and selected AI-supported functions. The AI components were mainly employed in the production and presentation of multimedia learning materials, including talking avatars, AI-generated or AI-assisted voices, visual content generation, and selected interactive learning activities. The integration of these technologies resulted in a multimodal learning environment containing written information, audio, animated and educational videos, interactive game-based activities, children's songs, and disaster-rescue characters.

Table 7: Technology/Platform used

No.	Platform	Category and Address links
1	D-ID	AI Technology https://www.d-id.com/
2	HeyGen	AI Technology

		https://www.heygen.com/id-id
3	Canva AI	https://www.canva.com/id_id/ai-canva/
4	Wordwall / Wordwall AI	AI-Supported / Game-Based Platform https://wordwall.net/id
5	Bing Image Creator	AI Image Generation https://www.bing.com/images/create/ai-image-generator
6	Google Sites	Digital Delivery Platform https://sites.google.com/

In addition, this is done so that the product can be used even when children are not yet able to read. This product can also be used by all students who have a learning preference for audio, visual, or kinesthetic learning. The product can be accessed at the following link: <https://sites.google.com/view/digital-mobile-technology-game/beranda>. After the session on the use of AI-based digital mobile technology for game-based learning, teachers opened a discussion forum between groups, emphasized key learning points, and prepared an action plan. Finally, teachers evaluate learning from the learning process that has taken place. This is very necessary because it will determine how much knowledge and skill students acquire through learning.

Based on these steps, the first finding of this study indicates that students who participated in the integrated digital mobile and game-based learning intervention achieved higher cognitive learning outcomes than students in the control class. The experimental class obtained an average score of 87.43, compared with 78.76 in the control class, and Cohen's $d=1.19$. The statistical findings provide evidence that the observed difference between the experimental and control groups was both statistically and practically meaningful. The experimental group achieved a mean score 8.67 points higher than the control group, and the large Cohen's d value (1.19) indicates a substantial magnitude of the between-group difference. This suggests that the implementation of AI-based digital mobile technology game-based learning was associated with a meaningful improvement in students' learning outcomes rather than merely producing a statistically detectable difference. The large effect may be related to the integration of interactive game-based activities, multimedia content, and mobile accessibility, which can provide students with more engaging opportunities to interact with disaster education content. Nevertheless, the effect should be interpreted within the context of the present quasi-experimental design and study setting.

The second finding concerns students' affective learning indicators. The questionnaire results showed higher percentages in the experimental class across several indicators, including willingness to ask questions, ability to respond to questions, willingness to express ideas, note-taking, attentiveness during learning, and compliance with classroom rules. These descriptive findings suggest that the integrated intervention was associated with higher levels of student participation and motivation during learning. Nevertheless, these results should be interpreted as observed differences between the two learning conditions rather than as evidence of a causal effect of AI.

The third finding concerns students' psychomotor performance. The observer assessment, processed using MAXQDA, indicated higher performance in the experimental class across the assessed indicators, including perception, manipulation, precision, articulation, and naturalization. These findings suggest that the integrated learning intervention may support students' participation in learning activities involving practical and procedural skills. As with the affective outcomes, the psychomotor findings should not be interpreted as demonstrating that AI independently produced

the observed improvement, because AI-supported tools were implemented together with other digital, game-based, multimedia, and teacher-facilitated components.

In general, this study supports several prior related studies that employ innovative learning strategies, learning models, and technology-assisted learning. Previous research shows that learning with AI-based technology can increase the efficiency of the teaching and learning process (David Benny Gleneagles, 2024; Tsai et al., 2020). Another study also stated that the use of AI integrated into gamification can increase vocabulary acquisition in children (Namaziandost & Çakmak, 2025; X. Zhou et al., 2025). The use of new AI tools, including generative AI based on large language models such as the products developed in this study, also supports previous research indicating that the future problem of personalization in learning has been solved through AI, including for children with special needs (Fan et al., 2026; Plass & Froehlich, 2025). Previous research also shows that, through innovative learning, a positive learning community and experience can combine written and oral learning outcomes with good results, which can increase engagement and self-regulation in students (Zou & Jiang, 2025). The use of innovative action-based learning has also been proven to spur student learning activity in the classroom (Chai et al., 2026; Khusna & Anjani, 2025).

In the field of disasters, previous researchers have also used AI technology for construction preparedness in disaster-prone areas, with proven effective and efficient results (Chen et al., 2026; Kamari & Ham, 2022; Xiong et al., 2025). In fact, other studies also indicate that the framework for disaster prevention, mitigation, and response systems is more effective when assisted by AI. When compared with some results from previous research, this study identified a new element. The implementation of innovative teaching strategies, such as AI-based digital mobile technology game-based learning in disaster education for children, has affected not only cognitive aspects of disaster but also learning activities, student motivation, and psychomotor skills. It is, however, the community's involvement in teaching disaster preparedness that is important because, in some districts, indigenous people sometimes have knowledge to cope with disasters. This could democratise learning by gathering knowledge from any source.

CONCLUSIONS

This study examined an integrated learning intervention that combined AI-supported digital mobile technology, game-based learning, and disaster education for elementary school students. The findings should therefore be interpreted as the outcomes of the integrated intervention rather than as evidence of an independent causal effect of AI. First, the integrated intervention was associated with significantly higher cognitive learning outcomes in the experimental group than in the control group. Students in the experimental group ($M=87.43$, $SD=5.02$, $n=23$) achieved higher scores than those in the control group ($M=78.76$, $SD=9.15$, $n=21$), with a mean difference of 8.67 points. The between-group difference was statistically significant, $t(30.395) = 3.846$, $p < .001$, and the magnitude of the difference was large (Cohen's $d=1.19$). This indicates that the integrated intervention was associated with a substantial difference in students' cognitive learning outcomes.

Second, the descriptive findings indicated more favorable patterns of learning activity and motivation in the experimental group than in the control group. Students receiving the integrated intervention showed higher observed levels of participation, willingness to ask and answer questions, note-taking, attentiveness, and adherence to learning activities. These findings provide

descriptive evidence of more favorable affective engagement, but they should not be interpreted as evidence of a statistically significant effect.

Third, the observational findings indicated more favorable psychomotor performance among students in the experimental group, particularly in perception, manipulation, precision, articulation, and naturalization. These results suggest that the integrated intervention may support students' engagement in learning-related skills; however, because these outcomes were assessed descriptively, causal and statistical effect claims should be interpreted with caution.

Overall, the findings suggest that integrating AI-supported digital mobile technology with game-based learning may provide a promising approach to disaster education for elementary school students. The results should be interpreted within the context of the present study design, sample, and measurement procedures. Future studies with larger, more diverse samples, validated outcome measures, and designs that isolate the contributions of specific intervention components are needed to determine the extent to which AI, game-based learning, and other instructional components independently contribute to learning outcomes.

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CONFLICTS OF INTEREST STATEMENT

The authors declare that they have no known competing interests or personal relationships that could have appeared to influence the work reported in this paper.

AUTHOR CONTRIBUTIONS

Nur Isroatul Khusna wrote the paper, conceived and designed the experiments, and analyzed and interpreted the data. Jani performed the experiments and analyzed and interpreted the data and wrote the paper. Ivan Ashif Ardhana wrote the paper and conceived and designed the experiments. Rian Vebrianto wrote the paper and contributed reagents, materials, analysis tools or data. Nurhayati wrote the paper and contributed reagents, materials, analysis tools, or data. Restu Putri Pamungkas performed the experiments and analyzed data

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