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STEM-based disaster mitigation digital learning model: A means of improving primary school students' psychological preparedness for disaster

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Abstract

Conventional learning models were considered less effective at developing children's psychological preparedness. Previous studies have produced a STEM-based Disaster Mitigation Digital Learning Model that has been certified legitimate by experts; nevertheless, more research is required to determine its effect on disaster psychological preparedness in children. This study sought to determine the effectiveness of this STEM-based learning model in enhancing children's psychological preparedness for disasters. The method utilized was a quasi-experiment with a non-equivalent control group design. The study included 600 grade 5 elementary school students. The research tool was a validated psychological disaster preparedness questionnaire, and the data were analyzed for the normality test, homogeneity test, paired sample t-test, and independent sample t-test. The results revealed a substantial difference between the mean post-test of the experimental and control groups. Children in the experimental group who learned using the STEM-based learning model demonstrated more psychological disaster preparedness than the control group. This finding demonstrated that a STEM-based digital learning model was more effective than traditional techniques in shaping disaster psychological preparedness. This model was intended to provide children with improved adaption abilities and psychological preparedness, allowing them to be more resilient and ready to confront potential crises in the future.

Keywords: Digital learning, Disaster mitigation, Elementary school, Psychological disaster preparedness, STEM-based learning.

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1. Introduction

Disaster mitigation in susceptible places is critical for saving lives, reducing financial losses, and ensuring social and environmental balance. Disasters such as earthquakes, floods, and landslides pose significant hazards, thus disaster-resistant infrastructure, early warning systems, and preparedness training are required to prepare communities for emergency circumstances [1-3] . Mitigation not only reduces the risk of death and economic damage, but it additionally supports education through learning [4-6]. These efforts raise public awareness of environmental issues and promote sustainable planning. Thus, catastrophe mitigation is more than just technical prevention; it is also part of long-term development for a more resilient society.

In addition to physical mitigation, psychological preparedness for disasters is a crucial factor that must be developed, particularly for children [7, 8]. They are a particularly susceptible population, and disasters frequently have a profound emotional impact on them [9]. Because their mental and emotional development is still in progress, children are more prone to feel fear, perplexity, or trauma. Individuals, especially children, with disaster psychological readiness have the mental and emotional power to identify hazards, remain calm in emergencies, and regulate their feelings and thoughts during and after disasters. This state of readiness does not imply that children will be devoid of dread or anxiety, but rather that they will have a better understanding, mental resilience, and confidence to deal with emergencies, reducing negative psychological impacts [10].

Psychological readiness is especially important for children since it helps them cope with and adjust to disasters while also increasing resilience to long-term trauma [11]. With this preparedness, people are more likely to have superior coping mechanisms, allowing them to respond to emergencies calmly. Another advantage is that students feel safer and are less likely to panic, lowering the chance of trauma. In the long run, children who are more psychologically prepared recover from disasters faster and can go on with their lives without suffering long-term psychological consequences [12]. This preparation also helps children acquire confidence in the face of challenges, which is vital for their future personal growth. As a result, children's psychological preparedness must be established from an early age to be more equipped to tackle numerous challenging situations.

However, a study of literature from several countries revealed that children's psychological preparedness for disasters is frequently low. In Indonesia, for example, primary school students have inadequate psychological preparedness, owing primarily to a lack of disaster mitigation training in schools [13]. Following Hurricane Katrina in the United States, many children had long-term trauma symptoms such as anxiety and behavioral regression, highlighting a critical need for post-disaster psychological treatment [14]. In India, cyclone-affected children had a significant prevalence of PTSD and depression symptoms that remained for a year after the disaster [15]. Meanwhile, another study found that although disaster education programs have been implemented in several countries, the psychological preparedness of children and families is still poor due to the absence of evaluation and long-term follow-up [16].

Comparative studies of children affected by the Chilean earthquake and Hurricane Katrina in the United States demonstrate that, despite cultural differences, children's psychological responses to catastrophes are often comparable. This emphasizes the need for extensive and universal mental health interventions for youngsters [17]. Children in low- and middle-income countries who are affected by climatic disasters are more likely to suffer from major mental health issues such as PTSD and depression [18]. Research from several nations shows that children harmed by catastrophes frequently have long-term trauma, highlighting the need for more psychological support in global emergency response plans [19]. Furthermore, research demonstrates that psychosocial therapies delivered through teacher training can increase children's psychological preparedness; yet, this training has not been widely implemented in many countries [20, 21].

On the other hand, research on psychological therapy for children affected by humanitarian disasters in low- and middle-income countries found limited evidence of benefits, indicating significant hurdles in establishing effective interventions [22]. In the United States, research has demonstrated that disasters can disturb the psychological well-being of children, particularly teenagers and that mental health should be included in worldwide emergency response strategies [23].

Overall, these studies emphasize children's poor psychological preparedness in the face of disasters, underlining the need for stronger and more concentrated education and psychological support programs for children all around the world.

These findings are supported by the results of an initial assessment of children's psychological disaster preparedness in Indonesia. This study included 600 students aged 6 to 12 years. The following ten indicators were used to assess children's disaster psychological preparedness:

Table 1.
Results of Initial Measurement of Psychological Disaster Preparedness.

No.	Indicators of Psychological Disaster Preparedness	Average Score
1	Being able to know what to do in certain situations	45.89
2	Being able to save oneself from various situations	46.02
3	Being able to manage feelings in various situations	45.67
4	Remaining calm when facing problems	45.90
5	Being able to control fear and anxiety	45.58
6	Showing confidence in oneself when facing difficult times	45.72
7	Calming others who are experiencing problems	45.88
8	Being aware of one's anxiety	45.63
9	Facing difficulties	45.49
10	Trying to avoid threats	45.34
	Total Average	45.78

The total average of the ten indicators reveals that children's psychological preparedness level is 45.78, indicating low psychological preparedness and a need for improvement in all categories. Based on the findings of the literature study and preliminary measures indicating that children's psychological disaster preparedness remains relatively low, efforts must be made to increase it using the appropriate approach. One useful approach is to incorporate disaster psychological readiness into the learning process.

Disaster mitigation education for elementary school children continues to encounter several challenges, resulting in poor psychological preparedness for disasters. Material delivery is frequently less interactive and engaging, typically in the form of lectures or simple texts that do not encourage students to comprehend fully. Approaches that emphasize theory over practical abilities leave students unprepared to deal successfully with emergencies. However, limited technology literacy in this learning is also a hurdle; students are unfamiliar with digital tools or platforms that can assist them in recognizing danger signs or reading risk maps more attentively. Furthermore, the restricted approach to learning, which focuses solely on one topic without any connections to other subjects, prohibits students from developing a more comprehensive understanding of the subject. Due to a lack of psychological preparedness exercises and simulations, students are unfamiliar with controlling emotions or coping with anxiety in the context of an emergency, making them subject to trauma and panic. Limited time and access to learning also limits students' ability to investigate the content outside of class. Meanwhile, a lack of collaboration in education impedes the development of communication and cooperation skills, which are critical in emergencies. These deficiencies indicate that disaster mitigation learning techniques should be revised to provide students with not only fundamental knowledge but also improved mental preparedness and practical skills while dealing with disasters.

A previous study produced a STEM-based Disaster Mitigation Digital Learning Model that was deemed valid by experts. This model is an educational strategy that incorporates STEM (Science, Technology, Engineering, and Mathematics) concepts into disaster mitigation education, utilizing digital platforms to offer materials and training to children. This model invites students to recognize natural catastrophe events from a scientific standpoint (science), use technology as a tool (technology), comprehend safety measures (engineering), and apply mathematical abilities to analyze risk data. The concept focuses not only on theory but also on interactive experiences like simulations and scenarios, allowing them to practice dealing with emergencies using digital technologies.

The primary benefit of this STEM-based Disaster Mitigation Digital Learning Model is its multidisciplinary approach and more interactive and engaging learning approaches for children. The model helps them develop the intellectual and practical abilities required in emergencies. Children feel more comfortable utilizing early warning or risk mapping tools as their technical literacy improves. Disaster simulations on digital platforms allow them to practice controlling emotions and dealing with fear, thereby enhancing their psychological preparedness. Furthermore, flexible access facilitates youngsters to learn anytime and from anywhere, repeating material as needed to fortify learning. With these benefits, the program not only enriches mitigation knowledge, but also children's mental resilience, emergency reaction skills, and general psychological preparedness.

However, this study is still restricted to the feasibility validation test only. More research is required to determine the extent to which this STEM-based Disaster Mitigation Digital Learning Model influences children's psychological preparedness to face disasters. Additional study will allow a more in-depth assessment of how this model can advance children's emotional resilience, response abilities, and emotion management skills in emergencies. With more empirical data, the usefulness of this model is projected to be better assessed, allowing for wider use in disaster mitigation education.

Previous research has focused on disaster mitigation education for children, but its approaches have not completely integrated STEM-based digital learning models with the express goal of boosting psychological readiness. Research by Seddighi, et al. [10] explores catastrophe mitigation measures in the context of climate change, but the programs continue to use face-to-face methods that do not incorporate digital technology or STEM-based approaches Seddighi, et al. [10]. Estafetta, et al. [13] evaluated students' psychological readiness for disasters using traditional methods that did not rely on technology or STEM approaches to improve children's practical understanding of disaster mitigation [13]. Similarly, Raccanello, et al. [24] created a web application to improve children's emotional preparedness for earthquakes; however, this approach concentrates on emotional readiness rather than STEM-based understanding, which could help students' analytical and technical abilities in disaster situations Raccanello, et al. [24]. Rodavia, et al. [25] offered an online disaster preparedness application, although it was not expressly made utilizing the STEM paradigm or evaluated psychological readiness in depth [25]. Finally, Mangione, et al. [26] employed digital storytelling to teach disaster prevention, but they emphasized the emotional parts of the narrative rather than including more analytical STEM elements to improve students' technology literacy [26].

Consequently, this study's primary distinction is its unique approach. Unlike earlier research, this strategy employs the STEM approach in a digital format to enhance children's psychological resilience. This study aims to see if a STEM-based disaster mitigation digital learning model might increase children's psychological disaster preparedness.

2. Literature Review

2.1. STEM-based Disaster Mitigation Digital Learning Model

The STEM-based Disaster Mitigation Digital Learning Model is an innovative teaching model that combines STEM (Science, Technology, Engineering, Mathematics) principles with digital technology to improve children's preparedness for natural disasters. The model aims to introduce theoretical knowledge about disasters and train practical skills through a multidisciplinary interactive approach. In the science component, children are introduced to the scientific processes underlying natural phenomena such as earthquakes, floods and forest fires so that they scientifically understand the causes and impacts of disasters. In terms of technology, children are encouraged to use simulation apps or software to visualize disaster situations, practice emergency response and improve, and their technological literacy. The engineering aspect of the model emphasizes safety procedures and mitigation techniques such as earthquake-resistant building design or early warning systems. In contrast, the mathematical aspect trains children to analyze statistical data on disaster risk and calculate the likelihood of a disaster, enriching their critical thinking skills.

Previous research supports the effectiveness of STEM-based approaches in disaster mitigation learning. For example, a study by Kosim, et al. [27] showed that STEM-based student worksheets can improve students' understanding of earthquake disaster mitigation, with very positive student response results reaching 98.33% [27]. In addition, research by Sampurno, et al. [28] found that the introduction of STEM-D (Science, Technology, Engineering, Mathematics and Disaster) education through observation, discussion, and reflection can improve students' disaster literacy by linking STEM concepts with the phenomenon of disasters that often occur in Indonesia [28]. Furthermore, Agusty, et al. [29] found that STEM-based learning media in disaster mitigation education can improve students' problem-solving skills related to disasters Agusty, et al. [29]. Muslimin, et al. [30] also reported that the SETS (Science, Environment, Technology, and Society) approach in flood disaster mitigation encouraged higher student activity and very positive responses during the learning process [30]. In addition, research by Sudarmilah, et al. [31] identified that using educational-based games can make disaster mitigation learning more enjoyable for students, thus increasing their involvement in disaster mitigation [31].

These advantages suggest that a digital-based STEM approach to disaster mitigation can improve children's understanding and technological literacy and provide them with opportunities to develop mental resilience and practical skills in dealing with disasters, making them more holistically prepared in emergencies. Digital platforms offer flexibility of access so children can learn at their own pace and repeat material to reinforce understanding. Overall, the STEM-based Disaster Mitigation Digital Learning Model makes a significant contribution to building a generation that is more responsive to disaster risks and has the skills needed to act quickly and effectively in emergency situations.

2.2. Disaster Psychological Readiness

Disaster Psychological Readiness is a person's mental state reflecting their ability to face, manage and overcome various emotional impacts that arise during a disaster [8, 32, 33]. This readiness includes an individual's ability to remain calm, think clearly, and take appropriate action in emergencies. A person with good psychological readiness can overcome fear and anxiety and adapt to sudden changes and uncertain situations, often part of the disaster experience.

Here are some indicators that describe Disaster Psychological Readiness [13]:

1. Knowing What to Do in Certain Situations
   It is understanding the steps to take when a disaster occurs, such as evacuation locations and safety procedures.
2. Able to Save Yourself from Various Situations
   Recognizing potential dangers and acting quickly and effectively to save yourself from threats that may arise.
3. Able to Manage Feelings in Various Situations
   Able to control emotions such as fear, panic, or anger to stay focused on rescue efforts and the safety of self and others.
4. Stay Calm When Facing Problems
   Calmness and mental fortitude so as not to panic, even in a precarious situation, which is essential to be able to reason.
5. Able to Control Fear and Anxiety
   The ability to deal with fear or anxiety during a disaster and manage it so that it does not interfere with rescue actions.

6. Showing Confidence in Yourself When Facing Difficult Times
   Having confidence that one can face and overcome difficulties in disaster situations.
7. Calming Others Who Are Having Problems
   It can provide support or reassurance to others who may be more panicked or stressed, helping them feel calmer.
8. Being Aware of One's Anxiety
   Being aware of the level of anxiety felt but still being able to control it so that it does not affect behaviour in emergencies.
9. Facing Difficulties
   Be resilient and not give up quickly despite the difficulties that may arise during or after a disaster.
10. Trying to Avoid Various Threats
    It is recognizing and avoiding potentially dangerous situations or places and prioritizing the safety of oneself and others.

This indicator is used to assess the psychological disaster preparedness of elementary school students.

3. Research Methodology

The purpose of this study was to examine how the STEM-based Disaster Mitigation Digital Learning Model affected children's psychological preparedness for disasters. The method employed was a quasi-experiment with a nonequivalent control group design, with two groups: an experimental group that taught using the STEM-based digital learning model and a control group that used conventional methods.

The study included 600 grade 5 students from Indonesia, with 300 in the control group and 300 in the experimental group. The control group received conventional disaster mitigation learning, whereas the experimental group employed a STEM-based digital model.

The questionnaire instrument used in this study comprised 40 statements generated based on indicators of psychological disaster preparedness in children. Important parts of the indicators were children's ability to identify the proper action to take in different situations, as well as their ability to save themselves and manage their emotions under varied scenarios. Furthermore, the instrument evaluated children's calmness when facing problems, ability to handle fear and anxiety, and self-confidence in tough situations. The ability to calm others in distress, knowledge of one's anxiety, readiness to embrace obstacles, and avoidance of dangers were all assessed. Experts assessed the questions' validity, and the product-moment correlation results revealed that each question was constructively valid and highly reliable ($r = 0.932$).

The data was analyzed using SPSS version 26, which included descriptive statistical tests, normality tests, homogeneity tests, paired sample t-tests, and independent t-tests. This study investigated the following hypotheses:

- Ho: STEM-based learning model does not influence children's psychological preparedness for disasters.
- H1: STEM-based learning model influences children's psychological preparedness for disasters.

This study was designed to provide an overview of the usefulness of STEM-based learning models in enhancing children's psychological preparedness, allowing them to handle emergencies with more emotional resilience.

4. Results and Discussion

For six months, each group learned about disaster mitigation in the prescribed method: the experimental group employed the STEM-based Disaster Mitigation Digital Learning model, whereas the control group learned conventionally. The two methods were devised with various steps targeted at increasing children's psychological preparedness for catastrophes.

In the experimental group, the STEM-based model had numerous structured stages. The first level, exploration, introduced youngsters to the fundamental principles of natural catastrophes through an interactive video about disaster incidents. The second step involved risk analysis, in which they used digital programs to discover potential hazards around them and learned how to analyze data and interpret disaster risks, mixing math and science. The next stage, technology-based simulation, allowed children to exercise in digital scenarios, strengthening their adaptation and emotional management skills during disasters. The third stage, reflection, invited them to share their simulation experiences and discuss strategies for maintaining self-control and confidence in the face of crisis. This technique not only taught children about disasters, but also helped them regulate their anxieties, gain confidence, and develop psychological readiness.

In comparison, the control group used a traditional procedure with easier stages. The first phase was a classroom presentation in which children learned about different sorts of catastrophes, their causes, and basic response procedures. The second stage was a class discussion, in which children may ask questions and debate disaster-related topics. The final stage was the conclusion, in which the teacher recounted what had been learned. This strategy did not include any simulations or hands-on exercises that would allow children to practice adaptation skills or emotional management in crisis circumstances.

After six months, measures were taken to determine the psychological readiness of the youngsters in both groups. This measurement attempted to determine how effective the STEM-based digital learning model was in boosting psychological preparedness when compared to the conventional technique.

Following the therapy and assessment of elementary school children's psychological disaster preparedness, data was collected for descriptive statistical analysis. The goal of gathering this data was to get an overview of the pre-test and post-test outcomes for the two groups, the experimental group and the control group, as indicated in Table 2:

Table 2.
Results of Descriptive Statistics.

Descriptive Statistics	N	Minimum	Maximum	Mean	Standard Deviation
Pre-Test Experiment	300	61	68	45.45	1.133
Post-Test Experiment	300	88	97	94.45	1.157
Pre-Test Control	300	61	68	46.11	1.144
Post-Test Control	300	61	69	55.10	1.161

Table 2 shows the minimum, maximum, average, and standard deviation values for each group, which will be used for further analysis. The next step is to do a normality test to see if the data distribution meets the normality requirements, which is required before running the paired sample t-test and independent sample t-test. The normality test was carried out using the Kolmogorov-Smirnov and Shapiro-Wilk techniques, and the results are shown in Table 3:

Table 3.
Results of Normality Test.

Normality Test	Kolmogorov-Smirnov		
	Statistic	df	Sig.
Pre-Test Experiment	0.178	300	0.255
Post-Test Experiment	0.198	300	0.314
Pre-Test Control	0.232	300	0.209
Post-Test Control	0.215	300	0.701

According to this Table 3, all significance values (Sig.) in all four groups for the Kolmogorov-Smirnov and Shapiro-Wilk tests are more than 0.05, indicating that the data is regularly distributed. Because the data meets the normality assumption, parametric statistical tests can be used to conduct further analysis.

The next step is to use a paired sample t-test to see whether there are any significant mean differences between pre-test and post-test results within the same group. This test seeks to respond to the following question: "Does the application of the STEM-based disaster mitigation digital learning model affect the psychological disaster preparedness of elementary school children?" The analysis was carried out by comparing pre-test and post-test data in the experimental group (with a STEM-based model) with the control group (with a conventional approach). The results of this paired sample t-test are shown in Table 4.

Table 4.
Paired Samples Test.

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Pre-Test Experiment - Post-Test Experiment	-34.392	2.112	0.232	-33.937	-27.392	-111.319	298	0.000
Pair 2	Pre-Test Control - Post-Test Control	-0.700	3.309	0.391	-1.211	-.010	-2.291	298	0.012

In Table 4, the paired sample t-test results show that in Pair 1, the significance value (2-tailed) is 0.000 <0.05, indicating a significant difference in the average psychological readiness of children in the pre-test and post-test in the experimental group using the STEM-based digital learning model. In Pair 2, the Sig. (2-tailed) is 0.033 < 0.05, indicating a difference in the mean of the control group between the pre-test and post-test. However, the difference is lower than the experimental group. Based on these findings, we may conclude that the STEM-based digital learning model has a greater impact on children's psychological disaster preparedness than the conventional learning technique.
Next is the homogeneity test, with the following calculation results:

Table 5.
Results of Homogeneity Test.

Test of Homogeneity of Variance	Levene Statistic	df1	df2	Sig.
Based on Mean	2.392	1	598	0.094
Based on Median	1.292	1	598	0.392
Based on Median and with adjusted df	1.302	1	593.214	0.932
Based on trimmed mean	3.391	1	598	0.393

According to Table 5, the significant value for the homogeneity test based on the mean is 0.094 > 0.05, indicating that the variance of post-test data between the experimental and control classes is homogeneous. Thus, the requirement for variance homogeneity is satisfied, allowing us to proceed with the independent sample t-test.

The next stage is to conduct an independent sample t-test to address the question: "Is there a significant difference in psychological disaster preparedness between children who learn with STEM-based digital models compared to conventional learning?" This analysis was performed using post-test data from the experimental and control groups, and the findings are shown in Table 6.

Table 6.
Independent Samples Test.

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	**Sig.**	**t**	**df**	**Sig. (2-tailed)**	**Mean Difference**	**Std. Error Difference**	**95% Confidence Interval of the Difference**	
									Lower	**Upper**
Psychological Disaster Preparedness	Equal variances assumed	3.382	0.093	85.123	598	0.000	38.629	0.2321	30.332	33.292
	Equal variances not assumed			85.123	130.302	0.000	38.629	0.2321	30.332	33.292

Table 6 shows that the significant value (Sig 2-tailed) is 0.000, which is less than 0.05. This suggests that there is a significant difference in psychological disaster preparedness between students who learned using the STEM-based digital model and those who used traditional learning techniques. This finding is corroborated by statistics in Table 2, which demonstrate that the mean post-test score of students who learned using the STEM-based digital model was greater than that of the control group. This suggests that youngsters in the experimental group had a larger improvement in psychological preparedness following STEM-based learning.

Visualization of the difference in post-test scores of the control class and the experimental class can be seen in the following figure.

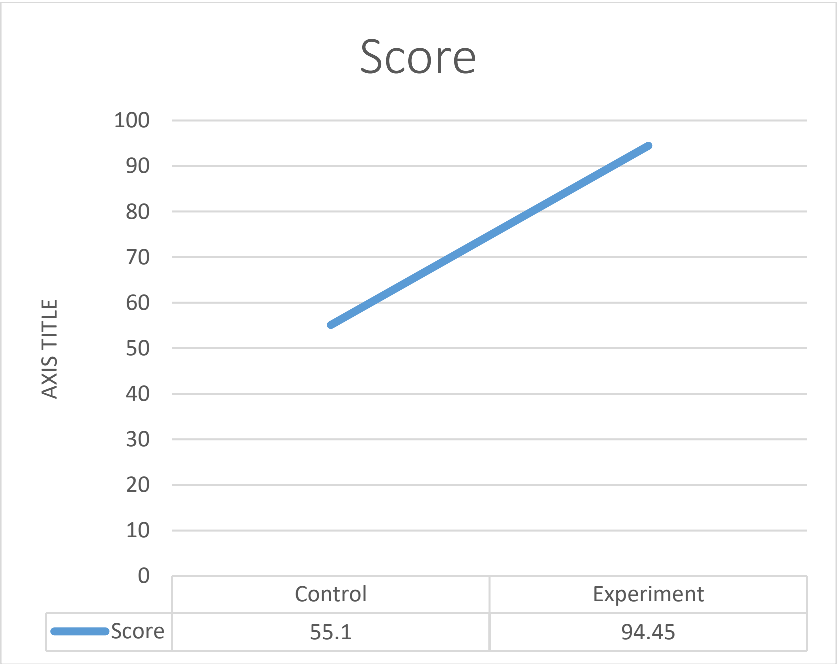

Figure 1.
Visualization of differences in post-test scores of controls and experimental classes.

According to Figure 1, there is a significant difference in average post-test scores between the control and experimental classes for children's psychological disaster readiness. The control group had a mean post-test score of 55.1, demonstrating that traditional learning methods had little influence on enhancing children's psychological preparedness. In contrast, the experimental class improved significantly, with a mean post-test score of 94.45. These findings show that the STEM-based disaster mitigation digital learning model is substantially more effective at improving children's psychological preparedness to deal with emergencies. This remarkable contrast between the two groups implies that STEM-based learning can help children build greater psychological preparedness than conventional methods.

5. Discussion

This study found that the STEM-based disaster mitigation digital learning approach was much more effective in boosting children's psychological preparedness for disasters. Several similar studies have shown the benefits of technology-based or STEM education in disaster mitigation but using different emphases and techniques. Raccanello, et al. [24] created a web application to help youngsters prepare for earthquakes, however, they focused on emotional resilience rather than analytical abilities and technology in disaster mitigation [24]. Similarly, Seddighi, et al. [10] examined disaster mitigation education in the context of climate change using traditional face-to-face approaches rather than digital technology or STEM integration to support students' psychological resilience Seddighi, et al. [10]. Rodavia, et al. [25] developed a digital tool for disaster preparedness for primary school pupils that included basic knowledge and exercises but did not specifically address STEM or psychological resilience evaluation [25]. Furthermore, Elangovan and Kasi [20] gave psychological preparedness training to teachers to improve students' psychosocial readiness for disaster impacts, although they emphasized the role of teachers rather than incorporating technology or STEM techniques into direct student instruction Elangovan and Kasi [20]. Winarni and Purwandari [34] used mobile applications in earthquake mitigation learning to boost student knowledge, however, they focused on imparting mitigation information rather than psychological resilience using a STEM approach [34]. Overall, this study takes a novel strategy by merging STEM-based digital education, which not only focuses on cognitive and technical abilities but also significantly enhances students' psychological preparedness. Thus, this study makes an innovative contribution to disaster mitigation education at the primary school level.

The STEM-based digital learning methodology is more effective in boosting children's psychological preparedness for disasters than traditional techniques. This STEM approach combines science, technology, engineering, and mathematics, helping youngsters to get a better knowledge of disasters while also developing psychological resilience. The STEM approach also offers an interactive and applicable learning strategy that is tailored to children's requirements in developing overall psychological readiness [29, 35]. Conventional learning methods, on the other hand, typically rely on lectures, short discussions, and the usage of text- or image-based resources. While these methods help deliver basic facts about catastrophes, they often fail to attract children's interest and do not provide opportunities for practical practice in emergency circumstances [25, 36, 37]. STEM-based learning, on the other hand, makes use of digital technology and disaster simulations to provide pupils with hands-on experience. These exercises allow youngsters to not only comprehend disaster theory but also experience regulating their emotions and responses when a disaster occurs.

Makransky and Lilleholt [38] and Hermon, et al. [39] found that simulation-based learning can considerably increase students' psychological readiness, particularly emotional regulation, and decision-making capacity [38, 39]. Simulations expose students to emergency circumstances in a safe atmosphere, allowing them to practice overcoming fear and anxiety. In line with these findings, the current study found that students in the experimental group who used the STEM-based digital learning model had a much higher level of psychological preparedness than the control group. In addition to simulations, the STEM approach to disaster mitigation education incorporates risk analysis and participatory activities. Risk analysis enables youngsters to comprehend the potential threats around them in a scientific manner [40, 41]. Children are taught to identify danger signs and calculate risk levels using technology such as risk map apps or disaster monitoring systems. For example, research findings indicate that students trained in STEM-based risk analysis methods are calmer and more organized in emergency circumstances because they have a better awareness of disaster causes and suitable preventative actions [42-44].

Children learn hands-on in STEM-based interactive exercises by creating earthquake-resistant buildings or utilizing technological tools to forecast potential earthquakes. These activities not only help them enhance their cognitive and motor skills for dealing with calamities, but they also boost their confidence. This approach is consistent with constructivist learning theory, which claims that knowledge is easier to comprehend when students can "experience" it firsthand [45]. These practical exercises teach youngsters not just in-depth learning, but also how to handle their stress, fear, and anxiety. According to research, children who are taught catastrophe mitigation using technology and simulation have a considerable reduction in anxiety levels [46-48]. They gain confidence in dealing with unpredictable situations and are better emotionally prepared. The study also underlines that STEM-based strategies assist youngsters improve their problem-solving abilities, which is an important component of psychological readiness during calamities. This leads to the conclusion that the STEM approach, which involves simulations, risk analysis, and interactive tasks, provides more hands-on experience and practical understanding than other methods of preparing children for emergencies. This strategy allows children to frequently practice responses in a safe environment, allowing them to remain calm and confident in emergencies.

The STEM approach to disaster mitigation helps youngsters comprehend disaster theory while also providing them with more practical hands-on experience. STEM-based learning technology, such as simulation applications, augmented reality (AR), and virtual reality (VR), enables children to "experience" crisis scenarios in a safe and regulated setting. This technology produces a virtual experience that is remarkably like real-world settings, allowing youngsters to rehearse their responses without risk [49-53]. They can use these simulations to visually and auditorily experience scenarios like earthquakes or floods, which will help them overcome their concerns through repeated exposure. Boydstun, et al. [54] found that using VR in disaster mitigation learning can considerably increase children's mental readiness [54]. Children who trained in experiencing earthquake simulations in virtual reality reported less anxiety and an increased capacity to manage emotions when confronted with similar events regularly. VR enables users to notice danger signs, respond calmly, and adapt to the simulated situation, thus increasing their resilience mentally Noghabaei and Han [55]; Smith [56] and Stone, et al. [57]. Walker, et al. [58] stated that simulation-based technology can help children develop psychological resilience by teaching them how to deal with stress in near-real-world scenarios while remaining safe.

Technology-based risk analysis is one part of the STEM approach that improves children's psychological preparedness for disasters. Children are taught to use data-driven tools to assess potential disaster risks in their environment. They learn to notice natural signs, assess the level of danger, and determine the necessary self-protection methods. Children, for example, can use STEM-based learning apps that display maps of disaster-prone areas as well as current weather information. Shirai, et al. [59] discovered that training children to utilize risk map applications strengthened their self-awareness and ability to control fear [59]. They were better prepared for emergency circumstances due to their greater understanding of dangers and preventive measures [59-61].

The STEM approach also incorporates engineering principles, allowing youngsters to comprehend the resilience of building structures and catastrophe survival techniques. Children are frequently asked to design small earthquake-resistant buildings or test the structures they build as part of this learning process. These activities not only enhance their technical knowledge, but also help them build problem-solving, creativity, and decision-making abilities. According to research, youngsters who participate in disaster-resistant building design projects are more confident and capable of overcoming fear when confronted with situations requiring quick thinking [62-66]. Such activities help youngsters to be more self-sufficient and prepared to confront obstacles, which is a significant component of psychological preparedness. In addition to technology and engineering, the STEM approach incorporates math to help youngsters understand disaster-related patterns and information. Children can use simple statistics to understand graphs about the frequency of catastrophes or calculate the chance of a disaster occurring in a certain area. This technique trains kids to think critically and rationally, which helps to prevent excessive fear when faced with disaster risks.

The STEM-based digital learning methodology also allows students to complete interactive tasks independently. With digital access, they can repeat simulation materials or exercises at any time, allowing for ongoing reinforcement of psychological preparedness. According to Rusling, et al. [67] children who practiced disaster adaption simulations and exercises regularly reported less fear and more self-confidence [67]. This strategy enables youngsters to learn at their own pace, explore deeper into the material, and comprehend the critical actions in an emergency.

Furthermore, interactive learning is a key component of a successful STEM-based digital learning model to strengthen children's psychological disaster preparedness. This method engages children in simulations, experiments, and data analysis rather than passively receiving information, making them more involved in the learning process [68-73]. With this emotional and cognitive engagement, children have a deeper and more relevant comprehension of catastrophic events. In terms of psychological disaster preparedness, STEM-based interactive learning allows youngsters to practice frequently using simulations that simulate real-life emergency circumstances. This teaches children to respond calmly and successfully when confronted with unexpected circumstances. For example, Fino, et al. [74] discovered that children who engaged in crisis simulations using digital devices had lower anxiety levels and higher mental preparation than children who just received theoretical learning [74]. The study also found that repetition in interactive activities can improve self-management abilities and reduce fear, both essential for psychological readiness during disasters.

In addition to reducing anxiety, interactive learning helps children develop social skills that are necessary in emergencies, such as cooperating and assisting one another. Many STEM-based interactive exercises urge youngsters to work together to solve problems or build catastrophe mitigation strategies. For example, people could collaborate to create a small earthquake-resistant building or use a simulation tool to calculate the best evacuation route. These exercises teach kids how to interact effectively and support one another, which might increase their confidence and psychological preparedness.

Overall, a comparison of the STEM approach to conventional methods revealed that STEM was significantly more effective in strengthening children's psychological preparedness for disasters. Conventional approaches based on lectures or texts frequently lack immersive experiences, making it difficult for youngsters to establish necessary psychological preparedness. In contrast, the STEM approach exposes youngsters to emergency simulations that teach practical skills and a strong mentality. This study demonstrates that the STEM-based digital learning model not only helps students understand disasters in theory but also helps them develop the emotional resilience and psychological preparedness required to respond to disasters more confidently and effectively.

6. Conclusion

This study found that the STEM (science, technology, engineering, and mathematics) --based digital learning approach for disaster mitigation had a significant influence on enhancing elementary school children's psychological preparedness when disasters occur. Children who employ the STEM-based learning paradigm tend to be more psychologically prepared than those who learn using conventional means. This is evidenced by the difference in post-test results between the experimental and control groups, with the experimental group scoring higher, indicating more psychological preparedness. This STEM approach enables a more interactive and relevant learning style. This allows youngsters to immediately participate in simulations, risk analysis, and other interactive exercises. Such exercises give children real-life experience and teach them to remain calm and confident during emergencies. This improves their psychological resilience, particularly the ability to handle emotions in disastrous scenarios. Furthermore, the technology employed in this program enables children to access and study material independently, which improves their understanding and adaptive skills in coping with crisis circumstances. Overall, this study demonstrates that STEM-based digital learning models are an excellent choice for strengthening children's psychological preparedness for dealing with disasters. This technique not only gives a theoretical grasp of disaster mitigation but also improves practical skills and emotional readiness. Based on these findings, STEM-based learning models should be used more widely in disaster mitigation education systems, particularly in disaster-prone areas, to better educate the next generation to meet future disaster threats.

7. Research Limitations

This study is limited by the relatively short duration of the intervention, so the long-term effects of the STEM-based learning model on children's psychological readiness in facing disasters cannot be known in depth. To ensure a stable and sustainable impact, longer duration testing and repeated evaluations will provide a more accurate picture of the effectiveness of this model over a longer period.

8. Recommendations for Future Research

Future research is recommended to test the effectiveness of this STEM-based learning model with longer duration and involve long-term evaluation, for example through repeated testing several months or years after the initial intervention. This will provide a more comprehensive understanding of how children's psychological disaster preparedness can be maintained or improved in the long term.

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