Developing Digital Comics to Enhance Landslide Disaster Literacy among Elementary School Students

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https://doi.org/10.17977/um065.v6.i9.2026.3

Article history
Submitted: 15 May 2026
Revised: 3 June 2026
Accepted: 7 June 2026
Published: 9 June 2026

Keywords
ADDIE
Digital comics
Disaster literacy
Elementary schools
Landslide mitigation

Abstract
This study's core research objective is to develop a digital comic themed on landslide disaster mitigation. The comic is targeted at fifth-grade primary school students in East Java, Indonesia, meets three preset criteria (learning validity, practicality, and effectiveness), and deeply integrates literacy related to landslide disaster risk reduction. This study adopts the research and development (R&D) method and advances all work in full compliance with the ADDIE five-phase research framework throughout the implementation process. Research data is collected through observation, interviews, questionnaires, and academic achievement tests. Core research tools include supporting instruments: expert validation forms, teacher-student response questionnaires, and pre-test and post-test assessment questions. All data processing is completed using descriptive quantitative analysis and N-Gain analysis. The final core outcomes show that the developed product received a score of 83% from media experts, 87% from teaching material experts, and 95% from frontline practitioners, which meets the requirements for high effectiveness. The 89% student response rate reaches the standard for high practicality. The average N-Gain value of 0.6 represents a moderate learning gain, which can improve students' academic performance, while also cultivating their learning motivation, active participation, and early-stage disaster prevention awareness.

1. Introduction

Hydrometeorological disasters, in recent years, have emerged as one of the most severe and widening hazards threating Indonesia. The dominance of mountainous areas, high rainfall intensity and land use changes in various regions of Indonesia makes the potential for landslides a very high concern. Data from the National Disaster Management Agency has shown that landslides are one of the highest level disasters and life-threatening factors to human. Disaster incidents in Indonesia during the year 2024 were still dominated by hydrometeorological disasters, particularly landslides that caused casualties, destruction of residential areas, public facilities and education (Kurniawan & Nirmalasari, 2022; Kurniawati, 2020; Pahleviannur, 2019). This condition shows that disaster mitigation must be done in a systematic and sustainable way, not only through physical infrastructure but also by strengthening disaster education from an early age (Budi et al., 2026; Susilo et al., 2025; Suwaryo & Yuwono, 2017; Wu et al).

Disaster education are strategic measures that lead to a culture of preparedness, which sees effects on increasing community through awareness-raising about potential risks in the surrounding environment. Disaster literacy, particularly among elementary school-aged children is an urgent need because they are among the most vulnerable groups during disaster. Disaster literacy is not just knowledge about the types of disasters and what causes disasters, but also includes being able to recognize warning signs, understand mitigation measures, and make appropriate decisions in emergency situations (Afrian 2019; Cecep & Permana 2011; Labudasari & Rochmah 2020). Increasing disaster literacy for elementary school students is necessary because in the concrete operational stage of development, students more easily understand the material by experiencing visual images, stories and contextual learning (Asrizal & Festiyed, 2020; Manek, 2023; Reza et al., 2024; Wilujeng & Sukarni, 2022).

However, the implementation of disaster mitigation education in elementary schools still faces various challenges. Disaster education generally remains focused on lecture-based methods and the use of theoretical textbooks, making it less effective at providing meaningful learning experiences for students. Disaster mitigation material is also often presented in a fragmented manner without connecting it to real-world conditions in the students' immediate surroundings. As a result, students tend to struggle to understand concrete and practical disaster mitigation steps. Furthermore, the lack of innovative learning media makes disaster education less

ISSN: 2797-3174

engaging and fails to optimally enhance student engagement and preparedness. Yet, elementary school students typically grasp material more easily through visual media and interactive activities (Genika et al., 2023; Wibowo et al., 2017). Other studies also indicate that disaster mitigation education in elementary schools has yet to widely adopt contextual learning models and media, resulting in students' understanding of disaster mitigation remaining suboptimal (Noviana et al., 2023; Salsabila & Dinda, 2021; Sih & Kirana, 2016; Xiao et al., 2026)

Advances in digital technology offer opportunities to develop learning materials that are more innovative, engaging, and tailored to the characteristics of 21st-century learners. One medium with great potential for use in disaster education is the digital comic. Digital comics are technology-based visual learning materials that combine illustrations, text, color, and storytelling in an electronic format, thereby creating a learning experience that is both enjoyable and easy to understand. The use of digital comics is considered effective in helping students understand abstract concepts through visualization and contextual narratives. Various studies indicate that digital comics can enhance learning motivation, reading interest, student engagement, and conceptual understanding more effectively than conventional media (Galan, 2015; Hidayati et al., 2024; Khotimah & Hidayat, 2022). Furthermore, visual story-based media is considered capable of strengthening memory and helping students understand real-world situations related to disaster mitigation (Akgün & Akgün, 2020).

Several previous studies have developed digital comics for use in various learning contexts. Previous research indicates that digital comics are effective in improving students' learning outcomes and thinking skills (Jannah & Sandika, 2023; Khotimah & Hidayat, 2022). Other studies have also found that disaster-based visual media can increase students' preparedness for potential disasters in their surrounding environment (Mahamood et al., 2024; Rasmet et al., 2025). Nevertheless, a review of the literature indicates that research on the development of digital comics for disaster mitigation education still has several limitations. Most previous studies have focused primarily on earthquake and flood mitigation (Aprianti & Nadiyyah, 2024; Johnson et al., 2014), whereas the development of digital media specifically addressing landslide mitigation for elementary school students remains relatively limited. Furthermore, previous studies generally emphasized only the visual and interactive aspects of the media without systematically integrating disaster literacy into the learning narrative. The media developed have also not been designed based on the cognitive developmental characteristics of elementary school students, so aspects of risk understanding and preparedness have not been the primary focus in the development of disaster education media.

Given these issues, there is a research gap in the development of disaster education materials capable of integrating disaster literacy, digital technology, and the characteristics of elementary school students into a single contextual and interactive educational product. Therefore, the novelty of this study lies in the development of a digital comic integrating disaster literacy based on the ADDIE model (Analysis, Design, Development, Implementation, and Evaluation) for landslide mitigation education in elementary schools. Unlike previous studies, the digital comic developed here serves not only as a visual learning medium (Hosler & Boomer, 2011) but is also designed to build students' ability to recognize landslide risks, understand mitigation steps, make decisions in emergency situations, and foster preparedness through a contextual storytelling approach closely tied to students' daily lives. The integration of disaster literacy into the narrative of the digital comic is the key distinguishing feature of this study, as the learning process emphasizes not only cognitive aspects but also the early development of students' disaster awareness and response capabilities.

The ADDIE model was selected in this study due to its structured yet adaptable stages, making it appropriate for developing digital instructional media. The model consists of five phases about analysis, design, development, implementation, and evaluation, which guide the development process systematically to produce learning media that are valid, practical, and effective for classroom use (Molenda, 2003). Based on this framework, the present study focuses on developing a digital comic integrated with disaster literacy content on landslide mitigation for elementary school students. By utilizing engaging visual stories, the developed media helps students understand disaster mitigation concepts more easily and contextual learning experiences. In addition, the integration of disaster literacy is expected to foster students' awareness, preparedness, and responsiveness toward potential landslide disasters in their environment. A developmental approach is employed to innovate digital disaster education media at the elementary school level, which is expected to provide useful contributions and become a reference for further studies.

2. Method

This research is an R&D concerning for making of a digital comic that combines disaster literacy into landslide mitigation learning in elementary schools. To ensure a systematic yet flexible process, this research employs the ADDIE development model, which comprises five core stages: Analysis, which identifies learning needs and learner characteristics; Design, which develops the instructional plan and product blueprint; Development, which involves product creation, validation, and revision; Implementation, which tests the product in the learning environment; and Evaluation, which assesses the effectiveness and quality of the developed product for further improvement (Molenda, 2003). These stages are particularly well-suited for creating digital learning media.

ISSN: 2797-3174

After the analysis phase profile of learning needs, student characteristics, landslide mitigation materials and disaster education conditions in elementary schools. Following the storyline of the digital comic, media interface, disaster literacy integration, content development and research instruments were prepared during the design phase. The developed digital comic was created based on the design plan and then validated by media experts, material experts, and language experts to examine its feasibility and quality. In the implementation stage were carried out trials of activities with elementary school students to measure the practicality and effectiveness of learning media in classrooms. The last step of the development process was evaluation, which aimed to examine the overall process and revise the product based on suggestions from experts and results from trials.

The Study was undertaken at an elementary school in East Java Qualitative and Quantitative data were used in this research. With qualitative data includes opinions, suggestions, appraisals and responses of validators and users on digital comics developed. For quantitative responses, however, were obtained from expert validation scores as well as teacher and student questionnaire results as well students test scores in relation to their understanding of landslide mitigation material. Different methods were used to collect the data, including observations, interviews, questionnaires and tests. Required and barriers to disaster mitigation learning at the elementary school level were identified through observations as well as interviews. Questionnaires were given to assess the validity, practicality and user perceptions of media developed for learning. We also conducted tests to assess students' understanding of landslide mitigation concepts after engaging with the digital comic. Research tools used a four-point Likert scale with categories: (1) very poor situation, (2) poor situation, (3) good situation and (4) very good situation. The resultant validation was interpreted quantitatively descriptively by taking the percentage level of product feasibility with the following formula. The validity of the developed product was determined based on the criteria presented in Table 1.

$$P = \frac{\sum X}{\sum Xi} \times 100\% \quad (1)$$

Notes:
P = Eligibility percentage
∑X = Total score obtained
∑Xi = Maximum possible score

Table 1. Validity Criteria

Percentage	Validity Criteria
85.01%–100%	Considered highly valid and suitable for use without requiring revisions.
70.01%–85%	Categorized as sufficiently valid and appropriate for use with slight improvements.
50.01%–70%	Classified as less valid and in need of substantial revisions before implementation
0%–50%	Invalid and cannot be used

To verify the effectiveness of a self-developed digital comic learning medium themed on landslide disaster mitigation, this study takes the magnitude of improvement in students' understanding before and after using the developed learning medium as its core indicator. It adopts N-Gain analysis, which can measure this degree of improvement, and its corresponding formula as the core basis for data analysis.

$$N\text{-}Gain = \frac{\text{Posttest} - \text{Pretest}}{\text{Maximum Score} - \text{Pretest}} \quad (2)$$

A score of greater than 0.7 is included in the high category based on N-Gain criteria to percent increase in students learning outcomes, Moderate scores from 0.3 to 0.7. These tend to be a fair, although about half the students achieving better, between their expected and actual achievement levels. On the other hand, N-Gain < 0.3 is categorized as low, indicating a rise in students' understanding still has to be improved.

3. Results and Discussion

3.1. Result

3.1.1. Analysis Phase

The analysis was accomplished via a review of documents, field observations, and interviews with the principal and fifth-grade teachers at an elementary school. From the analysis results, disaster mitigation material about landslides is already being taught in thematic learning and IPAS (Integrated Science and Technology), but still not optimally implemented in the learning process. Results of the interviews suggest that textbooks and teacher-centered instruction remained the primary approaches used in teaching. The instructional media currently used have not been able to incorporate disaster literacy in a contextual and

ISSN: 2797-3174

appealing manner for students. Beyond that, the content is presented very abstractly and without supporting imagery and thus students do not get a feel for causes, warning signs and mitigation steps relating to landslides. The researcher also observed the learning activities and conducted teachers needs assessment. Observation results indicated that whiteboards, speakers, and LCD projectors were available. Each teacher had been provided with a laptop, though these were still rarely used in the learning process. Students had difficulty understanding the learning material. The learning resources used consisted of textbooks and student workbooks. The media used by teachers in the learning process included images of landslides and textbooks, while the Chromebooks provided by the school and other digital media were rarely utilized in learning activities.

Analysis of students' answers on learning outcomes regarding environmental and disaster mitigation materials found that more than 2/3, about 65% of students failed to meet the Minimum Competency Criteria determined by the school. These results indicate that learning difficulties still occur which require the development of teaching media so that students can understand better.

3.1.2. Design Phase

In the designing phase, it was created a digital comic integrating disaster literacy into to landslide mitigation for elementary students, this was the product design, just before development (see Figure 1). This comic was designed according to the results of needs analysis, the characteristics of elementary school students, learning outcomes and principles of engaging interactive visual learning. The digital comic was designed with several key components, namely a contextual story about a landslide event in the students' local community, main characters consisting of local community members, integration of disaster mitigation concepts before, during, and after a landslide, digital and colorful illustrations, and simple and communicative language appropriate for the students' developmental level. In addition, the researchers also developed a storyboard, plot outline, learning materials, and assessment instruments used in the product development process.

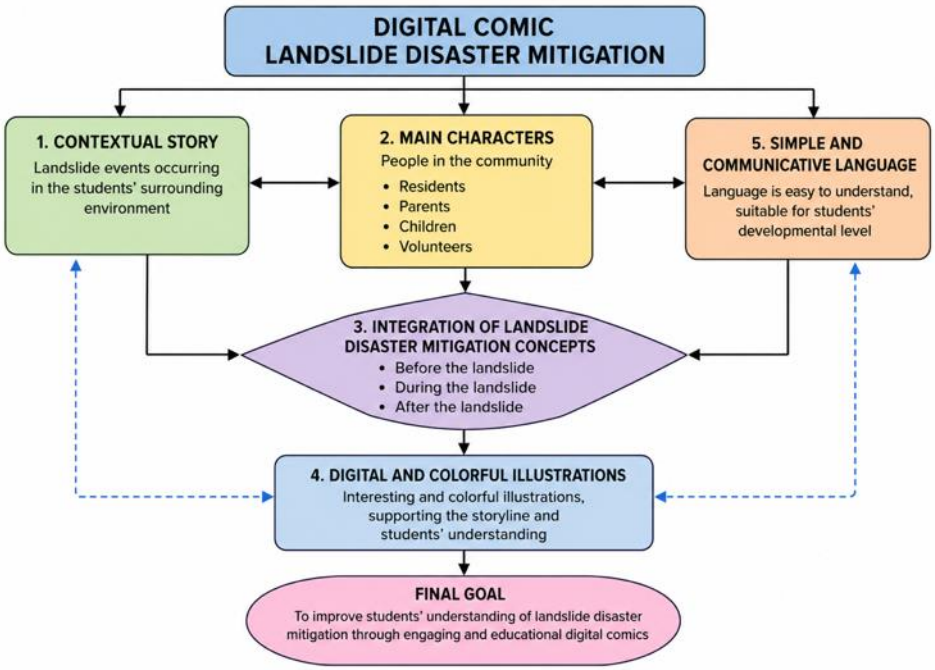

Figure 1. Comic Storyline

3.1.3. Development Phase

The development phase of this study was conducted systematically to produce an educational digital comic suitable for use in teaching landslide disaster mitigation in elementary schools. In this phase, the researcher began to implement the product design developed in the design phase into a tangible product in the form of an interactive digital comic that is engaging for elementary school students.

The developed product contains landslide mitigation material presented in the form of contextual visual stories so that students can more easily understand disaster-related material through learning experiences closely tied to their daily lives. The stories in the comic depict the surrounding environmental conditions prone to landslides, early warning signs of the disaster, self-rescue actions, as well as mitigation steps before, during, and after a landslide occurs. The characters in the comic are modeled after the local community surrounding the students, thereby enhancing students' emotional engagement and interest in learning.

ISSN: 2797-3174

During the development process, the researchers designed several key components of the product, including the development of a comic storyline aligned with disaster mitigation learning objectives, creating comic characters and figures that are relatable to the lives of elementary school students, integrating landslide mitigation material into the story's dialogue and illustrations, creating full-color digital illustrations using digital design software, designing the layout of text, images, and panels. Examples of the digital comic pages developed in this study are shown in Figure 2.

Figure 2. Digital Comic Design

After the initial product was developed, the next step was expert validation to determine the suitability of the digital comic. Validation was conducted by three validators: a media expert, a content expert, and a practitioner/user. The media expert assessed the integration, media design, and usability aspects of the digital comic, and the results are presented in Table 2. The content expert evaluated the accuracy, thematic relevance, language, and effectiveness of the disaster mitigation material, with the results shown in Table 3. Furthermore, the practitioner/user assessed the appearance, content quality, practicality, and usability of the digital comic, as presented in Table 4. A summary of the validation results from all validators is provided in Table 5, indicating that the developed digital comic is highly valid and suitable for use in elementary school learning.

Table 2. Media Expert Validation Results

No	Evaluation Aspect	Score	Validity (%)
1	Integration	13	86%
2	Media Design	33	83%
3	Usability	8	80%
	Average Validity	54	83%

Table 3. Expert Validation of Content

No	Evaluation Aspect	Score	Validity (%)
1	Content	26	86%
2	Thematic Relevance	18	90%
3	Language	8	80%
4	Effectiveness	14	93%
	Average Validity	54	87%

Table 4. Results of the Practitioner/User Survey

No	Evaluation Aspect	Score	Validity (%)
1	Appearance	18	90%
2	Content	19	95%
3	Practicality and Usability	20	100%
	Average Validity	57	95%

ISSN: 2797-3174

Table 5. Summary of Expert Validation Results

No	Validator	Validity (%)	Category
1	Media Expert	83%	Highly valid
2	Content Expert	87%	Highly valid
3	Practitioner/User	95%	Highly valid

According to the validation results indicate that the developed educational digital comic was categorized as "highly valid" for implementation in the learning process. The high validation scores indicate that the product meets standards for appropriate content and media design, and instruction in elementary school. Still, the validators gave a number of tips how to improve it making the product even better. The suggestions included the following, rewording certain disaster terms to make them elementary school student-friendly, with images on the first signs of a landslide, adjusting the spot of the text and images to make them more proportional at a glance, modify it to have a more vibrant color palette appropriate for elementary grade school students and to make it appeal visually.

To do so, the researcher revised the product by fixing parts that were still bad based on these inputs. Updated language and images, comic book panel layout, color palette and visual design were all aspects that were subsequently revised. After finishing the revision stage, it was developed into a digital comic for implementation or field trial in order to see its practicality and efficacy as part of a learning process.

3.1.4. Implementation Phase

The initial validation of disaster literacy integrated in a digital comic product Being instead it's called the implementation phase started. In this stage, the product was used in learning to analyze how feasible and effective the developed learning medium is. It was carried out gradually, with each trial being comprised of individual trials, small-group trials, and full-scale trials with fifth-grade elementary school students. Prior to conducting the trial activities, the researchers produced appeal material, research instruments, observation guidelines, student response questionnaires as well as pretest and posttest items used in this study. Teachers were also given guidance on the ways to utilize the digital comic through a learning implementation system.

3.1.4.1. Results of the Individual Pilot Study

An individual pilot study was conducted with three fifth-grade elementary school students with high, moderate, and low academic abilities. The selection of students with varying abilities aimed to determine the readability, clarity of the material, and ease of use of the digital comic across different student characteristics. During the pilot study, students were asked to read and use the digital comic independently under the supervision of the researcher. Next, the students were asked to provide feedback through an evaluation questionnaire covering aspects of media presentation, clarity of content, ease of use, and visual appeal. Additionally, the researcher observed the students' responses and activities while they were using the learning media.

Based on the results of individual trials, students responded positively to the digital comic that was developed (see Table 6). Students were drawn to the illustrations, colors, and storyline presented. Additionally, the use of simple language helped students understand the material on landslide mitigation more easily. Although the comic received a "very good" rating, students also provided some feedback, such as increasing the text size in certain sections and adding illustrations of self-rescue actions to make them clearer. Based on this feedback, the researcher made minor revisions before proceeding to the small-group testing phase.

Table 6. Results of the Individual Pilot Test

Value Interval	Frequency	Percentage (%)
65-68	2	66.7%
69-72	0	0%
73-76	1	33.3%
N	3	
Mean	68	

3.1.4.2. Results of the Small-Group Pilot Test

Following revisions in step 2, the researcher performed a small-group pilot test with 10 fifth-grade students aged 10-11 years, consisting of 4 boys and 6 girls. The participants were recruited from a on slopes of Mount Lawu, East Java, Indonesia, a region prone to landslides. The location was selected because it reflects the environmental context addressed in digital comic. This pilot test sought to evaluate ideal use of digital comics as a part of the learning process, and student interactions with the medium during collaborative classroom exercises.

ISSN: 2797-3174

In this stage, the lesson was conducted using digital comics as the primary medium for delivering material on landslide mitigation. Teacher guided the students in reading the comics, discussing the story's content, identifying disaster mitigation steps, and answering questions related to the material studied. After the lesson concluded, the students were asked to complete a feedback questionnaire regarding the use of the medium.

Results of a small pilot study suggest that digital comics would be feasible for educational use (see Table 7). Students seemed more engaged in the learning process, especially when analysing aspects of the story and measures to mitigate disasters. Another reason which motivated comics is having engaging manner by way of illustrations and stories that relate directly to students daily lives. Also, teachers say that comics improves students' understanding of previously challenging and abstract material results indicated that the product was suitable for large-scale pilot-phase use.

Table 7. Results of the Small-Group Pilot Test

Value Interval	Frequency	Percentage (%)
65-68	3	30%
69-72	1	10%
73-76	4	40%
77-80	2	20%
N	10	
Mean	72.5	

3.1.4.3. Results of the Large-Scale Pilot Study

In this phase, students completed a pretest which was administered prior to instruction in order to measure their baseline knowledge of landslide mitigation. It then used the created digital comics for the learning process. After the instructional activities were completed, students took a posttest to evaluate improvements in their learning outcomes following the use of the digital comics. Results of the large-scale pilot test showed that students achieved an average score of 88.43 (see Table 8).

Table 8. Results of the Large-Scale Pilot Test

Value Range	Frequency	Percentage (%)
80-84	6	17%
85-89	10	28%
90-94	9	26%
95-100	10	29%
N	35	
Mean	88.43	

Table 9 shows that 10 students (29%) experienced a high level of improvement in learning outcomes, while 25 students (71%) experienced a moderate level of improvement. The overall average N-Gain score was 0.6, indicating a moderate improvement in learning outcomes. This suggests that the use of digital comics is quite effective in improving students' learning outcomes regarding landslide mitigation.

Table 9. N_{gain} Analysis

Value	Criteria	N_{gain}	
		Frequency	Percentage (%)
$\langle g \rangle \geq 0.7$	High	10	29
$0.7 > \langle g \rangle \geq 0.3$	Moderate	25	71
$\langle g \rangle < 0.3$	Low	0	0
Total		35	100

The researcher also measured student responses to the use of learning media. The results of the student response questionnaire showed a percentage of 89% in the very positive category (see Table 10). Students stated that digital comics made learning more interesting, enjoyable, easy to understand, and not boring. Overall, the results of the implementation indicate that digital comics incorporating disaster literacy are: (1) suitable for use in learning; (2) practical for use by teachers and students; (3) effective in improving student learning outcomes; (4) capable of increasing the motivation and interest of elementary school students in learning about landslide disaster mitigation.

ISSN: 2797-3174

Table 10. Results of the Student Response Questionnaire for Individual, Small-Scale, and Large-Scale Trials

No	Question	Percentage		
		Individual Trial	Small-Scale Trial	Large-Scale Trial
1	I am interested in the visual appeal of the digital comics used	70%	70%	94%
2	I find the font type and size in the digital comics easy to read	80%	80%	85%
3	I can understand the material clearly because the images displayed are high-quality and supportive	80%	80%	97%
4	I find the background colors and text comfortable to look at	100%	100%	88%
5	I understand the presentation of the instructional material	90%	90%	85%
6	I find the sentences in the digital comics easy to understand and clear	100%	100%	94%
7	I consider the medium used appropriate for the learning material	90%	90%	94%
8	I can understand the language used in the digital comic	100%	100%	85%
9	I understand the spelling of the language used	100%	100%	85%
10	I can understand the material well after using the digital comic	100%	100%	94%
11	I can understand the instructions for using digital comics well	80%	80%	91%
12	I can access digital comics easily	90%	80%	94%
13	I feel that digital comics help me increase my interest in learning	90%	90%	91%
	Total	1.168%	1.160%	1083%
	Average	90%	89%	90%
	Criteria	Very Positive	Very Positive	Very Positive
	Average Response	89%		
	Criteria	Very Positive		

3.1.5. Evaluation Phase

Based on the evaluation results, students responded very positively to the use of digital comics in landslide mitigation education. Students stated that the learning medium was engaging, easy to use, and helped them understand the material more clearly through colorful illustrations, contextual stories, and simple language. In addition, students appeared more active, focused, and enthusiastic throughout the learning process.

In their comments, professors and teacher alike were very impressed as digital comics made the disaster mitigation material more tangible and less abstract then conventional textbooks. The medium in which the instruction were delivered was considered to be one that increased motivation, focused attention and participation among students. However, many made relevant points for improvement including clearer use of illustrations, larger font size and simplification of the narrative to help students to follow. Using this feedback, the researchers then finalized the visual presentation, layout and language used. Digital comic integrating disaster literacy was found appropriate, feasible and a potentially effective tool for landslide mitigation education in elementary schools.

3.2. Discussion

The outcome of this development research was an educational medium in a digital comic form that integrated disaster literacy into landslide mitigation material for elementary school students. It is built based on the ADDIE models of Analysis, Design, Development, Implement and Evaluation. With the research results, the digital comic developed is feasible and practical and effective to use in learning. This study uniquely contributes to the creation of a digital comic for integrating content with contextual visual stories about landslide mitigation disaster literacy in elementary school learning based on the unique characteristics of elementary school students.

Textbooks and lecture-based methods are still typically used in the field of disaster mitigation education only limited to elementary schools which forced students to have difficulty understanding abstract concepts (Afifah et al., 2022; Masturah et al., 2018). Meanwhile, other digital learning support tools such as Chromebooks, LCD projectors, and internet connectivity either have not been fully optimized in the learning process. The analysis result also showed that students who have not graduated from minimum competency standard on environmental and disaster topics are about 65%. This condition shows that innovative learning media need to be developed, which can help students understand their lessons concretely and fun. It is as in the opinion of Lestari et al., (2024) and Sugiarto et al., (2023) that learning media can improve the effectiveness of the teaching and learning process.

Digital comics were developed by integrating visual elements, contextual narratives, and landslide mitigation material that is relevant to students' daily lives. The use of colorful illustrations, simple language, and characters that reflect the local environment helps students grasp the material more easily. This aligns with

ISSN: 2797-3174

Piaget's theory of cognitive development, which states that elementary school students are in the concrete operational stage and thus find it easier to understand material through visualization and real-world experiences. This view is supported by Hosler and Boomer (2011) who states that visual media can clarify abstract material by making it more concrete, thereby making it easier for students to understand the learning material.

In addition, integrating disaster literacy into digital comics helps students understand mitigation measures before, during, and after a landslide occurs. Presenting the material through contextual visual stories enables students to not only grasp the concepts theoretically but also understand the application of disaster mitigation in daily life. This is important because early disaster education can improve students' preparedness for disaster risks in their surrounding environment. (Septikasari & Ayriza, 2018) state that disaster education in elementary schools plays a crucial role in building students' knowledge and preparedness for disasters.

The validation results also showed that the digital comic received a "highly valid" rating from media experts, subject matter experts, and practitioners/users. The validation scores 83% as media experts, 87% as subject matter Experts, and As Practitioners/users 95% confirmed, these findings indicate that the content for content criteria, visual presentation, readability, suitability for elementary school students. Validators also offered many suggestions for improvement, including simplifying the terminology related to disasters, adding illustrations of landslide warning signs, and improving formatting of text and images. Product validation and revision are important stages in development research to produce a product that is fit for use in learning (Septikasari & Ayriza, 2018).

During the implementation phase, results from individual, small-group, and large-scale trials indicated that the digital comic is practical for use in learning. Students appeared more active, focused, and enthusiastic when using the learning medium. This was evident from student responses, which averaged 89% in the "very positive" category. The aspects that received high percentages indicate that students were interested in the visual presentation, ease of use, and clarity of the material presented in the digital comics. Engaging learning media can enhance students' motivation and interest in learning throughout the learning process (Zahra et al., 2023).

The results of the large-scale pilot study showed an improvement in student learning outcomes after using digital comics. The average N-Gain score of 0.6 falls into the moderate category, indicating that the medium is quite effective in improving students' understanding of landslide mitigation. Twenty nine percent of students showed a high improvement in learning outcomes, while the other 71% fell into the moderate category. This improvement in learning outcomes occurred because students gained visual and contextual learning experiences that helped them understand disaster mitigation concepts more concretely. This aligns with the opinion of Utomo (2023), who states that interactive learning media can enhance the effectiveness of learning and help students gain more meaningful learning experiences.

The findings of this study are also supported by previous research. Utomo (2023) demonstrated that the use of digital comics can enhance motivation and learning outcomes among elementary school students. Cunningham et al (2025) also indicated that visual story-based learning media helps students understand abstract concepts in a more concrete and engaging manner. Thus, the results of this study reinforce the finding that digital comics are effective for use in elementary school learning, particularly for disaster mitigation material.

During the evaluation phase, students and teachers provided very positive feedback regarding the use of digital comics in learning. Teachers stated that the learning medium helped explain material previously considered abstract in a more concrete way through illustrations and visual storytelling. Additionally, the use of digital comics increased students' attention, motivation, and participation during the learning process. This indicates that digital comic-based learning media can create a more interactive and enjoyable learning environment. This view is supported by Ndabaga et al., (2023), who states that visual media can help create more active, engaging, and effective learning.

3.3. Implications

The findings of this study suggest that elementary school teachers can utilize digital comics as an innovative alternative learning medium to enhance students' understanding of disaster mitigation from an early age. The use of digital media also supports 21st-century learning, which emphasizes the use of technology in the learning process. Furthermore, integrating disaster literacy into elementary school education is essential for improving students' preparedness for disaster risks in their surrounding environment.

3.4. Limitations

Nevertheless, this study still has limitations. The product trial was conducted at only one elementary school and was limited to landslide mitigation material; therefore, the study's findings cannot yet be widely

ISSN: 2797-3174

generalized. Furthermore, the developed media is still in the form of a simple digital comic and does not yet include audio features or interactive animations. The authors of this paper propose that an interactive learning application covering a wider range of disaster-related content can be developed in the future to enhance the appeal and practical effectiveness of learning. This article confirms that digital comics integrated with disaster literacy, when used as a teaching medium for landslide disaster risk reduction education in primary schools, are both feasible and effective. They can improve learning outcomes, and cultivate students' learning motivation, engagement, and disaster preparedness capacity.

4. Conclusion

Digital comics incorporating disaster literacy in landslide mitigation materials are therefore appropriate and user-friendly, effective for use in elementary school education at the primary level based on the findings of this study. This media was designed by ADDIE model that allows students to more clearly contextualism the content through visual narratives of disaster mitigation materials, engaging illustrations and language patterns that are easy to understand. Digital comics have been shown through expert validation and pilot testing to enhance student motivation, engagement, and learning outcomes. Moreover, the implementation of disaster literacy in instructional media can help students comprehend and prepare to face landslides as early as possible. So, a new alternative medium of instruction which is now being explored in elementary schools are digital comics that can foster interactive and impactful learning experiences. Overcoming some disadvantages associated with traditional paper-based comic.

Author Contributions

All authors contributed equally to this paper. All authors have read and approved the final manuscript.

Funding

No funding support was received.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/ or publication of this article.

Data Availability

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

Declaration on AI Use

The authors declare that no artificial intelligence (AI) or AI-assisted tools were used in the preparation of this manuscript.

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