Al-Ishlah: Jurnal Pendidikan
Vol.18, 2 (June, 2026), pp. 1708-1725
ISSN: 2087-9490 EISSN: 2597-940X, DOI: 10.35445/alishlah.v18i2.9442

Project-based Digital Worksheets for Earthquake Disaster Literacy in Indonesian High Schools: Development and Effectiveness

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ARTICLE INFO

Keywords:

disaster literacy;
project based learning;
digital worksheet;
earthquake education

Article history:

Received 2026-02-10
Revised 2026-04-24
Accepted 2026-05-28

ABSTRACT

Indonesia, particularly the Aceh region, is highly susceptible to geological disasters, highlighting the critical need to strengthen disaster literacy among secondary school students. However, disaster education in schools remains limited and is predominantly delivered through conventional materials that lack contextual relevance and interactivity. This study develops and evaluates the effectiveness of Project-Based Learning e-worksheets for enhancing earthquake disaster literacy among high school students, with a focus on knowledge, attitudes, and skills. The research utilizes the ADDIE development model and a quasi-experimental pretest–posttest control group design. The sample consists of 66 students from the Science Club extracurricular activity at Labschool USK Banda Aceh High School, with an experimental group from grade X (n=35) and a control group from grade XI (n=31). To account for potential initial ability differences due to grade level, data analysis employed Analysis of Covariance (ANCOVA) with pretest scores as covariates. The results indicate that PjBL-based digital worksheets are significantly more effective than guided inquiry worksheets in improving disaster literacy. Large effect sizes were observed for knowledge ($F=375.526$; $p<0.005$; $\eta^2=0.856$) and attitude ($F=277.399$; $p<0.005$; $\eta^2=0.815$), and the experimental group achieved significantly higher skill scores according to the Independent Samples t-test ($t=22.431$; $p<0.001$). Expert validation and feedback from teachers and students confirmed the high validity and practicality of the developed product. These findings suggest that integrating PjBL into digital worksheet formats promotes active student engagement through contextual disaster projects, thereby enhancing conceptual understanding, fostering preparedness attitudes, and developing practical disaster mitigation skills. Therefore, PjBL-based digital worksheets constitute an effective and applicable medium for supporting earthquake disaster education in secondary schools, especially in disaster-prone regions.

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1. INTRODUCTION

Indonesia is situated at the convergence of active tectonic plates, which renders the country highly susceptible to natural disasters (Asrillah et al., 2019; Ayuningtyas et al., 2021; Muksin et al., 2023). According to the United Nations International Strategy for Disaster Reduction, a disaster is defined as a serious disturbance that causes losses to human life, including material, economic, or environmental impacts, where the consequences exceed the capacity of the local community to manage them (Gelgel, 2020; Kamil et al., 2020). The region's vulnerability is exemplified by the recurrent destructive earthquakes in Aceh. The 2004 earthquake and tsunami, as well as the 2016 Pidie Jaya earthquake, illustrate how the release of seismic energy in subduction zones with thick sediment layers can generate highly destructive tremors, leading to significant loss of life and extensive infrastructure damage (Muksin et al., 2023; Sarkawi et al., 2025).

A range of disasters may be anticipated through effective mitigation efforts (Hamid, 2021). Mitigation comprises a series of actions focused on disaster prevention and management, regardless of whether the causes are natural or non-natural (Juhadi et al., 2022). Mulyadi and Hamidy (2021) define mitigation as efforts undertaken to reduce or eliminate losses and casualties resulting from natural disasters. The development of disaster literacy represents one form of disaster mitigation.

Disaster literacy is defined as the ability to understand, evaluate, and apply disaster information at every stage of disaster management, from mitigation to recovery (Brown et al., 2014). It encompasses an individual's capacity to comprehend the social and environmental dimensions of risk, as well as to access and utilize resources sustainably for self-rescue and post-disaster recovery. To operationalize disaster literacy, Brown et al. (2014) proposed a hierarchical model with four levels of competence: basic literacy (knowledge of mitigation), functional literacy (ability to follow instructions), communicative or interactive literacy (adaptation in various situations), and critical literacy (evaluation and processing of information). This model serves as a framework for developing individual capabilities in disaster response. In educational contexts, Chung and Yen (2016) further elaborated this framework into three complementary areas of learning: knowledge (conceptual understanding), attitude (awareness and responsibility), and skills (concrete actions). Integrating the literacy level model with these three educational domains creates a comprehensive approach to building holistic and tiered disaster literacy (Khairunnisa et al., 2021). The primary objective of disaster literacy development is to equip students and communities with sufficient understanding of various threats, enabling them to take appropriate measures to minimize potential risks (Mufit et al., 2020). Therefore, disaster education is essential for fostering and reinforcing disaster literacy, which directly contributes to effective and sustainable disaster risk reduction (Suarmika et al., 2022).

Indonesia is highly susceptible to natural disasters, necessitating the systematic introduction of disaster literacy, particularly in Aceh province, which has experienced significant disaster events. Systematic disaster education seeks to provide the community, especially students, with a comprehensive understanding of disaster characteristics and mitigation strategies to minimize potential risks. Disaster education is essential for community protection prior to disasters, for imparting appropriate behavioral responses during disasters, and for facilitating rapid recovery and loss minimization after disasters (Cerulli et al, 2020). Consequently, disaster education should be implemented from an early age through formal institutions such as schools, as well as within the family environment, which serves as the foundation of basic education (Tuker & Sozcu, 2021).

Masocha et al. (2025) report that public knowledge regarding disasters, including among school students, remains relatively low. This situation is attributed to the insufficient integration of disaster literacy education within school subjects, limited availability of teaching materials, and the absence of systematic incorporation of disaster-related content into the curriculum (Masocha et al., 2025). Several factors contribute to this low level of integration, including the demanding national curriculum, inadequate teacher training, and a scarcity of engaging, contextual, and technology-based learning

resources (Juhadi et al., 2021). Notably, this issue persists despite the fact that many schools are situated in disaster-prone areas, which should heighten the urgency for disaster awareness and mitigation knowledge. Moreover, disaster literacy remains insufficiently embedded in the Indonesian education system, particularly at the high school level, where disaster-related content is often not systematically included in curricula or teaching materials (Mustofa & Handini, 2023). Consequently, many students possess only a limited understanding of disaster mitigation and preparedness, resulting in a generally low level of community resilience (Amri et al., 2022).

Science education provides an effective framework for systematically integrating disaster-related content due to its focus on natural phenomena and scientific methodologies (Amri et al., 2022). Despite this potential, disaster-related topics are frequently addressed only incidentally, such as during disaster warnings, which limits the development of deep and lasting understanding (Astuti et al., 2021). Furthermore, traditional and minimally interactive instructional methods impede the internalization of knowledge and the cultivation of comprehensive disaster-related attitudes and skills (Berlianawati et al., 2025). Consequently, innovative teaching materials are required that not only fulfill curriculum standards but also promote active participation, critical thinking, and practical skills among students within authentic disaster contexts.

Project-Based Learning (PjBL) is widely regarded as an effective approach for addressing these challenges and achieving holistic educational goals. PjBL enables students to engage directly in solving authentic problems through exploration, planning, and product creation, which fosters the development of higher-order thinking and collaboration skills (Khoiri et al, 2023). Additionally, PjBL aligns with the core dimensions of disaster literacy: knowledge is constructed through independent exploration and investigation; attitudes such as responsibility and awareness are cultivated through participation in meaningful projects; and practical skills are developed through the planning and execution of tangible products, including simulations or evacuation videos (Suradika et al, 2023). In disaster-related contexts, these activities allow students to move beyond theoretical understanding and actively participate in problem-solving processes that enhance higher-order thinking, collaboration, and adaptability in complex situations (Khoiri et al., 2023). Therefore, PjBL serves not only as a method for content delivery but also as a comprehensive learning framework that integrates cognitive, affective, and psychomotor domains in alignment with the requirements of disaster literacy.

In the context of disaster education, the effectiveness of PjBL can be optimized by integrating it into e-Worksheets (electronic worksheets), which utilize digital technology to present interactive content, simulations, and direct feedback (Johan et al, 2021). The synergistic combination of the PjBL pedagogical approach and the advantages of this digital format is expected to increase the appeal, contextual relevance, and effectiveness of disaster literacy learning, while directly addressing the limitations of learning resources that have hitherto hampered the achievement of disaster literacy (Chistyakov et al, 2023). This is particularly relevant when faced with real-world conditions, as identified based on an analysis of the needs and characteristics of students at Labschool USK Banda Aceh High School, where students' disaster knowledge is still low and not supported by adequate learning tools. On the other hand, there is great potential for utilizing science extracurricular activities as a platform for disaster learning through real projects. Therefore, this study aims to develop and test the effectiveness of PjBL-based e-Worksheets in improving high school students' disaster literacy. Focusing on the domains of knowledge, attitude, and skills, this study is expected to provide measurable, practical, and impactful solutions for strengthening disaster resilience at the school level, especially in disaster-prone areas such as Aceh.

Existing research provides a strong foundation for advancing disaster education. Juhadi et al. (2021) developed a disaster literacy model grounded in local wisdom and integrated into the school curriculum. Sari et al. (2022) and Berlianawati et al. (2025) demonstrated that PBL-STEM-based e-Worksheets can effectively enhance student literacy. Despite these contributions, a systematic review of the literature identifies several substantive research gaps. First, most studies focus on junior high school populations, limiting the generalizability of findings to high school students, who require more

advanced cognitive and pedagogical strategies. Second, the predominant learning approaches remain conventional and do not fully leverage interactive digital technologies, including real-time simulations, contextual videos, and dynamic feedback mechanisms, which are essential for effective disaster training. Third, while project-based approaches are recognized as effective in STEM education, their implementation in disaster literacy for high school students through digital media remains limited and insufficiently integrated.

In response to the identified research gaps, the present study was designed to address this void by developing a project-based learning (PjBL) electronic student worksheet (e-Worksheetss) tailored for high school students. Rather than merely replicating or adapting existing models, the study broadens the empirical scope and enhances the pedagogical approach by systematically incorporating interactive multimedia elements, including evacuation simulations and disaster documentary videos, within the PjBL framework. Consequently, the research not only evaluates the effectiveness of e-Worksheets at an advanced level but also challenges traditional learning paradigms by presenting a model that is contextual, participatory, and aligned with the demands of 21st-century education.

The novelty of this research is demonstrated by the integration of three critical elements not previously combined in earlier studies: (1) comprehensive application of project-based learning (PjBL) within high school disaster education; (2) utilization of the e-Worksheets platform featuring interactive multimedia specifically designed for disaster simulation and training; and (3) implementation of this model in extracurricular activities, providing a flexible, interest-driven alternative learning environment. This approach not only extends prior research but also offers a substantive contribution through a hybrid model that serves as a reference for developing disaster literacy in schools with curricular integration challenges. Additionally, it reinforces the function of extracurricular activities as laboratories for contextual learning. The anticipated outcome is the development of structured guidelines enabling teachers and students to participate in more focused, creative, and effective project-based learning, thereby enhancing overall disaster literacy.

Chung and Yen (2016) identify three interrelated dimensions for assessing disaster literacy: knowledge, attitude, and skills. The knowledge dimension encompasses understanding the definition, causes, impacts, and dangers of disasters, as well as preparedness knowledge through mitigation planning and response knowledge related to emergency procedures and post-disaster rescue. The attitude dimension involves prevention awareness, including hazard identification, prevention values, and a sense of responsibility in promoting preparedness. The skills dimension refers to practical actions such as evacuation route planning, participation in simulations, and responsive behavior during emergencies. This conceptual framework provides both a robust theoretical foundation and a practical guide for developing assessment instruments and designing effective disaster education materials (Platini, Abdurrahman, & Lengkana, 2022).

In the context of Aceh, a region highly vulnerable to disasters, these three dimensions are essential. Sufficient knowledge regarding the characteristics of earthquakes and tsunamis enables communities to comprehend environmental risks. A constructive attitude toward prevention and collective responsibility fosters a culture of disaster preparedness. Additionally, practical skills in evacuation and emergency response are critical for saving lives during disasters. An imbalance among these dimensions may reduce the effectiveness of disaster risk reduction efforts in Aceh.

The Project-Based Learning (PjBL) approach is theorized to simultaneously influence three key dimensions of learning. By engaging in authentic projects, such as the creation of evacuation maps or disaster simulations, students build conceptual knowledge through independent exploration and develop proactive attitudes by participating in contextual problem solving. Furthermore, the planning and implementation of these projects directly enhance practical skills, including team coordination and the application of safety procedures. Consequently, PjBL provides an integrated learning framework in which progress in one dimension reinforces the others, thereby supporting the holistic and sustainable development of disaster literacy.

2. METHODS

2.1 Participants

The participants in this study were students from Syiah Kuala University Laboratory High School during the 2025/2026 academic year who participated in the Science Club extracurricular activity. The research subjects were selected based on their relatively homogeneous exposure to science activities and their readiness for project-based learning. Although the sampling method is described as purposive sampling, in practice, it more closely resembled convenience sampling, as only students from a single school and one extracurricular activity were included.

The research sample included 66 students: 35 first-year high school students in the experimental group and 31 second-year high school students in the control group. Science Club members generally demonstrated higher interest and motivation in science learning, as well as more intensive learning experiences, compared to the broader high school population. These attributes may influence student responses to the implementation of Project Based Learning (PjBL)-based e-Worksheetss. The experimental group received instruction using PjBL-based e-Worksheetss, whereas the control group participated in lessons utilizing guided inquiry-based LKPD.

The selection of 10th grade high school students as the experimental group and 11th grade high school students as the control group in the research and development of project-based e-Worksheets to improve disaster literacy was guided by pedagogical considerations and the developmental characteristics of student learning. Grade X was designated as the experimental group because students at this stage are in the early phase of secondary education and remain receptive to innovative learning approaches, particularly project-based e-Worksheets, which emphasizes exploratory, collaborative, and contextual activities related to disaster issues. This stage is considered suitable for introducing foundational disaster literacy. In contrast, Grade XI served as the control group, as these students possess more established learning experiences and are accustomed to conventional instructional methods, making them an appropriate comparison group for evaluating the effectiveness of the developed e-Worksheetss. The selection of these grade levels also considered curriculum continuity and the similarity of general student characteristics, ensuring that observed differences in disaster literacy outcomes could be more reliably attributed to the implementation of project-based e-Worksheets.

The primary limitation of this study is the specificity of the sample, which does not adequately represent the broader population of high school students. Consequently, generalization of the findings should be approached with caution and restricted to students who share similar characteristics, especially those with a strong interest in science and experience with project-based learning.

2.2 Research Design and Procedures

A quasi-experimental design with a pretest-posttest control group structure was employed. This approach enables objective comparison of treatment effects, even in the absence of full subject randomization. The procedure began with a pretest administered to both groups to assess students' initial disaster literacy skills. The experimental group then engaged in learning activities using PjBL-based e-Worksheetss, while the control group received conventional instruction with guided inquiry LKPD. Upon completion of the learning process, both groups completed a posttest to evaluate changes in disaster literacy skills. The study was conducted over one semester during the 2025/2026 academic year and included preparation, implementation, data collection, and analysis stages.

2.3 Instruments

The research instruments utilized in this study comprised e-Worksheets validation sheets, teacher and student response questionnaires, and disaster literacy instruments that assessed knowledge, attitudes, and skills (Chung & Yen, 2016). The knowledge component was evaluated through a written test consisting of questions developed according to disaster literacy indicators and structured to

address multiple levels of Bloom's Taxonomy. These levels included recalling and understanding fundamental disaster concepts (C1–C2), applying knowledge to mitigation and evacuation scenarios (C3), and analyzing and evaluating basic disaster situations (C4–C5). The attitude component was assessed using a questionnaire with 18 statements representing three primary constructs: prevention awareness, prevention values, and a sense of responsibility regarding disasters. These constructs reflect students' abilities to identify potential hazards, recognize the significance of mitigation efforts, and demonstrate concern and preparedness in supporting disaster-related activities within school and community contexts.

Skill aspects were assessed using observation sheets completed for each student participant during a single earthquake evacuation simulation session. The observation sheets included 21 assessment criteria encompassing pre-earthquake preparation, actions during the earthquake, the evacuation process, post-evacuation activities, and an overall evaluation of student involvement. While the simulation was conducted in groups, the skills assessment emphasized individual performance throughout the simulation. All disaster literacy instruments were developed based on relevant indicators, adapted from multiple reference sources, and aligned with the students' characteristics and the specific learning context.

Skill assessment was performed during a single observation session within an earthquake evacuation simulation exercise. While a single observation may not fully capture stable skill mastery, the simulation was systematically designed and aligned with standard disaster preparedness procedures. The scenario comprised earthquake sign identification, evacuation decision-making, movement to a designated safe point, and adherence to safety protocols. Although the simulation was conducted in groups, the assessment evaluated the performance of each individual student throughout the exercise.

Two assessors, each trained in the use of observation sheets and assessment criteria, conducted the observation assessment. The training process involved standardizing interpretations of skill indicators, reviewing performance examples, and performing preliminary assessment trials. Inter-rater reliability was evaluated using the Inter-Class Correlation (ICC) coefficient, with reliability classified as good to very good.

The content validity of all instruments in this study was evaluated through expert review by four individuals: two science education lecturers with expertise in developing learning and disaster literacy assessment instruments, and two high school science teachers experienced in implementing science curricula and integrating disaster mitigation material in schools. The validation process involved providing the draft instruments to these experts, who assessed the suitability of the indicators, the clarity of item wording, and the relevance of the instrument content to the objectives of disaster literacy measurement.

Expert assessments were evaluated using the Aiken index to establish content validity, applying a criterion value of at least 0.75 to indicate instrument feasibility. Items failing to meet this threshold were revised according to expert recommendations prior to inclusion in the pilot test. The revised instrument subsequently underwent empirical testing to assess construct validity and reliability. Construct validity was examined using Pearson Product Moment correlation, and reliability of the knowledge test instrument was assessed with the Kuder–Richardson (KR-20) formula. The instrument was considered reliable if the reliability coefficient was categorized as high.

2.4 Data Analysis

Descriptive and inferential statistical techniques were employed to analyze the research data. Improvement in students' disaster literacy skills was assessed by comparing pretest and posttest scores within each group. Due to differences in sample characteristics between the experimental and control groups, which were drawn from different grade levels, the primary inferential analysis utilized Analysis of Covariance (ANCOVA) with pretest scores as covariates. This approach was intended to

control for variations in students' initial abilities, thereby enabling a more accurate assessment of the treatment's effect on posttest scores.

Before conducting ANCOVA, normality was assessed using the Shapiro–Wilk test and homogeneity of variance was evaluated with Levene's test. All assumptions were satisfied. ANCOVA was then used to examine differences in posttest scores between the experimental and control groups, controlling for pretest scores. In addition to statistical significance, the effect size was reported as eta squared (η^2) to indicate the practical significance of implementing Project Based Learning (PjBL)-based e-Worksheetss. All statistical analyses were conducted using SPSS 16.00 for Windows at a significance level of 0.05.

3. FINDINGS AND DISCUSSION

3.1 Findings

Disaster literacy represents an essential competency for the younger generation, particularly in disaster-prone regions such as Indonesia. Despite its importance, students' disaster literacy levels remain low, which is attributed to the limited integration of disaster-related content in educational resources and the lack of dedicated teaching materials. To address this issue, the present development research produced a Project-based Electronic Student Worksheet designed to enhance disaster literacy comprehensively, encompassing knowledge, attitudes, and skills. The study was conducted at USK Labschool High School in Banda Aceh using the ADDIE (Analysis, Design, Development, Implementation, Evaluation) development model and involved students participating in the Science Club extracurricular activity.

Figure 1. Project-based e-LKPD to improve students' disaster literacy

The development stage yielded highly satisfactory outcomes. Expert validation of the e-worksheets resulted in an average score of 4.48, classified as highly valid, with a reliability coefficient of 0.87, demonstrating strong agreement among validators. The disaster literacy assessment instrument was validated using Aiken's V test ($V \geq 0.667$); only one aspect of the observation sheet required revision, as it was determined to assess compliance rather than cognitive skills. Subsequent empirical testing refined the instrument, reducing the number of items from 26 to 20, and the attitude questionnaire from 21 to 18 valid and reliable statements (Cronbach's Alpha 0.892). A small group test with 10 students demonstrated the product's practicality, achieving a score of 81.25%, as well as high validity and reliability for the instrument (Cronbach's Alpha 0.944 for test questions and 0.978 for questionnaires).

The implementation phase employed a quasi-experimental approach utilizing a pretest-posttest control group design. The experimental group (35 students) engaged in project-based e-Worksheets activities, which included the following sequence: the first session introduced the e-Worksheetss, featured disaster video viewing, essential question responses, and planning for evacuation video projects; the second session involved presentation and peer review of video drafts; the third session comprised a live evacuation simulation, video publication, reflection, and posttest administration. In contrast, the control group (31 students) participated in guided inquiry-based LKPD with a more conventional, structured sequence. These students identified problems, analyzed evacuation procedures, engaged in discussion, and composed reflections based on the LKPD guide, but did not produce any tangible products such as videos. Data collection during implementation utilized triangulation with two primary instruments.

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The evaluation stage of the ADDIE model involved comprehensive data analysis to determine the feasibility and effectiveness of the developed product. Data were collected from questionnaires completed by teachers and students, who served as product users. Analysis indicated that students provided highly positive responses, with an average score of 81.75, while teachers also reported highly positive responses, with an average score of 81.67. These findings suggest that the product is both feasible for use and well accepted in educational settings. To quantitatively assess product effectiveness, learning outcome data were analyzed, beginning with prerequisite tests such as normality and homogeneity assessments. Upon meeting these assumptions, effectiveness testing proceeded using Analysis of Covariance (ANCOVA), with pretest scores included as covariates to control for initial group differences. The ANCOVA results demonstrated a significant effect of product use on the dependent variable. The strength of this effect was further examined using an effect size test, specifically the Partial Eta Squared value, to evaluate the impact of the e-Worksheets on enhancing students' disaster literacy.

Prior to conducting ANCOVA tests and effect size calculations, several prerequisite tests were performed. The initial prerequisite was a normality test, designed to verify that the data on disaster literacy improvement in both the experimental and control groups were normally distributed. The results of the normality test for pretest and posttest disaster literacy knowledge data are presented in Table 1.

Table 1. Results of the Normality Test for the Disaster Literacy Pretest and Posttest in the Knowledge Aspect

Tests of Normality							
Disaster Literacy Knowledge Aspect		**Kolmogorov-Smirnov[a]**			**Shapiro-Wilk**		
		Statistic	**df**	**Sig.**	**Statistic**	**df**	**Sig.**
Pre-Test	Experimental	.148	35	.050	.953	35	.138

	Control	.116	31	.200*	.947	31	.126
Post-Test	Experimental	.145	35	.061	.953	35	.144
	Control	.112	31	.200*	.956	31	.229

Calculations performed using SPSS 16.00 for Windows indicated that pretest and posttest results with significance values greater than 0.05 were considered normally distributed, whereas values below 0.05 indicated non-normality. The normality test analysis presented in Table 1 demonstrates that all significance values for the pretest and posttest data on disaster literacy in the knowledge aspect exceeded 0.05. Specifically, in the experimental class, the Shapiro-Wilk test yielded significance values of 0.138 for the pretest and 0.144 for the posttest. In the control class, the pretest and posttest significance values were 0.126 and 0.229, respectively. These findings indicate that the pretest and posttest data for disaster literacy in the knowledge aspect in both classes are normally distributed, thereby meeting one of the prerequisites for subsequent analysis using the ANCOVA test.

Table 2 presents the results of normality test calculations for pretest and posttest data on disaster literacy as measured by attitude.

Table 2. Results Of the Normality Test for Pretest and Posttest Data on Disaster Literacy Based on Attitude

Tests of Normality							
Disaster Literacy Attitude Aspect		**Kolmogorov-Smirnov[a]**			**Shapiro-Wilk**		
		Statistic	**df**	**Sig.**	**Statistic**	**df**	**Sig.**
Pre -Test	Experimental	.158	35	.027	.950	35	.114
	Control	.135	31	.162	.938	31	.071
Post -Test	Experimental	.149	35	.047	.966	35	.340
	Control	.131	31	.188	.955	31	.213

The normality of disaster literacy data related to attitude was assessed using the Shapiro–Wilk test. For both the experimental and control classes, the pretest and posttest significance values exceeded 0.05. Specifically, the experimental class yielded Shapiro–Wilk significance values of 0.114 for the pretest and 0.340 for the posttest, while the control class produced values of 0.071 for the pretest and 0.213 for the posttest. Although the Kolmogorov–Smirnov test indicated some significance values below 0.05, the Shapiro–Wilk test was prioritized due to the sample size in each group being less than 50. Therefore, the pretest and posttest data on disaster literacy in terms of attitude are considered normally distributed, meeting the prerequisite for subsequent ANCOVA analysis.

Table 3 presents the results of the normality test calculations for disaster literacy observation data related to skills.

Table 3. Results of the Normality Test for Disaster Literacy Observation Data on Skills

Tests of Normality							
Disaster Literacy Skill Aspect		**Kolmogorov-Smirnov[a]**			**Shapiro-Wilk**		
		Statistic	**df**	**Sig.**	**Statistic**	**df**	**Sig.**
Observation	Experiment	.094	35	.200*	.975	35	.608
	Control	.088	31	.200*	.977	31	.719

Based on the results of the normality test using Shapiro–Wilk, the significance value of the disaster literacy observation data in terms of skills in the experimental class was 0.608 and in the control class was 0.719. Both significance values were greater than 0.05, so it can be concluded that the observation

data in both classes were normally distributed. Thus, the data has met the normality assumption as a prerequisite for further analysis using the ANCOVA test.

The second prerequisite test in ANCOVA is the homogeneity test, which checks whether the data variance in the experimental and control classes is the same. The increase in disaster literacy in both classes is normally distributed. Table 4 shows the normality test results for the pretest and posttest data on disaster literacy knowledge.

Table 4. Results of Pretest and Posttest Homogeneity of Disaster Literacy Knowledge Aspect

Test of Homogeneity of Variance					
		Levene Statistic	**df1**	**df2**	**Sig.**
Disaster Literacy Knowledge Aspect	Based on Mean	1.223	1	64	.273
	Based on Median	1.150	1	64	.288
	Based on Median and with adjusted df	1.150	1	62.450	.288
	Based on trimmed mean	1.180	1	64	.281

Table 4 shows that the homogeneity test produced a significance value of 0.273, which is greater than 0.05. This means the variance of pretest and posttest scores for disaster literacy knowledge is homogeneous. Because this assumption is met, Analysis of Covariance (ANCOVA) can be used as a follow-up test. Including pretest scores as covariates helps control for initial differences between groups. As a result, comparing posttest results between the experimental and control groups becomes more accurate, since any differences are more likely due to the intervention rather than unequal variances or starting abilities.

Table 5 below shows the normality test results for pretest and posttest data on disaster literacy attitudes.

Table 5. Results of Homogeneity of Pretest and Posttest Disaster Literacy in Terms of Attitude

Test of Homogeneity of Variance					
		Levene Statistic	**df1**	**df2**	**Sig.**
Disaster Literacy Attitude Aspect	Based on Mean	.188	1	64	.666
	Based on Median	.207	1	64	.651
	Based on Median and with adjusted df	.207	1	61.782	.651
	Based on trimmed mean	.182	1	64	.671

The homogeneity test for the attitude aspect yielded a significance value of 0.666, which exceeds the threshold of 0.05. This result demonstrates that the variance of data between groups is homogeneous. Consequently, the data satisfy one of the prerequisites for analysis, allowing for subsequent testing using ANCOVA.

Table 6 presents the results of the normality test for disaster literacy observation data related to skills.

Table 6. Homogeneity test results for disaster literacy observation data on skills

Test of Homogeneity of Variance					
		Levene Statistic	**df1**	**df2**	**Sig.**
Disaster Literacy Skill Aspect	Based on Mean	.002	1	64	.968
	Based on Median	.009	1	64	.925
	Based on Median and with adjusted df	.009	1	63.932	.925
	Based on trimmed mean	.003	1	64	.959

The data homogeneity test yielded a significance value of 0.968, which exceeds the threshold of 0.05. This result demonstrates that the variance among groups is homogeneous. Consequently, the observation data satisfy a key prerequisite for further statistical analysis using ANCOVA. Following the fulfillment of all prerequisite tests, the analysis proceeded with the ANCOVA test. The results of the ANCOVA test for disaster literacy, specifically regarding knowledge, are presented in Table 7.

Table 7. Results of the Ancova Test Analysis of Disaster Literacy Knowledge Aspects

Dependent Variable:Postest Disaster Literacy Knowledge Aspect						
Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	19610.422[a]	2	9805.211	467.482	.000	.937
Intercept	2090.108	1	2090.108	99.650	.000	.613
Pretest	10993.950	1	10993.950	524.157	.000	.893
Kelompok	7876.489	1	7876.489	375.526	.000	.856
Error	1321.396	63	20.975			
Total	315600.000	66				
Corrected Total	20931.818	65				
a. R Squared = .937 (Adjusted R Squared = .935)						

The ANCOVA test, using pretest scores as covariates, demonstrated that the overall model was significant (F = 467.482; Sig. = 0.000 < 0.05) with an R Squared value of 0.937. This result indicates that 93.7% of the variation in posttest scores for disaster literacy in the knowledge aspect is attributable to the learning model and pretest scores, with the remaining variation explained by other factors outside the model. The covariate analysis revealed that pretest scores significantly affected posttest scores (F = 524.157; Sig. = 0.000), suggesting that students' initial abilities contributed substantially to learning outcomes. Additionally, the group variable had a significant effect on posttest scores for disaster literacy in knowledge after controlling for pretest scores (F = 375.526; Sig. = 0.000). The Partial Eta Squared value of 0.856 indicates a very large treatment effect. Descriptive analysis showed that the adjusted mean increase in disaster literacy knowledge was 77.107 for the experimental group and 55.202 for the control group. These findings demonstrate that students who participated in project-based e-Worksheets exhibited greater improvement in disaster literacy knowledge than those who did not receive the treatment. Therefore, the learning treatment implemented in the experimental class is effective in enhancing disaster literacy in the knowledge aspect compared to the control class.

Following the ANCOVA analysis of disaster literacy in the knowledge domain, hypothesis testing was conducted to determine the statistical significance of observed differences. The null hypothesis (H0) posited no difference in the increase in disaster literacy knowledge between students who received project-based e-Worksheets and those who did not, while the alternative hypothesis (Ha) posited a difference between these groups. The ANCOVA results yielded a significance value of 0.000, which is less than the threshold of 0.01, indicating that H0 is rejected and Ha is accepted. These findings demonstrate a significant difference between the experimental and control groups regarding the improvement in disaster literacy knowledge.

Table 8. Results of the Ancova Test Analysis of Disaster Literacy in Terms of Attitude

Dependent Variable:Postest Disasater Literacy Attitude Aspect						
Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	6450.738[a]	2	3225.369	186.814	.000	.856
Intercept	2441.662	1	2441.662	141.422	.000	.692
Pretest	1064.753	1	1064.753	61.671	.000	.495
Kelompok	4789.317	1	4789.317	277.399	.000	.815
Error	1087.702	63	17.265			
Total	335293.000	66				
Corrected Total	7538.439	65				
a. R Squared = ,856 (Adjusted R Squared = ,851)						

An analysis of covariance (ANCOVA; Table 8) was conducted to compare the increase in disaster literacy attitudes between the experimental class, which received the intervention, and the control class, which did not, while controlling for initial pretest scores. The analysis revealed a highly significant difference in posttest scores between the two groups. After adjusting for initial scores, the experimental class demonstrated significantly higher final scores than the control class ($F = 277.399$, $p < 0.05$). The effect size was substantial, with a partial eta squared (η^2p) value of 0.815, indicating that 81.5% of the variance in final scores was attributable to the intervention, after accounting for baseline ability. Descriptive analysis showed that the adjusted mean increase in disaster literacy attitudes was 78.539 for the experimental group and 61.359 for the control group. These findings suggest that the intervention was highly effective in enhancing students' disaster literacy attitudes. The ANCOVA test yielded a significance value of 0.000, which is less than 0.05, leading to the rejection of H0 and acceptance of Ha. Therefore, the data indicate a significant difference between the experimental and control classes in improving disaster literacy attitudes.

In the analysis of disaster literacy data, skills measured through observation sheets were not analyzed using the ANCOVA test. The observation data consisted of a single measurement, lacking pretest and posttest data that could serve as covariates. Since ANCOVA requires covariates to control for initial group differences, its application to the observation data on skill aspects is not methodologically justified. Consequently, differences in disaster literacy skill aspects between the experimental and control classes were analyzed using the Independent Samples t-test, which is suitable for comparing the means of two independent groups based on a single measurement.

Prior to performing the Independent Samples t-test, prerequisite analyses were conducted, including normality and homogeneity tests on disaster literacy data related to skills. Table 9 presents the results of the Shapiro-Wilk normality test.

Table 9. Results of the Normality Test for Disaster Literacy Skills

Tests of Normality

Disaster Literacy Skill Aspect		**Kolmogorov-Smirnov[a]**			**Shapiro-Wilk**		
		Statistic	**df**	**Sig.**	**Statistic**	**df**	**Sig.**
Observation	Experimental	.094	35	.200*	.975	35	.608
	Control	.088	31	.200*	.977	31	.719

The results of the Shapiro-Wilk normality test indicate that disaster literacy scores for both groups are normally distributed. The significance value (p) for the experimental group is 0.608, and for the control group is 0.719. As both p values exceed 0.05, the null hypothesis of normal distribution is not rejected. Therefore, the normality assumption is satisfied for subsequent analyses.

The subsequent prerequisite for assessing disaster literacy skills is the homogeneity test. The results of this test are presented in Table 10.

Table 10. Homogeneity Test Results for Disaster Literacy Skills

		Levene Statistic	df1	df2	Sig.
Disaster Literacy Skill Aspect	**Based on Mean**	**0.002**	**1**	**64**	**0.968**
	Based on Median	0.009	1	64	0.925
	Based on Median and with adjusted df	0.009	1	63.932	0.925
	Based on trimmed mean	0.003	1	64	0.959

Levene's test for variance homogeneity indicates that the variance of disaster literacy skill scores between the experimental and control groups is homogeneous. The Levene Statistic is 0.002 with a significance level of p = 0.968. Since the p-value exceeds 0.05, the null hypothesis of equal variances is not rejected. Therefore, the assumption of variance homogeneity is met, allowing for subsequent parametric analysis.

Once the disaster literacy skill data were confirmed to be normally distributed with homogeneous variance, analysis proceeded using the Independent Samples t-test. Table 11 presents the results of this analysis.

Table 11. Independent Samples t-test for Disaster Literacy Skills Aspects

		Levene's Test for Equality of Variances		t-test for Equality of Means		
		F	Sig.	t	df	Sig. (2-tailed)
Disaster Literacy Skill Aspect	Equal variances assumed	0.002	0.968	22.43	64	0.000
	Equal variances not assumed			22.42	62.94	0.000

Table 11 presents a statistically significant difference in disaster literacy skills between the experimental and control groups. The Levene's test yielded a significance value of 0.968 (> 0.01), confirming that the assumption of variance homogeneity is satisfied; therefore, the results are interpreted using the Equal variances assumed row. A t-value of 22.431 with a significance level of 0.000 (< 0.01) demonstrates that the mean disaster literacy skill score in the experimental group is significantly higher than that of the control group. These findings indicate that the significance value of 0.000 < 0.05 leads to the rejection of H0 and acceptance of Ha. Consequently, the project-based e-Worksheets learning intervention is effective in enhancing students' disaster literacy skills.

In addition to the quantitative findings, this study incorporates qualitative data analysis to provide a more comprehensive understanding of the learning process and the impact of PjBL-based e-Worksheetss. Qualitative data were collected through observations of student engagement during project work and analysis of written reflections submitted at the conclusion of the learning process. Observational results indicated that over 85% of students in the experimental group actively participated in discussions, planning, and implementation of the simulation video project. This engagement was evidenced by idea generation, collaborative role allocation, and independent exploration of the features and resources available in the e-Worksheetss. Thematic analysis of 35 student reflection sheets identified three primary patterns. First, students reported that engaging in authentic projects enhanced the contextualization and memorability of disaster procedure knowledge. Second, students demonstrated an increased sense of collective responsibility for disaster preparedness, as reflected in their intentions to apply acquired knowledge within their home

environments. Third, students recognized the development of 21st-century skills, including collaboration, project management, and communication. These qualitative findings contextualize and reinforce the quantitative results; the substantial effect size ($\eta^2p > 0.8$) observed in knowledge and attitude outcomes was not solely attributable to information transfer, but was facilitated by active, meaningful, and student-centered learning processes. Therefore, the effectiveness of PjBL-based e-Worksheets is substantiated through data triangulation, with quantitative data indicating the extent of improvement and qualitative data elucidating the mechanisms underlying this improvement through engagement and internalization of learning experiences.

The effectiveness of project-based learning (PjBL) in significantly enhancing disaster literacy attitudes can be attributed to its integration of cognitive and affective domains. First, PjBL converts theoretical knowledge about disasters into meaningful personal experiences through experiential learning. Students not only acquire cognitive understanding of evacuation procedures but also directly engage in planning, producing simulation videos, and practicing evacuation. These authentic experiences foster emotional connections and a sense of personal responsibility, as evidenced by students' reflections expressing their intention to apply this knowledge in their home environments. Second, the disaster context in Aceh, characterized by vulnerability and a traumatic history, increases the relevance and urgency of this learning approach. The simulation video project serves not merely as an academic task but as an activity with direct implications for life safety, thereby eliciting strong affective engagement such as concern, awareness, and collective responsibility. Third, the social and collaborative aspects of PjBL establish group norms that reinforce positive attitudes. Through teamwork, students influence, observe, and reinforce alert behaviors, resulting in the formation and strengthening of individual attitudes through peer interactions. Consequently, PjBL not only facilitates knowledge transfer but also intentionally creates conditions for attitude development through authentic experiences, high contextual relevance, and supportive social dynamics. This combination is less commonly achieved in conventional learning approaches that emphasize one-way information delivery.

The broader theoretical implications for learning extend beyond validating the effectiveness of e-Worksheetss. This study presents a transferable model for implementing Project-Based Learning (PjBL) in extracurricular contexts, which can bridge the gap between a dense formal curriculum and the need for contextual competency development. The model demonstrates that extracurricular environments can be transformed into flexible contextual learning laboratories, enabling intensive and meaningful application of the PjBL approach without the constraints of the core curriculum's rigid time structure and workload. This principle is applicable to other fields, including environmental education, health, and entrepreneurship, where holistic competency development requires in-depth exploration and direct involvement that regular classroom learning often cannot accommodate. Additionally, these findings contribute to the theoretical understanding of the dynamic interaction among the three domains of literacy—cognitive, affective, and psychomotor—within the PjBL framework. The research indicates that these domains reinforce each other through cycles of authentic experiences designed within the project. Activities such as planning and creating disaster simulation videos act as catalysts, integrating conceptual understanding (knowledge) with the development of responsible attitudes and awareness (affective), as well as their application in real actions such as evacuation simulations (psychomotor). This interaction is facilitated by experiential learning mechanisms, where emotional involvement and personal reflection in relevant projects deepen the internalization of knowledge and transform it into dispositions and capacities for action. Therefore, this study advances learning theory by demonstrating that PjBL, particularly when supported by digital technology, serves not only as a method for achieving cognitive goals but also as a robust pedagogical framework for synergizing the multidimensional development of learners in an integrated manner. It also offers an alternative pathway for implementing contextual and learner-centered education outside the formal curriculum structure.

The research project produced a video simulation of earthquake evacuation, accompanied by a rubric designed to assess the quality of the simulation. The assessment rubric was developed based on Chung and Yen's (2016) disaster literacy framework, which encompasses the dimensions of knowledge, attitude, and skills, and was adapted to align with the Project-Based Learning (PjBL) model. The rubric evaluates four primary criteria: (1) content accuracy, which assesses the correctness of disaster information, including procedures such as drop, cover, and hold on, as well as the appropriateness of evacuation routes according to school maps; (2) creativity, which measures the originality of ideas, innovative delivery, and effective use of props; (3) clarity of message, which considers the quality of narration, language, and instructional clarity; and (4) team collaboration, which is evaluated through active participation and the division of roles during video production. Quantitative analysis of video artifacts from 35 students in the experimental group indicated high average scores across all criteria (content accuracy: 4.2; creativity: 4.0; message clarity: 4.3; collaboration: 4.4 on a scale of 1 to 5). These results provide direct evidence of students' ability to apply knowledge, demonstrate responsibility, and exhibit technical and collaborative skills, representing achievements beyond traditional written assessments. Qualitative analysis of video content and student reflections revealed deeper contextual understanding, enhanced collective awareness, and mastery of 21st-century skills. Visualization of the data using a radar chart further supports these findings by illustrating that the experimental group consistently outperformed the control group in all assessment areas, particularly in content accuracy and team collaboration. These results confirm the effectiveness of PjBL-based e-Worksheets in fostering holistic and meaningful learning outcomes.

Although this study does not explicitly present a statistical correlation analysis, such as Pearson or Spearman tests, between the increases in knowledge, attitude, and skill scores post-intervention, several strong indications suggest integration among these three aspects. First, quantitative findings demonstrate that the experimental group achieved a significant increase and a large effect size ($\eta^2 > 0.8$) in both knowledge and attitude. This outcome indicates that the PjBL intervention improved conceptual understanding while simultaneously fostering awareness and responsibility. Second, qualitative data from participant observations and reflections provide further evidence: participants who were actively involved in the simulation video project, which required the application of knowledge, also exhibited improvements in collaboration, planning, and evacuation procedure execution skills. Thematic analysis of reflections revealed that students perceived their understanding as “more contextual and embedded” and noted the emergence of “collective awareness and responsibility,” indicating that positive attitudes developed alongside enhanced knowledge and skills. Third, although skill measurement was conducted separately through single-session observation, the average skill scores of the experimental group were significantly higher than those of the control group. This achievement was observed in the same group that experienced a substantial increase in knowledge and attitude. Therefore, even in the absence of numerical correlation analysis, the consistent and mutually reinforcing data patterns across the three domains suggest that PjBL serves as an integrated framework that holistically and synergistically develops knowledge, attitudes, and skills. The implication is that learners with greater knowledge and more positive attitudes are more likely to demonstrate improved skills, as all three are cultivated through the same authentic project experience. Future research could employ correlation or regression analysis to empirically test the strength of these relationships.

Several key limitations of this study warrant consideration. The primary limitation concerns the sample, which consisted exclusively of students from a single school (SMA Labschool USK) who participated in the Science Club extracurricular activity. This approach closely resembles convenience sampling and does not represent the broader population of high school students, as these participants typically demonstrate higher interest and motivation in science and are more familiar with project-based learning. Consequently, this limitation restricts the external validity of the findings, and generalizations should be made cautiously and only to students with similar characteristics. The substantial effectiveness (with a large effect size) of the PjBL-based e-Worksheets observed in this

context may not extend to students in typical schools or those with average interest levels, as the experimental group may have been more receptive to educational innovations. Furthermore, the quasi-experimental design employed experimental (class X) and control (class XI) groups from different grade levels, rather than randomizing within the same grade. Although ANCOVA was applied to control for initial differences, variations in maturity and academic experience between grades X and XI may have acted as confounding variables influencing posttest outcomes, despite claims of curricular and general student similarity. An additional methodological limitation pertains to the assessment of skill-related outcomes, which relied on a single simulation observation session without a pretest. This approach limits the ability to determine the stability and depth of skill mastery and precludes controlling for baseline abilities, as was possible for knowledge and attitude measures. While these limitations do not undermine the positive results of the study, they underscore the need for further research involving more diverse populations and more rigorous designs to confirm the broader applicability of the developed model.

4. CONCLUSION

This study developed and evaluated a Project-Based Learning (PjBL)-based electronic worksheet designed to enhance earthquake disaster literacy among high school students. The findings indicate that the developed e-worksheet was valid, practical, and positively received by teachers and students, and that its implementation significantly improved students' disaster literacy in the domains of knowledge, attitudes, and skills compared with the control group. The integration of authentic projects, such as evacuation simulation videos and disaster-response activities, supported students' conceptual understanding, preparedness awareness, collaboration, and practical mitigation skills. However, this study was limited by its small and specific sample, which involved Science Club students from a single school, and by the use of different grade levels for the experimental and control groups, which may have introduced potential confounding variables despite statistical control. In addition, the skill component was assessed through a single post-intervention observation, limiting the ability to determine long-term skill mastery or improvement from baseline. Future research should involve larger and more diverse samples, apply randomized or same-grade experimental designs, include repeated or longitudinal assessments of disaster-response skills, and examine the relationships among knowledge, attitudes, and skills to better understand how PjBL-based digital worksheets contribute to holistic disaster literacy development.

Acknowledgments: The authors acknowledge Syiah Kuala University Laboratory High School (Labschool USK) Banda Aceh for supporting the implementation of this research, as well as the teachers, students, and expert validators who contributed to the research process.

Conflicts of Interest: The authors declare that there are no conflicts of interest regarding the publication of this article

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