

Innovative AI-Based E-Comics Promoting Flood Disaster Education in Elementary Schools

Wanda Sri Andini, Enjang Yusup Ali, Atep Sujana

wandaandini21@upi.edu, enjang@upi.edu, atepsujana@upi.edu

UPI Regional Campus Sumedang, University Pendidikan Indonesia, Sumedang, Indonesia

*Correspondence to: Atep Sujana

Universitas Pendidikan Indonesia

email: atepsujana@upi.edu

Abstract: This study aimed to develop an AI-based E-Comic named SAMBA (Save the Earth Together) as a flood disaster education medium for elementary school students and to evaluate its validity and practicality. The study employed a Research and Development (R&D) approach using the ASSURE model, consisting of analyzing learners, stating objectives, selecting strategies and media, utilizing materials, requiring learner participation, and evaluating and revising the product. The developed e-comic integrates AI-generated illustrations, learning videos, interactive quizzes, and digital flipbook technology to support engaging and contextual disaster learning. Practicality testing involved 47 fifth-grade elementary school students using a student response questionnaire, while product quality was evaluated through expert validation by media, material, and language experts. The validation results indicate that the e-comic is highly feasible for instructional use. Practicality testing based on student responses obtained categorization as excellent, demonstrating that students found the e-comic engaging, accessible, and easy to use. These findings confirm that the SAMBA e-comic is both valid and practical as an innovative learning medium for elementary flood disaster education. This study contributes to the advancement of technology-enhanced learning by integrating AI-generated visual content, interactive multimedia features, and contextual disaster education into an engaging digital e-comic that supports elementary students' disaster preparedness and environmental awareness.

Keywords: AI-based learning media; disaster literacy; E-comic; elementary education

Article info: Submitted May 24, 2026 | Revised Jun 6, 2026 | Accepted Jun 13, 2026 | Published Jul 25, 2026

Recommended citation: Andini, W. S., Ali, E. Y., & Sujana, A. (2026). Innovative AI-Based E-Comics Promoting Flood Disaster Education in Elementary Schools. *Jurnal Pendidikan Dan Pengajaran Guru Sekolah Dasar (JPPGuseda)*, 9(2), 158–172. <https://doi.org/10.55215/jppguseda.v9i2.48>

Introduction

Education is one of the many aspects of human life that has been significantly influenced by the rapid development of science and technology (Bozkurt et al., 2026; Sri Takshara & Bhuvaneswari, 2026; Ali et al., 2025). The advancement of digital technology in the 21st century demands innovative learning media capable of integrating digital literacy, visual literacy, and interactivity into the learning process (Riskiani et al., 2025; Zawacki-Richter et al., 2019). Technology utilization is no longer merely a tool for delivering information, but also a means of creating contextual, engaging, and meaningful learning experiences for elementary school students (Haleem et al., 2022). In this context, digital learning media should be designed not only to present instructional content but also to actively involve students in exploring, interpreting, and connecting new knowledge with their everyday experiences. Such an approach is particularly important in elementary education, where developmentally appropriate and engaging learning environments can strengthen students' active participation and support deeper understanding of learning concepts.

Fundamentally, education aims to develop students' knowledge, understanding, and skills so that they can master various important concepts applicable in daily life. According to Bloom, concept mastery is not merely the ability to memorize information, but also the ability to understand, interpret, and connect learning materials holistically (Anggraini & Sari 2022; Anderson & Krathwohl, 2001). In line with Ainul et al. (2025), who emphasized the role of science education in building students' understanding of basic scientific concepts, successful learning highly depends on students' ability to interpret natural phenomena scientifically. Therefore, conceptual understanding becomes an important indicator for enabling students to apply scientific knowledge

in real-life contexts. This ability is particularly important in science-related subjects that require students to connect theoretical knowledge with environmental phenomena encountered in everyday life.

Students' ability to absorb and construct concepts is strongly influenced by the quality of literacy and their ability to comprehend information presented through learning materials (Crompton & Burke, 2023; Marmoah et al., 2022). Literacy serves as a crucial foundation for students to develop a comprehensive understanding of various phenomena in their environment. More specifically, environmental literacy refers to an individual's ability to understand, apply, and participate in complex environmental issues (Miterianifa & Mawarni, 2024). The urgency of such literacy becomes even more significant when students are confronted with learning materials requiring direct application in daily life, one of which is natural disaster education. Schools can provide students with knowledge about various types of disasters as well as mitigation measures that should be taken (Nuriman et al., 2022). Thus, schools have the potential to become centers of disaster education that provide practical guidance for dealing with emergency situations (Rahmat et al., 2024).

The urgency of understanding natural disaster concepts becomes increasingly important considering Indonesia's geographical condition, as the country is located on the Pacific Ring of Fire and is highly vulnerable to hydrometeorological disasters (Ambarita, 2024; Dufty, 2008). Data from the Indonesian National Disaster Management Agency showed that in early 2025, floods were the dominant disaster in West Java, with 44 recorded incidents. The impacts of such disasters greatly threaten the most vulnerable group, namely children, who often have limited knowledge in responding to emergency situations (Sukamto et al., 2021). This condition requires systematic efforts to reduce disaster risks through mitigation, defined in Government Regulation No. 21 of 2008 as a series of efforts to enhance preparedness and capacity in facing disaster threats. Adequate mitigation understanding enables individuals to respond more quickly and appropriately during emergencies (Langitan et al., 2022).

Theoretically, fifth-grade elementary school students are in the concrete operational stage, meaning that their thinking ability still heavily depends on physical objects and real experiences. Therefore, conceptual understanding will be more effective when supported by visual media and contextual storytelling (Aisyapuri et al., 2025). However, in practice, learning activities in several elementary schools located in flood-prone areas still face various challenges in delivering disaster-related materials effectively. Although students are exposed to real disaster risks due to recurring annual floods, the learning process still encounters several obstacles. This gap highlights the need for learning media that can bridge students' concrete experiences of flooding with scientific concepts through accessible visual and contextual representations. Moreover, integrating authentic disaster contexts into digital learning materials may enable students to develop a more meaningful understanding of flood-related concepts while strengthening their preparedness and ability to respond appropriately to potential disasters.

Despite the urgent environmental context, observations and interviews with fifth-grade teachers revealed a significant gap in the learning process. The use of technology in classrooms remains very limited, while learning materials are still delivered conventionally through limited narrative textbooks. Consequently, complex and abstract disaster-related concepts fail to be visualized effectively, as students are merely asked to imagine them without dynamic supporting media. Tristaningrat & Ariyana (2025) stated that the lack of innovative learning resources may reduce students' participation and hinder optimal concept mastery. This condition indicates the need for learning media capable of presenting disaster concepts in a more concrete, visual, and interactive manner so that students can better understand mitigation-related content.

In response to these problems, innovative learning media are needed to bridge the transition from abstract concepts to more concrete understanding. According to Gene Yang, educational comics possess great potential because they are visual, narrative, motivating, and popular among students (Arsitawati et al. 2020). Previous studies have demonstrated that digital comics can improve students' engagement, concept understanding, and learning motivation in various elementary school subjects. Furthermore, the combination of visual storytelling and educational content allows students to understand complex concepts more easily than through text-based explanations alone. Therefore, the integration of disaster-related content into digital comics can provide a contextual learning experience that connects scientific concepts with students' real-life experiences in flood-prone environments. Such media can also support students in developing disaster awareness and preparedness by presenting appropriate responses and preventive actions through engaging and age-appropriate narratives (Pratiwi et al., 2026; Wijayanti et al., 2024).

Artificial Intelligence (AI) has increasingly been utilized in education to support the creation of innovative learning media (Junaidi, 2026). Recent developments show that AI is not only used as an administrative tool but also as a means of designing adaptive and engaging instructional materials, including digital stories, educational comics, and interactive learning content. AI-generated visual content enables educators to develop learning materials more efficiently while maintaining contextual relevance and visual attractiveness. The integration of AI into educational media also provides opportunities to increase students' engagement through

richer visual representations and interactive learning experiences. Therefore, AI has considerable potential to support the development of digital learning media that are more attractive and meaningful for elementary school students (Putri & Ikhsan, 2025; Molina et al., 2024; Zerkouk et al., 2025).

Although previous studies have reported the effectiveness and feasibility of digital comics for science learning, environmental literacy, and disaster mitigation education (Aini et al., 2023; Nasrullah et al., 2021; Zuhroh et al., 2022), most of these studies focused on conventional digital comics or static visual media. Limited studies have integrated Artificial Intelligence (AI) technology with interactive multimedia features such as digital flipbooks, learning videos, quizzes, and educational games within a single disaster education platform for elementary school students. Furthermore, previous studies rarely addressed the contextual issue of flood disaster education by combining AI-generated visual content and interactive learning experiences. Therefore, a research gap remains regarding the development of AI-based interactive e-comics that integrate disaster education, multimedia features, and AI-generated visual content within a single learning platform for elementary school students.

The novelty of this study lies in the integration of AI-generated illustrations, digital flipbook technology, learning videos, quizzes, and educational games within a single flood disaster education e-comic specifically designed for elementary school students. Unlike previous studies that primarily developed conventional digital comics or focused on a single multimedia feature, this study combines multiple interactive components to support disaster literacy through a more contextual and engaging learning experience. Based on these conditions, this study offers an innovation through the development of the AI-based SAMBA E-Comic, which integrates AI-generated illustrations, digital flipbook technology, learning videos, quizzes, and educational games into a single learning media ecosystem. The developed e-comic is designed to present flood disaster materials in a more concrete, contextual, and interactive manner, enabling students to explore mitigation concepts through visual storytelling and multimedia activities. Through this integration, SAMBA is expected to support disaster literacy learning that is more engaging and relevant to elementary school students.

This study aims to develop the AI-based SAMBA E-Comic on flood disaster mitigation materials for elementary schools, as well as to examine its validity through expert evaluations and assess its practicality based on user responses. The study is expected to contribute to the development of innovative digital learning media that support disaster literacy, technology-enhanced learning, and contextual science education in elementary schools. By integrating AI-supported visual storytelling with contextual disaster mitigation content, the developed e-comic is expected to facilitate students' understanding of flood-related concepts through accessible and engaging learning experiences. Furthermore, this study provides a foundation for the future implementation of technology-enhanced disaster education that is responsive to students' real-world contexts and learning needs.

Methods

Research Type and Design

This research is a research and development that aims to produce learning media in the form of SAMBA E-Comics and test the level of feasibility and practicality of its use. The development model used is the ASSURE (Bilici et al., 2025) model because it emphasizes the analysis of student characteristics as the basis for designing adaptive and effective learning media (Kustandy & Darmawan, 2020). The development procedure was carried out through six stages: (1) Analyze Learners, (2) State Objectives, (3) Select Methods, Media, and Materials, (4) Utilize Media and Materials, (5) Require Learner Participation, and (6) Evaluate and Revise. These stages provide a systematic framework for ensuring that the developed e-comic is aligned with students' developmental characteristics, learning needs, and the specific context of flood disaster mitigation education. The systematic integration of learner analysis, instructional objectives, media selection, and active participation also ensures that the AI-based SAMBA E-Comic is not only technologically innovative but pedagogically relevant. Through the evaluation and revision stage, the developed media can be refined based on expert and user feedback to enhance its feasibility, practicality, and suitability for elementary school learning.

In the Analyze Learners stage, students' characteristics, learning needs, learning styles, and classroom conditions were identified through observations, teacher interviews, and learning style questionnaires. The findings revealed that students experienced difficulties in understanding flood disaster concepts due to the limited use of visual and interactive learning media. Based on these findings, learning objectives were formulated in accordance with the learning outcomes of the social science subject, focusing on students' understanding of flood disaster causes, impacts, and mitigation efforts (State Objectives). In the Select Methods, Media, and Materials stage, an AI-based digital e-comic was designed by integrating contextual stories, AI-generated illustrations, learning videos, interactive quizzes, and digital flipbook technology. The

developed media was subsequently validated by material, media, and language experts to ensure its feasibility before implementation (Utilize Media and Materials). During the Require Learner Participation stage, fifth-grade students actively engaged with the e-comic by reading the stories, interacting with multimedia features, watching embedded videos, completing quizzes, and providing feedback through response questionnaires. Finally, in the Evaluate and Revise stage, validation results, observation findings, and student responses were analyzed to identify necessary improvements and refine the product, resulting in the final version of the SAMBA E-Comic.

This study was conducted in two elementary schools in Sumedang Regency, namely SDN Sukasirna I and SDN Cibeureum III. The research participants consisted of seven expert validators and 47 fifth-grade students. The validators comprised three media experts, namely two university lecturers experienced in digital learning media development and one Information and Communication Technology (ICT) teacher; three material experts, consisting of a science education lecturer, a science teacher, and an elementary school principal with experience in curriculum implementation and instructional supervision; and one Indonesian language education lecturer who served as the language expert. Purposive sampling was employed to select 47 fifth-grade students from schools implementing the Merdeka Curriculum. The students had not formally studied flood disaster material, while the selected schools were located in areas with a history or potential risk of flooding, ensuring the contextual relevance of the learning content. One of the schools was also recognized as a Sekolah Penggerak with adequate technological facilities to support the implementation of digital learning media.

Prior to data collection, official permission was obtained through a university research authorization letter approved by the participating schools. Participation was voluntary, conducted under the supervision of classroom teachers, and participant confidentiality was maintained throughout the study. The sample size was determined based on formative evaluation stages, consisting of an individual trial involving 5 students, a small-group trial involving 14 students, and a field trial involving 28 students. These stages were conducted progressively to identify product weaknesses, gather user feedback, and evaluate the practicality of the e-comic before producing the final version. The progressive evaluation process enabled the researchers to refine the SAMBA E-Comic based on evidence obtained from different levels of student interaction and use. This approach ensured that the final product was responsive to students' needs, understandable in terms of content and presentation, and practical for implementation in elementary school learning contexts.

The data were collected using the following instruments: (1) learning style questionnaire, used to identify students' characteristics and learning preferences as the basis for designing the AI-based SAMBA E-Comic, (2) expert validation sheets, used to evaluate the feasibility of the developed product in terms of media, material, and language aspects. The validation instruments were adapted from the standards of the National Education Standards Board, (3) student response questionnaire, used to assess the practicality of the developed media based on attractiveness, ease of use, usefulness, and learning motivation, (4) interview guidelines, used to identify learning needs and obtain feedback from teachers regarding the developed media, (5) observation guidelines, used to examine students' participation, engagement, and classroom conditions during the implementation of the AI-based SAMBA E-Comic. Prior to implementation, the instruments were reviewed by expert validators to ensure content relevance, clarity, and suitability for assessing the feasibility and practicality of the developed learning media.

Quantitative and qualitative data analysis techniques were employed in this study. Quantitative data were obtained from expert validation sheets and student response questionnaires, while qualitative data were collected from interviews, observations, comments, and suggestions provided by validators and participants. Different rating scales were used for expert validation and student response questionnaires. The expert validation sheets employed a four-point rating scale, while the student response questionnaire employed a four-point Likert scale. The scoring criteria are presented in **Table 1**.

Table 1. Rating Scale Used in Expert Validation and Student Response

Score	Expert Validation	Student Response
4	Excellent	Strongly Agree
3	Good	Agree
2	Poor	Disagree
1	Very Poor	Strongly Disagree

The obtained scores were converted into percentages and interpreted according to the feasibility and practicality criteria presented in **Table 2**. The percentage results were used to determine the feasibility and practicality levels of the developed product.

Table 2. Criteria for Expert Validation and Student Responses

Percentage Range (%)	Validity Category	Practicality Category
75.01 – 100.00	Highly Feasible	Highly Practical
50.01 – 75.00	Feasible	Practical
25.01 – 50.00	Less Feasible	Less Practical
00.00 – 25.00	Not Feasible	Not Practical

The validation instruments were adapted from the National Education Standards Board criteria and were employed to assess the feasibility of the developed media from material, media, and language perspectives. Quantitative data obtained from validation sheets and student response questionnaires were analyzed using descriptive percentage techniques to determine the feasibility and practicality levels of the product. Meanwhile, qualitative data in the form of critiques, comments, and suggestions from validators and users were analyzed descriptively and used as the basis for product revisions during the Evaluate and Revise stage of the ASSURE model. The combination of quantitative and qualitative data provided a more comprehensive basis for evaluating the quality of the SAMBA E-Comic by identifying both measurable levels of feasibility and specific aspects requiring improvement. This integrated analysis ensured that the revision process was evidence-based and contributed to producing a learning medium that was both instructionally appropriate and responsive to users' needs.

Result and Discussion

Analyze Learner Characteristics

The initial stage of developing the SAMBA E-Comic began by identifying the profiles of 47 fifth-grade students as the research subjects. This analysis served as a crucial foundation to ensure that the developed media was adaptive and aligned with students' learning needs. The research subjects were between 10–12 years old, which, according to Piaget's cognitive development theory, falls within the concrete operational stage. At this stage, students require strong and contextual visual stimuli to construct understanding of abstract phenomena. Therefore, the integration of AI technology in generating realistic illustrations within the SAMBA E-Comic was designed to address these visual learning needs. By presenting flood disaster mitigation concepts through concrete and contextually relevant visual representations, the e-comic can help students connect abstract scientific information with situations that are familiar to their daily lives. This alignment between students' cognitive characteristics and AI-supported visual content also strengthens the potential of the SAMBA E-Comic to facilitate meaningful understanding and active engagement in disaster mitigation learning.

The results of interviews with teachers and several students revealed that most students had direct experience with flood disasters. This condition was influenced by the location of school, which is situated in an area prone to annual flooding, including a major flood event in 2016 that left a strong impression on students. However, these experiences were not always accompanied by adequate conceptual knowledge regarding disaster mitigation measures. This finding indicates a gap between students' disaster experiences and their understanding of disaster-related learning content, highlighting the need for learning media that can present mitigation concepts in a contextual and accessible manner. Therefore, learning media that explicitly connects students' lived experiences with scientifically accurate mitigation concepts is needed to transform experiential knowledge into structured understanding. Such contextualization can help students recognize the relevance of disaster mitigation knowledge to their everyday lives while strengthening their preparedness and capacity to respond appropriately to future flood risks (Rahayu et al., 2026; Gokmenoglu et al., 2023).

In addition, students demonstrated a high level of digital literacy, particularly in smartphone usage. This condition provided an opportunity to develop technology-based learning media that are compatible with students' daily learning habits and technological experiences. Nevertheless, digital technology had not been optimally utilized in classroom learning, which was still predominantly conducted through conventional approaches. One contributing factor was the limited integration of digital technology into classroom instruction. Therefore, the development of the SAMBA E-Comic received positive support from teachers as an alternative digital learning medium. The integration of an accessible digital format with contextual flood disaster content can therefore bridge students' existing technological familiarity with their learning needs. Furthermore, the use of the SAMBA E-Comic may provide a more engaging learning experience while enabling teachers to incorporate digital technology meaningfully into disaster mitigation instruction.

The analysis of students' learning styles indicated a tendency toward visual learning preferences. The distribution of students' learning styles is presented in **Table 3**.

Table 3. Distribution of Students' Learning Styles

Trial Stage	Visual	Auditory	Kinesthetic	Total
Individual Trial	3	1	1	5
Small Group Trial	6	4	4	14
Large Group Trial	17	5	6	28
Total	26	10	11	47

Visual learning style emerged as the dominant modality, with 26 out of 47 students categorized as visual learners. These findings supported the development of a visual-based learning medium in the form of a digital comic. To accommodate students with auditory and kinesthetic learning preferences, the SAMBA E-Comic was also equipped with learning videos, interactive quizzes, and educational games. This design reflects the ASSURE principle of aligning instructional media with learner characteristics. The integration of these features provides students with diverse opportunities to access and process flood disaster mitigation concepts according to their individual learning preferences. Furthermore, the combination of visual, auditory, and interactive elements can strengthen student engagement and facilitate more meaningful learning experiences. Thus, the SAMBA E-Comic promotes a more inclusive learning environment while maintaining its primary emphasis on visual learning.

The findings from the learner analysis stage provided an important foundation for the development of the SAMBA E-Comic. The dominance of visual learners reinforced the suitability of digital comics as the primary learning medium, while the integration of videos, quizzes, and games was intended to accommodate diverse learning preferences. These findings are consistent with [Imanulhaq & Ichsan \(2022\)](#), who reported that elementary school students benefit from visual representations when learning abstract concepts. It also emphasized that the integration of visual and interactive elements can support student engagement during learning activities ([Latief et al., 2026](#); [Indriana et al., 2025](#)). Accordingly, the SAMBA E-Comic was designed to translate these learner characteristics into a multimedia learning environment that connects visual storytelling with active and interactive learning experiences. This alignment between learner characteristics and media design strengthens the pedagogical relevance of the developed product for elementary school students.

Furthermore, the interview findings revealed that students possessed disaster-related experiences but limited understanding of mitigation procedures. This condition became an important consideration in designing contextual storylines and learning content within the e-comic. Rather than focusing solely on disaster events, the developed media was designed to present disaster mitigation concepts through situations that were familiar to students' daily lives. In this way, the learner analysis stage played a crucial role in ensuring that the developed product was relevant to students' characteristics, learning needs, and environmental context. The contextualization of learning content also enabled students to connect their prior experiences with scientifically appropriate mitigation strategies, thereby transforming lived experiences into meaningful learning opportunities. Moreover, this approach strengthened the potential of the SAMBA E-Comic to promote disaster literacy by helping students understand not only the causes and impacts of floods but also appropriate actions for prevention, preparedness, and response ([Ferede et al., 2026](#); [Marmoah et al., 2022](#)).

State Objectives Stage

At this stage, the learning objectives were formulated based on the learning outcomes of the social science subject, particularly the material focused on flood disasters, including their causes, impacts, and mitigation efforts. The selection of this topic was contextual because the research was conducted at a school located in a disaster-prone area, particularly an area that is vulnerable to flooding. The learning objectives were therefore aligned with the environmental conditions of the school and the lived experiences of the students. This alignment enabled the learning objectives to connect curricular expectations with students' real-world experiences, making the learning content more relevant and meaningful. Furthermore, the contextual objectives were intended to support students in developing not only conceptual understanding but also awareness and preparedness in responding to potential flood disasters.

In line with the learning outcomes that emphasize students' ability to reflect on environmental changes caused by natural factors and human activities and predict their impacts on social and economic life, three learning objectives were formulated. First, students were expected to explain the factors causing floods through visual literacy activities and video observations in the SAMBA E-Comic accurately. Second, students were expected to provide examples of flood prevention efforts at home and school through the analysis of story scenarios presented in the SAMBA E-Comic appropriately. Third, students were expected to classify flood mitigation measures into pre-disaster, during-disaster, and post-disaster phases through the exploration of interactive features in the SAMBA E-Comic accurately.

The formulation of these objectives was based on the findings obtained during the analyze learners stage. The results indicated that students had prior experiences with flood disasters but demonstrated limited understanding of disaster mitigation concepts. Therefore, the learning objectives were designed not only to introduce factual knowledge about floods but also to guide students in identifying causes, recognizing preventive actions, and distinguishing mitigation measures across different disaster phases. The use of the ABCD format helped ensure that each objective was specific, observable, and aligned with the characteristics of elementary school learners (Sari et al., 2020; Kiliçkaya, 2016). In addition, the objectives served as an instructional framework for determining the content, multimedia features, and interactive activities embedded in the SAMBA E-Comic. This finding supports the ASSURE model, which emphasizes that instructional objectives should be formulated based on learner characteristics and learning needs before selecting learning strategies and media.

The alignment between learner needs and instructional objectives became an important foundation for the subsequent stages of media development. As noted by Ali & Saputra (2023), effective instruction requires consistency between learning objectives, learning resources, and instructional technology. Similarly, the integration of multimedia elements should be guided by clearly defined learning objectives to ensure that learning activities remain focused on the intended outcomes (Kusmayadi et al., 2026; Ali & Juanda, 2025). Thus, the objectives formulated in this study provided a clear direction for designing the content and interactive features of the SAMBA E-Comic. This alignment also ensured that each visual, interactive, and multimedia component within the e-comic served a clear pedagogical purpose rather than functioning merely as an additional technological feature. Consequently, the SAMBA E-Comic was designed to support purposeful learning experiences that remained closely connected to the intended competencies and students' contextual needs.

Select Strategies, Technology, Media, and Materials Stage

The selection of strategies and media in this study was motivated by the gap between textbook materials, which tend to be general, and the contextual needs of students living in flood-prone areas. To bridge this gap, an independent digital literacy strategy was implemented through a student-centered learning approach that positioned students as active participants in exploring disaster mitigation content through narratives and interactive features embedded in the SAMBA E-Comic. The integration of technology in media development involved hardware such as laptops and smartphones, as well as various Artificial Intelligence (AI)-based applications and interactive digital platforms. ChatGPT and Gemini were utilized to assist in developing storylines, adaptive dialogues, and text-to-image prompts. Canva AI was employed to generate comic illustrations efficiently, while Ibis Paint X was used for manual visual refinement to ensure visual consistency and content accuracy. Furthermore, Heyzine was utilized to convert the comic into an interactive flipbook format, Educaplay was used to develop gamification-based educational games, and TikTok served as a source of audiovisual references related to disaster mitigation content.

The selection of these strategies and technologies was closely aligned with the findings obtained during the Analyze Learners stage. Students demonstrated a high level of familiarity with digital technology and showed a dominant preference for visual learning. Therefore, digital comics enriched with multimedia and interactive elements were considered appropriate for accommodating students' learning characteristics and technological experiences. The student-centered approach adopted in this study was intended to provide opportunities for learners to actively explore learning content rather than solely receive information from teachers. Through narratives, videos, quizzes, and educational games, students were positioned as active users of the developed media (Salendab & Tago, 2026; Aryani & Lestari, 2025). This approach is consistent with the ASSURE model, which emphasizes the alignment between learner characteristics, instructional strategies, and learning media.

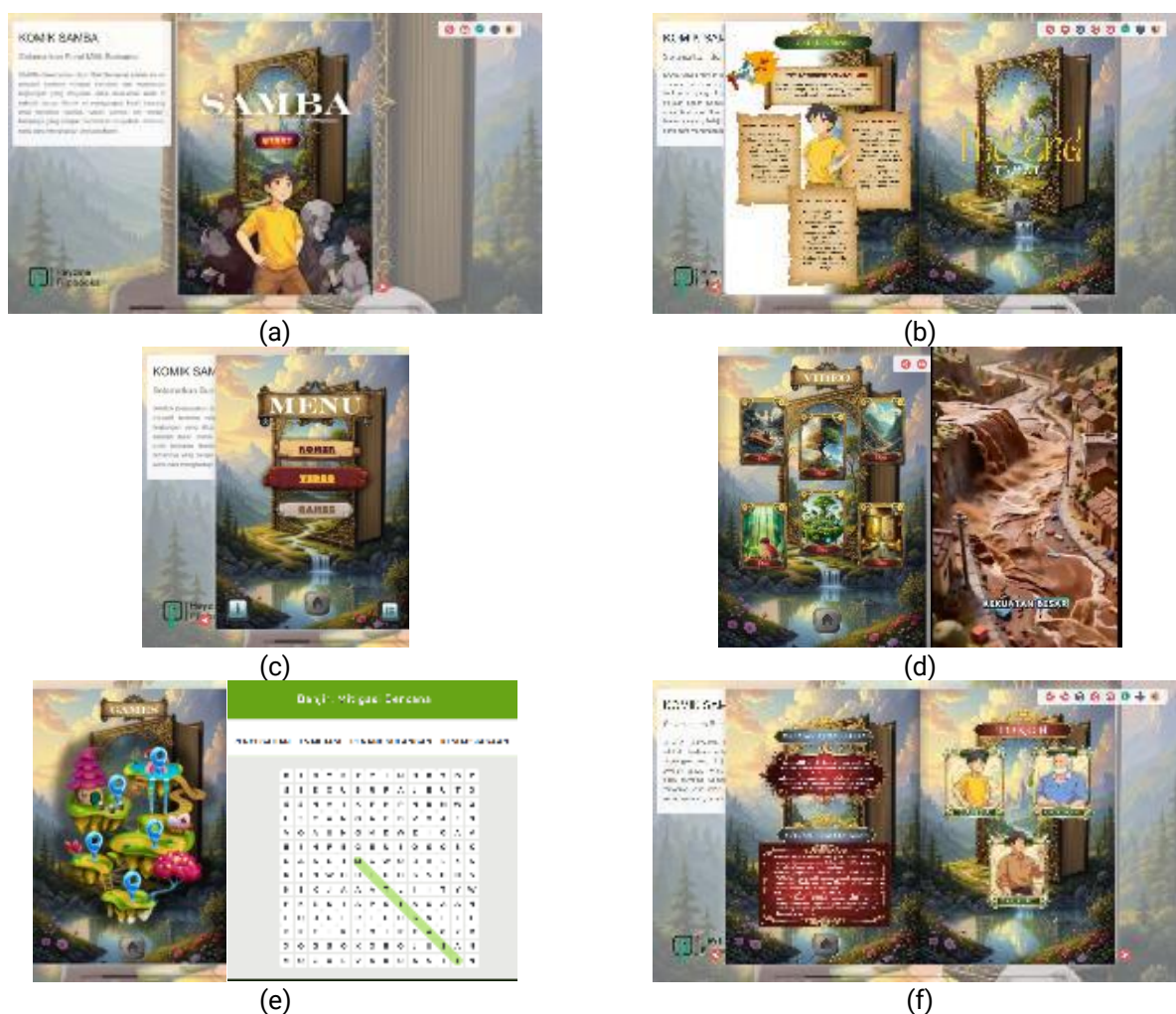
Artificial Intelligence (AI) played an important role in supporting the efficiency of the media development process, particularly in generating illustrations and assisting content creation. The integration of AI-based tools enabled the development of visual materials that were relevant to the flood disaster context while maintaining production efficiency. Similar findings were reported by Handoyo & Nugroho (2025), who noted that AI can facilitate the creation of educational media by improving the efficiency of visual content production. In addition, the integration of text, images, videos, and interactive activities within a single learning environment reflects multimedia learning principles. Rather than functioning as separate components, these features were designed to complement one another in presenting disaster mitigation content. This design is consistent with the Theory of Multimedia Learning, which highlights the importance of combining visual and verbal information in instructional media (Aryani & Lestari, 2025). Furthermore, Aeni et al. (2026) emphasized that AI-supported digital media can provide more contextual and interactive learning resources for students.

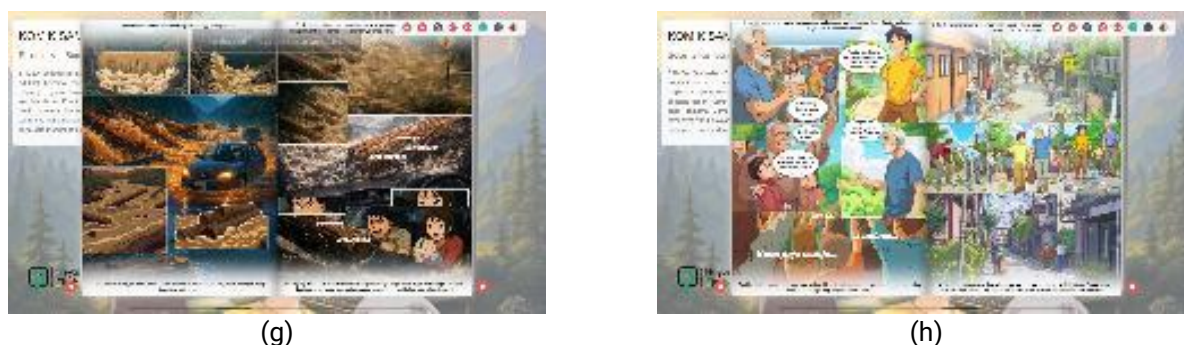
These findings indicate that the selection of strategies, technologies, media, and materials was not conducted arbitrarily but was based on the characteristics, needs, and learning context identified during the previous ASSURE stage. Consequently, the developed SAMBA E-Comic was designed to reflect both curricular requirements and learner needs within a technology-enhanced learning environment. The integration of contextual flood disaster content, visual storytelling, and interactive features further ensured that the selected media components were directly relevant to students' experiences and learning characteristics. This alignment allowed the e-comic to function not only as a digital representation of instructional content but also as an interactive learning environment that supports students' active engagement and understanding. Furthermore, the systematic selection of these components strengthened the pedagogical coherence of the SAMBA E-Comic and supported its suitability for elementary school disaster mitigation learning.

Utilize Technology, Media, and Materials Stage

The development of the SAMBA E-Comic began with the preparation of a storyboard based on an orientation–conflict–resolution narrative structure that integrated disaster mitigation materials into the storyline. Visual innovation was carried out by utilizing Artificial Intelligence technologies, including Canva AI, Gemini, and ChatGPT, to produce initial illustration concepts, which were then manually refined using Ibis Paint X to maintain character consistency. The final product was converted into an interactive flipbook through the Heyzine platform, complete with hyperlink navigation directing students to learning videos and Educaplay-based educational games. This development process ensured that the technological components were integrated with the instructional content and narrative structure rather than functioning as independent features. Furthermore, the combination of AI-assisted visual production, interactive navigation, and contextual learning activities enhanced the potential of the SAMBA E-Comic to provide an engaging and coherent learning experience for elementary school students.

This presents several components of the developed SAMBA E-Comic, including the front cover, menu page, video page, game page, and selected comic scenes representing the beginning, climax, and resolution of the story (**Figure 1**).



**Figure 1.** Comic design results

(a) Front Cover, (b) Back Cover, (c) Menu Page, (d) Video Page, (e) Games Page, (f) Opening Story Display, (g) Comic Climax Display, (h) Comic Resolution Display

Prior to implementation, the developed product underwent expert validation to evaluate its feasibility from media, material, and language perspectives. This process was conducted to ensure that the content, visual presentation, and language used in the e-comic were appropriate for elementary school students and aligned with the objectives of disaster mitigation education. This presents the recapitulation of expert validation results. The validation process also served as an important quality-control mechanism to identify potential weaknesses in the developed product before it was introduced to students. Feedback from the experts was considered in refining the content, visual elements, and language to improve the overall quality and usability of the e-comic. Therefore, expert validation ensured that the SAMBA E-Comic was not only technically feasible but also pedagogically appropriate for supporting contextual flood disaster mitigation learning.

Table 4. Recapitulation of Expert Validation Results of the SAMBA E-Comic

No	Validation Aspect	Average Score	Maximum Score	Percentage
1	Media Experts	66.3	72	92.10%
2	Material Experts	58.0	60	96.70%
3	Language Expert	59.0	60	98.33%
Overall Average				95.71%

The validation process involved seven validators consisting of three media experts, three material experts, and one language expert. The overall average score reached 95.71% (**Table 4**), indicating that the SAMBA E-Comic met the criteria for a highly feasible learning medium. The high validation scores suggest that the developed media was considered appropriate in terms of content accuracy, visual design, language suitability, and technical functionality. These findings indicate that the integration of AI-generated illustrations, interactive multimedia features, and contextual disaster mitigation content was successfully implemented within a single digital learning medium. Although the quantitative results indicated a highly feasible product, several revisions were conducted based on qualitative feedback provided by the validators. The revisions focused on improving readability, navigation, content enrichment, and language accuracy.

Table 5. Revisions Based on Expert Validation Results

No	Aspect	Revision Implemented
1.	Media	- Enlarged font sizes and replaced several font types to improve readability for elementary students. - Added a transitional page after the menu section to improve navigation flow. - Modified the Home button function so that it directed users to the Main Menu instead of the opening page.
2.	Material	Added analytical and reflective questions related to disaster causes and mitigation actions.
3.	Language	Revised punctuation usage, particularly commas, to improve language accuracy and readability.

The revision process demonstrates that product development within the ASSURE model is iterative in nature. Validation was not limited to obtaining feasibility scores but also served as a mechanism for identifying areas requiring improvement before classroom implementation. The qualitative suggestions provided by validators contributed to refining both the technical and instructional aspects of the SAMBA E-Comic. These findings are consistent with [Susanto et al. \(2023\)](#), who emphasized that learning media should be evaluated from content, language, and visual perspectives before implementation. Similarly, [Iskandar & Fachrudin \(2020\)](#) highlighted the importance of aligning instructional media with students' characteristics and learning needs. In

this study, validator feedback played an important role in ensuring that the developed media was appropriate for elementary school learners and functioned effectively as a disaster mitigation learning resource. Thus, the iterative revision process strengthened the alignment between the e-comic's instructional design, students' learning characteristics, and the contextual demands of flood disaster mitigation education.

Require Learner Participation

The implementation phase was conducted through three stages of trials to evaluate the practicality of the SAMBA E-Comic from the students' perspective. The trials consisted of an individual trial involving five students, a small-group trial involving 14 students, and a large-group trial involving 28 students. The results of the practicality assessment are presented in **Table 6**.

Table 6. Empirical Test Results of the SAMBA E-Comic

Trial Stage	Number of Respondents	Average Score	Percentage
Individual Trial	5	56.8	94.67%
Small-Group Trial	14	55.28	92.14%
Large-Group Trial	28	54.14	90.24%
Overall Average	47	55.4	92.35%

The results indicate that the SAMBA E-Comic achieved an overall practicality score of 92.35%, categorized as highly practical. High practicality scores were consistently obtained across all trial stages, indicating that students responded positively to the developed learning media. Qualitative feedback from students highlighted three main aspects of the media. First, the visual appearance of the e-comic was perceived as attractive due to the use of colorful AI-generated illustrations and contextual disaster-related scenes. Second, students showed positive responses toward the interactive features, particularly the educational games and quizzes integrated into the flipbook. Third, the combination of stories, videos, and interactive activities contributed to students' willingness to explore the learning content independently. These findings suggest that the integration of engaging visual narratives, interactive features, and multimedia content not only enhanced the attractiveness of the SAMBA E-Comic but also supported students' active participation and independent engagement with flood disaster mitigation learning.

These findings suggest that the SAMBA E-Comic was well accepted by students and could be implemented easily in elementary school learning contexts. The consistently high practicality scores across individual, small-group, and large-group trials indicate that the media functioned effectively from the users' perspective in terms of usability, attractiveness, and accessibility. The findings are consistent with [Marsita et al. \(2024\)](#), who reported that practicality scores above 85% indicate that learning media are easy to use and suitable for classroom implementation. In addition, the positive responses toward the visual and gamification features support the view of [Sugiyanto et al. \(2024\)](#), who emphasized that interactive elements can increase students' engagement with learning media. Therefore, the high level of practicality demonstrates that the SAMBA E-Comic successfully combines ease of use, visual appeal, and interactive learning features to create a user-friendly medium that supports active and engaging disaster mitigation learning for elementary school students.

However, it is important to note that the practicality results reflect students' perceptions of the usability and attractiveness of the media rather than its effectiveness in improving learning outcomes or disaster preparedness ([Sugiyanto et al., 2024](#); [Marsita et al., 2024](#)). Therefore, the findings of this study support the practicality of the SAMBA E-Comic as a disaster mitigation learning medium, while further studies are needed to examine its impact on students' knowledge, attitudes, and disaster preparedness competencies. Future research should employ experimental or quasi-experimental designs to provide stronger evidence regarding the extent to which the SAMBA E-Comic contributes to students' learning outcomes and disaster preparedness. In addition, longitudinal investigations could examine whether the knowledge and preparedness skills developed through the e-comic are retained and applied in real-world disaster situations. Such studies would provide a more comprehensive understanding of the SAMBA E-Comic's pedagogical contribution beyond its practicality and user acceptance.

Evaluate and Revise

The final stage of the ASSURE model involved evaluating the overall quality of the SAMBA E-Comic based on expert validation and student responses. The results showed that the media achieved a feasibility score of 95.71%, categorized as highly feasible, and a practicality score of 92.35%, categorized as highly practical. Although the product met the established criteria, several revisions were made based on feedback from validators and students, including improving font size, color contrast, layout arrangement, and navigation features. These revisions enhanced the readability and usability of the media for elementary school students.

The evaluation process therefore functioned not only as a final assessment but also as an important quality-improvement mechanism within the ASSURE model. The integration of expert judgments and student responses provided complementary evidence regarding the instructional appropriateness and practical usability of the developed media. Overall, the revised SAMBA E-Comic demonstrates a strong alignment between technological design, instructional content, and the learning characteristics of elementary school students (Aryani & Lestari, 2025; Sugiyanto et al., 2024; Marsita et al., 2024).

The evaluation and revision process ensured that the final product was refined both technically and pedagogically. The findings indicate that the SAMBA E-Comic is a valid and practical digital learning medium for flood disaster education in elementary schools. However, this study was limited to evaluating the feasibility and practicality of the product. Therefore, future research is recommended to investigate the effectiveness of the SAMBA E-Comic in improving students' disaster-related knowledge and preparedness through experimental research designs. Future studies could also examine whether the integration of interactive features and contextual storytelling contributes to students' long-term retention and their ability to apply disaster mitigation knowledge in authentic situations. Such investigations would provide stronger empirical evidence regarding the broader educational value of the SAMBA E-Comic in strengthening elementary students' disaster literacy and preparedness.

However, this study was limited to evaluating the feasibility and practicality of the developed product. The study did not measure learning effectiveness, disaster preparedness, or learning gains through experimental procedures such as pre-tests and post-tests. In addition, the implementation was conducted in a limited number of elementary schools. Therefore, future studies are recommended to examine the effectiveness of the SAMBA E-Comic through broader implementation and experimental research designs. Future research could also involve larger and more diverse samples across different geographical and disaster-risk contexts to strengthen the generalizability of the findings. Such studies would provide more comprehensive evidence of the SAMBA E-Comic's potential to improve students' disaster-related knowledge, preparedness, and ability to apply mitigation strategies in authentic situations.

Conclusion

This study developed the AI-based SAMBA E-Comic using the ASSURE model as a digital learning medium for flood disaster education in elementary schools. The findings indicate that the developed media met the criteria of validity and practicality, making it suitable for supporting disaster education learning activities, particularly in flood-prone areas. The study also contributes to the development of technology-enhanced learning media through the integration of AI-generated illustrations, multimedia features, and interactive activities within a contextual learning environment. However, this study focused on product development and only evaluated the feasibility and practicality of the media. Therefore, no conclusions can be drawn regarding its effectiveness in improving students' disaster preparedness or learning outcomes. In addition, the study involved a limited number of participants from two elementary schools. Future research is recommended to involve broader samples and experimental designs to examine the effectiveness of the SAMBA E-Comic in improving students' disaster-related knowledge, attitudes, and preparedness.

Author Contributions

WSA, EYA, and AS conceptualized the study. WSA and AS developed the methodology, while WSA and EYA conducted the formal analysis. The investigation was carried out by WSA. WSA and AS prepared the original draft, and WSA, EYA, and AS contributed to writing, reviewing, and editing the manuscript. EYA and AS provided overall supervision.

Funding

This research received no external funding.

Declaration of Competing Interest

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

Use of Artificial Intelligence

Generative AI (ChatGPT 5.6 and Gemini 3.5) was used to create illustrative figures in this manuscript. All figures were reviewed and approved by the authors, and their use is fully disclosed.

References

- Aeni, A. N., Hanifah, N., Rukmana, K., & Sujana, A. (2026). Pembinaan guru-guru di Pulau Tidung melalui seminar deep learning pada pembelajaran abad 21: *PengabdianMu: Jurnal Ilmiah Pengabdian Kepada Masyarakat*, 11(2), 361–377. <https://doi.org/10.33084/pengabdianmu.v11i2.10245>
- Aini, K., Hadi, W. P., Yasir, M., Rakhmawan, A., & Sutardja, M. C. (2023). Pengembangan komik sains terintegrasi literasi lingkungan pada topik mitigasi bencana banjir. *Experiment: Journal of Science Education*, 3(2), 27–39. <https://doi.org/10.18860/experiment.v3i2.26207>
- Ainul, S. A. S., Wakhidah, N., Wahyuni Fajar Arum, Hidayati, S., & Indayati, T. (2025). Analisis tingkat pemahaman konsep siswa pada pembelajaran IPA: Analysis of students' concept understanding level in science learning. *Edu-Sains: Jurnal Pendidikan Matematika Dan Ilmu Pengetahuan Alam*, 14(1), 7–15. <https://doi.org/10.22437/jmpmipa.v14i1.39419>
- Aisyapuri, R. P., Khairana, H., Damayanti, D. A., Reni, R., Ikawati, I., & Kurniawan, K. (2025). Kesesuaian implementasi pembelajaran MIPA dengan tahap perkembangan kognitif Piaget. *Intellektika: Jurnal Ilmiah Mahasiswa*, 3(5), 209–219. <https://doi.org/10.59841/intellektika.v3i5.3340>
- Ali, E. Y., & Juanda, N. (2025). The effect of lesson plans on teaching quality and learning outcomes. *Jurnal Pemberdayaan Masyarakat*, 4(1), 25–33. <https://doi.org/10.46843/jpm.v4i1.354>
- Ali, E. Y., & Saputra, Y. M. (2023). *Perencanaan pembelajaran di SD*. Indonesia Emas Group.
- Ali, E. Y., Nugraha, R. G., & Nugraha, B. (2025). The effectiveness of AI-based education management systems in implementing deep learning curriculum in elementary schools. *Journal of Integrated Elementary Education*, 5(2), 339–352. <https://doi.org/10.21580/jieed.v5i2.28004>
- Ambarita, Y. M. (2024). Pemahaman mahasiswa PGSD tentang konsep bencana alam dan penerapannya dalam pembelajaran. *Pedagog Jurnal Ilmiah*, 2(2), 39–44. <https://doi.org/10.71387/pji.v2i2.75>
- Anderson, L. W., & Krathwohl, D. R. (Eds.). (2001). *A taxonomy for learning, teaching, and assessing: A revision of Bloom's taxonomy of educational objectives* (Complete ed.). Longman
- Anggraini, D. F. K., & Sari, A. D. I. (2022). Pengembangan instrumen penilaian pemahaman konsep matematika siswa SD Negeri Kembangbahu 1 pada materi perkalian. *DIKDAS MATAPPA: Jurnal Ilmu Pendidikan Dasar*, 5(4), 979–987. <https://journal.matappa.ac.id/index.php/dikdas/article/view/2440>
- Arsitawati, N. K. S. D., Suharta, I. G. P., & Juniantari, M. (2020). Pengembangan media komik berbasis pendidikan karakter pada siswa SMA kelas X. *Jurnal Pendidikan dan Pembelajaran Matematika Indonesia*, 9(2), 52–61. <https://doi.org/10.23887/jppmi.v9i2.1690>
- Aryani, N., & Lestari, A. (2025). Menerapkan teori multimedia learning untuk meningkatkan kualitas pembelajaran. *Jurnal Media Akademik (JMA)*, 3(12), 1–14. <https://doi.org/10.62281/4cvx8h18>
- Bilici, S. C., Şentürk, M., Kizilay, E., Durak, H. Y., & Tokmak, H. C. (2025). SQD strategies integrated online TPACK-based professional development: Examining science teachers' TPACK practical and self-efficacy. *Research in Science & Technological Education*, 43(4), 1352–1381. <https://doi.org/10.1080/10494820.2023.2172047>
- Bozkurt, A., Crompton, H., Farrow, R., Kukulska-Hulme, A., Dron, J., West, R., Palalas, A., Bower, M., Xiao, J., Tlili, A., Henriksen, D., Pazurek, A., Huijser, H., Chiu, T. K. F., Jandric, P., Jordan, K., Curry, J., Kimmons, R., Cukurova, M., Reeves, T., Hwang, G.-J., Shea, P., Lodge, J., Weller, M., Ng, D., & Asino, T. I. (2026). Redefining educational technology: A critical collaborative inquiry. *Open Praxis*, 18(2), 192–211. <https://search.informit.org/doi/10.3316/informit>
- Crompton, H., & Burke, D. (2023). Artificial intelligence in higher education: The state of the field. *International Journal of Educational Technology in Higher Education*, 20(1). <https://doi.org/10.1186/s41239-023-00392-8>

- Dufty, N. (2008). A new approach to community flood education. *The Australian Journal of Emergency Management*, 23(2). <https://knowledge.aidr.org.au/resources/ajem-may-2008-a-new-approach-to-community-flood-education/>
- Ferede, A. T., Ayele, M. A., Mihrka, A. A., & Arara, A. A. (2026). The impact of contextualized teaching and learning approach on students' conceptual understanding of trigonometry. *Teaching Mathematics and Its Applications: An International Journal of the IMA*, 45(2), 161-180. <https://doi.org/10.1093/teamat/hraf008>
- Gokmenoglu, T., Yavuz, İ., & Sensin, C. (2023). Exploring the interplay between curriculum and textbooks in disaster risk reduction education: Insights and implications. *International Journal of Disaster Risk Reduction*, 96, 103949. <https://doi.org/10.1016/j.ijdrr.2023.103949>
- Haleem, A., Javaid, M., Qadri, M. A., & Suman, R. (2022). Understanding the role of digital technologies in education: A review. *Sustainable Operations and Computers*, 3, 275–285. <https://doi.org/10.1016/j.susoc.2022.05.004>
- Handoyo, I. S., & Nugroho, J. A. (2025). Membantu efisiensi workflow desain grafis dan motion graphic dengan pemanfaatan teknologi artificial intelligence. *Ranah Research: Journal of Multidisciplinary Research and Development*, 7(6), 4415–4426. <https://doi.org/10.38035/rj.v7i6.1779>
- Imanulhaq, R., & Ichsan, I. (2022). Analisis teori perkembangan kognitif Piaget pada tahap anak usia operasional konkret 7–12 tahun sebagai dasar kebutuhan media pembelajaran. *Waniambey: Journal of Islamic Education*, 3(2), 126–134. <https://doi.org/10.53837/waniambey.v3i2.174>
- Indriana, I., Ernawati, E., & Fitri, A. (2025). The effectiveness of using e-comics as a learning medium for tsunami disaster mitigation at SMA 1 Pertiwi Padang. *Jurnal Penelitian Pendidikan IPA*, 11(11), 516–522. <https://doi.org/10.29303/jppipa.v11i11.13315>
- Iskandar, R., & Fachrudin, F. (2020). Implementasi model ASSURE untuk mengembangkan desain pembelajaran di sekolah dasar. *Jurnal Basicedu*, 4(4), 1052–1065. <https://doi.org/10.31004/basicedu.v4i4.468>
- Junaidi, J. (2026). Education reform in the application of artificial intelligence in supporting learning media: AI and education for sustainable development goals (SDGs). In *AI, Policy, and the Future of Human-Centered Education*, 57-84. <https://doi.org/10.4018/979-8-3373-5781-2.ch003>
- Kiliçkaya, F. (2016). Teaching how to write instructional objectives to pre-service language teachers through the abcd model. *Online Submission*. <https://eric.ed.gov/?id=ED571537>
- Kusmayadi, K., Ibrahim, N., & Wibowo, S. (2026). E-Learning development based on multimedia learning strategies to improve learning outcomes. *Journal of Educational Sciences*, 10(3), 263-280. <https://doi.org/10.31258/jes.10.3.p.263-280>
- Kustandi, C., & Darmawan, D. (2020). *Pengembangan media pembelajaran: Konsep & aplikasi pengembangan media pembelajaran bagi pendidik di sekolah dan masyarakat*. Prenada Media.
- Langitan, R. E., Agusrianto, A., Oktavia, D. S., & Manggasa, D. D. (2022). Edukasi mitigasi bencana meningkatkan pengetahuan dan keterampilan masyarakat menghadapi bencana gempa bumi. *Madago Community Empowerment for Health Journal*, 1(2), 40–45. <https://doi.org/10.33860/mce.v1i2.1096>
- Latief, S. A., Arsyad, A. A., & Yunus, Y. (2026). Visual thinking in fractions: exploring elementary students' conceptual understanding through representation strategies. *Pertanika Journal of Social Sciences & Humanities*, 34(2), 1013. <https://doi.org/10.47836/pjssh.34.2.21>
- Marmoah, S., Poerwanti, J. I. S., & Suharno, S. (2022). Literacy culture management of elementary school in Indonesia. *Heliyon*, 8(4). <https://doi.org/10.1016/j.heliyon.2022.e09315>
- Marsita, W., Darmansyah, D., Novrianti, N., & Yusri, M. A. K. (2024). Pengembangan media video pembelajaran berbasis ARCS motivational pada mata pelajaran informatika kelas VII SMP. *Jurnal Pendidikan Tambusai*, 8(1), 3809–3814. <https://doi.org/10.31004/jptam.v8i1.12891>
- Miterianifa, M., & Mawarni, M. F. (2024). Penerapan model pembelajaran literasi lingkungan dalam meningkatkan pengetahuan dan kesadaran lingkungan. *Jurnal Sains dan Edukasi Sains*, 7(1), 68–73. <https://doi.org/10.24246/juses.v7i1p68-73>

- Molina, E., Cobo, C., Pineda, J., & Rovner, H. (2024). *AI revolution in education: What you need to know*. World Bank. <http://documents.worldbank.org/curated/en/099734306182493324>
- Nasrullah, Y., Akbar, Z., & Supena, A. (2021). Pengembangan media komik untuk meningkatkan pemahaman kesiapsiagaan bencana banjir pada anak. *Jurnal Obsesi: Jurnal Pendidikan Anak Usia Dini*, 6(2), 832–843. <https://doi.org/10.31004/obsesi.v6i2.1540>
- Nuriman, N., Agustiningsih, A., Mahmudi, K., Wardoyo, A. A., Wardani, R. P., & Barif, Z. A. (2022). Edukasi pendidikan mitigasi erupsi gunung Semeru pada siswa sekolah dasar. *Jurnal Basicedu*, 6(6), 9958–9966. <https://doi.org/10.31004/basicedu.v6i6.4180>
- Pratiwi, I. A., Handoyo, E., & Hidayah, I. (2026). Designing child-friendly digital comics integrating local wisdom and PBL-SSI for environmental disaster learning materials in primary schools. In *Proceedings of International Conference on Science, Education, and Technology*, 12, 248-262. <https://proceedings.unnes.ac.id/ISET/article/view/5408>
- Putri, I. A., & Ikhsan, J. (2025). Pemanfaatan artificial intelligence dalam pengembangan media pembelajaran untuk meningkatkan minat belajar peserta didik. *Journal of Learning Technology and Innovation*, 1(1), 16–30. <https://doi.org/10.64850/jolti.v1i1.113>
- Rahayu, S., Yasin, F., Pratama, A., Fitlayeni, R., Amini, A., & Pratama, M. A. (2026). Disaster mitigation based on Minangkabau indigenous knowledge in social studies learning. *Jàmbá: Journal of Disaster Risk Studies*, 18(1), 1-13. <https://doi.org/10.4102/jamba.v18i1.2047>
- Rahmat, H. K., Frinaldi, A., Rembrandt, R., & Lanin, D. (2024). Model kesiapsiagaan bencana berbasis sekolah melalui program satuan pendidikan aman bencana di Kota Tangerang. *Al-Isyraq: Jurnal Bimbingan, Penyuluhan, dan Konseling Islam*, 7(3), 655–668. <https://doi.org/10.59027/alisyraq.v7i3.844>
- Riskiani, G., Annas, A. N., & Kobandaha, F. (2025). Inovasi pembelajaran digital: Tinjauan literatur tentang model dan strategi yang efektif. *Educazione: Jurnal Multidisiplin*, 2(1), 120–128. <https://doi.org/10.37985/educazione.v2i1.41>
- Salendab, F. A., & Tago, K. L. (2026). Innovative approaches to revolutionize student-centered learning in the 21st century. In *Emerging Trends, Global Perspectives, and Systemic Transformation in AI*, 33-62. <https://doi.org/10.4018/979-8-3373-5102-5.ch002>
- Sari, P. P., Luardini, M. A., & Asi, N. (2020). An analysis of learning objective in english teacher lesson plans based on abcd aspect. *Journal Compound: Improving the Quality of English Education*, 8(1), 21-43. <https://doi.org/10.37304/jcp.v8i1.2012>
- Sri Takshara, K., & Bhuvaneswari, G. (2026). Empowering visually impaired individuals: The transformative roles of education, technology, and social connections in fostering resilience and well-being. *British Journal of Visual Impairment*, 44(2), 373-387. <https://doi.org/10.1177/02646196241310995>
- Sugiyanto, S., Muryani, C., & Ni'matussyahara, D. (2024). Strengthening student empathy in GeoCapabilities: Digital learning innovations and pedagogical strategies for disaster mitigation. *Contemporary Educational Technology*, 16(3), ep521. <https://doi.org/10.30935/cedtech/14913>
- Sukamto, F. I., Nurhidayat, S., & Verawati, M. (2021). Pelatihan siswa tanggap bencana sebagai upaya mitigasi bencana di Ponorogo: Training of disaster responsive students as disaster mitigation efforts in Ponorogo. *Amalee: Indonesian Journal of Community Research and Engagement*, 2(1), 15–22. <https://doi.org/10.37680/amalee.v2i1.178>
- Susanto, H., Ibrohim, I., Basuki, A., Purwanti, W. C., Gunawan, A., & Syafruddin, A. B. (2023). Revolutionary biology education: Development of advanced biology learning through websites and learning kits. *International Journal of Science and Society*, 5(5), 225–239. <https://doi.org/10.54783/ijssoc.v5i5.882>
- Tristaningrat, A. N., & Ariyana, I. K. S. (2025). The effectiveness of digital comics in improving science learning outcomes and scientific attitudes of fourth-grade elementary students. *Journal of Education Technology*, 9(2), 197–204. <https://doi.org/10.23887/jet.v9i2.98249>
- Wijayanti, F. Y., Handoyo, B., & Dembereldorj, U. (2024). Contextual e-comics in geography: A modern pedagogical tool for volcanic hazard mitigation awareness. *Future Space: Studies in Geo-Education*, 1(1), 20-30. <https://doi.org/10.69877/fssge.v1i1.6>

- Zawacki-Richter, O., Marín, V. I., Bond, M., & Gouverneur, F. (2019). Systematic review of research on artificial intelligence applications in higher education – where are the educators? *International Journal of Educational Technology in Higher Education*, 16(1), 39. <https://doi.org/10.1186/s41239-019-0171-0>
- Zerkouk, M., Mihoubi, M., & Chikhaoui, B. (2025). *A comprehensive review of AI-based intelligent tutoring systems: Applications and challenges*. arXiv. <https://doi.org/10.48550/arXiv.2507.18882>
- Zuhroh, N., Masrurroh, F., & Al-Anshori, I. H. (2023). Pengembangan media pembelajaran komik pada materi mitigasi bencana kelas V MI/SD menuju sekolah siaga bencana. *Proceeding of International Conference on Engineering, Technology, and Social Sciences (ICONETOS)*, 3(1), 30–35. <https://conferences.uin-malang.ac.id/index.php/ICONETOS/article/view/2119>