

Developing a mitigation board game integrating animal and plant behavioral indicators to foster problem-solving skills

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Citation: Wibowo, A., Fitriana, E., Anggarani, D. A., Daniarsih, A., Novaldi, M. D., Sa'diyah, H., & Kusmahardhika, N. (2026). Developing a mitigation board game integrating animal and plant behavioral indicators to foster problem-solving skills. *Research and Development in Education (RaDEn)*, 6(1), 295-314.
<https://doi.org/10.22219/raden.v6i1.43480>

Received: 24 January 2026

Revised: 14 April 2026

Accepted: 21 April 2026

Published: 20 May 2026



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Abstract: *Background*-Problem-solving skill is one of the essential 21st-century competencies that should be enhanced through contextual learning. Disaster mitigation learning in schools generally remains theoretical and has not fully encouraged students' active participation in developing higher-order thinking skills. *Objectives*-This study is aim to develop a disaster mitigation board game integrating animal and plant behavioral indicators to examine its validity, practicality, and effectiveness in enhancing students' problem solving skills. *Method*-This research and development employed the ADDIE model, consist of analyze, design, development, implement, and evaluate. The research subjects were 21 students of tenth-grade high school. Data were collected through media and material expert validation sheets, student response questionnaire, and problem-solving skill tests. Data were analyzed using descriptive quantitative analysis, N-Gain calculation, and paired sample t-test. *Results*-The validation results showed that the media obtained a score of 95% from media experts and 97% from material experts, categorized as very valid. Student responses indicated a practicality level of 92.33% categorized as very practical. The N-Gain value of 0.704 was classified as high effectiveness, and the paired sample t-test results revealed a significant improvement in students' problem-solving skills (0.00, $p < 0.05$) and Cohen's d 2.65. *Conclusions*-The disaster mitigation board game indicated potential effectiveness in improving students' understanding of adaptive behavior in living organisms within disaster context, as well as fostering critical and collaborative thinking skill. Further research is suggested to use massive field trial thus develop digital version to increase interactivity and accessibility.

Keywords: animal and plant behavior; board game; disaster mitigation; educational games; problem-solving skill

1. Introduction

Natural disaster represents a growing global challenge that continues to intensify each year. Indonesia, situated along the Pacific Ring of Fire, ranks among the countries with the highest disaster frequency, including earthquakes, floods, volcanic eruptions, and landslides (Wekke, 2021). While many disasters are triggered by natural processes, human activities also contribute to the occurrence and severity of certain disaster (SP et al., 2024; Spiridonov et al., 2025). For instance, deforestation, land-use change, and poor

environmental management can increase the risk of floods and landslides. Such disaster-prone conditions demand that communities cultivate preparedness and adaptive thinking in emergency situations (Bakhriansyah et al., 2025; Nasution et al., 2025). Disaster education needs to be provided from an early age as part of strengthening environmental literacy and fostering resilience to face disaster risk (Logayah et al., 2022; Ramadhan et al., 2019; Yusuf et al., 2022). However, disaster education in schools remains largely informational and theoretical, and is often not even taught (Hayudityas, 2020). Consequently, this situation does not fully train students in analyzing situations, making decisions, and developing problem-solving strategies when facing potential disaster (Haryanto & Lakoro, 2012; Yusuf et al., 2024).

Problem-solving skill is a crucial of the 21st century competency that students must possess to face complex real-world problems (Greenstein, 2012). Higher-order thinking skills foster students of ideas and creativity in developing new solutions, as well as curiosity toward understanding and addressing problem (Akhyar & Suryani, 2012). Students not only need to understand disaster concepts scientifically but also identify natural signs, assess risks, and determine appropriate mitigation measures. School-based learning rarely provides opportunities for students to develop problem-solving skills through contextual and reflective experiences (Anggarani et al., 2024). This results in students' lack of receptivity to information without developing analytical and responsive skills to real-world situations (Shongwe, 2024; Tawfik & Gatewood, 2022). Without well-developed problem-solving skills, disaster education risks remaining superficial, as students may understand concepts but fail to apply them effectively in real emergency situation (Johar et al., 2025; Rahim & Fauzi, 2023). The development of learning that encourages active participation, decision-making, and problem-solving based on real-life situations is urgently needed.

Animal and plant behavior, as contextual material, can serve as a source of relevant information to hone students' problem-solving skills (Wirayuda et al., 2024). Several studies have shown that animals often exhibit behavioral changes before earthquakes, while plants can be indicators of microclimate changes such as drought or pollution (Grant et al., 2011; SP et al., 2024; Upadhyay, 2020). Integrating an understanding of these biological behaviors into the context of disaster mitigation can strengthen ecological literacy while training students to think analytically about natural phenomena (Amalia, 2024; Colucci-Gray et al., 2006). Unfortunately, this approach is still rarely applied in disaster education. Learning delivered in an interactive format, such as through educational games, is easier for students to understand and apply (Anggraeni et al., 2022; Cheung & Ng, 2021; Nurhikmah et al., 2024).

Recent developments in game-based learning (GBL) in environmental education have shown a significant shift from content delivery toward experiential, simulation-based, and interactive learning approaches (Huizenga et al., 2017; Situmorang et al., 2024; Vázquez-Calatayud et al., 2024). GBL enables students to explore complex environmental systems and engage in decision-making processes within safe and controlled environments (Hwang & Chang, 2023; Vázquez-Calatayud et al., 2024). Various of GBL, including real games, simulation games, and board games have been widely implemented to enhance engagement, risk awareness, and disaster preparedness (Bai et al., 2024), while also supporting the development of environmental literacy and sustainability-oriented attitudes (Chuang et al., 2025; Tsai et al., 2020). However, despite these advancements, recent studies highlight that most implementations still predominantly emphasize motivational and affective outcomes rather than fostering higher-order competencies such as problem-solving and adaptive decision making

One potential alternative learning media for this purpose is educational board games. Board games have been proven effective in increasing student engagement (Booker & Mitchell, 2021), fostering a sense of collective responsibility (Vasconcelos et al., 2022), and developing critical thinking and problem-solving skills through simulations of real-life situations (Chen et al., 2021; Kuo et al., 2023). In Indonesian studies, indicate that the educational games are often developed to improve conceptual understanding and

engagement, but still lack integration with complex real world problem-solving context, particularly in environmental and disaster topics (Audria, 2024; Chew et al., 2023; Haryanto & Lakoro, 2012; Okra, 2023; Putra et al., 2024). Although disaster-themed board games have been developed, most still focus on geographic or technical aspects of mitigation, such as hazard mapping and evacuation procedures which tend to emphasize procedural knowledge rather than analytical interpretation.

Biological indicators such as changes in animal and plants responses offer a more dynamic and interpretative learning context, as they require students to observe patterns, infer causal relationships, and make decision based on uncertain environmental signals (Kuo et al., 2023; Rahman et al., 2024; Ramadhani et al., 2021). Biological indicators support contextual and constructivist understanding through interaction with real world phenomena (Upadhyay, 2020). For instance, abnormal behaviours such as monkeys moving to higher ground, large flocks of birds flying inland, crabs closing their burrows, or unusual silence among coastal birds can signal potential coastal hazards like tsunamis or extreme weather (Wisaksono et al., 2024). While ecological changes such as algal blooms or erratic fish movements may indicate marine pollution events (Brown et al., 2020). These phenomena require students to observe patterns, interpret environmental signals, and infer causal relationships under conditions of uncertainty. Moreover, integrating biological indicators aligns with indigenous and local knowledge systems, in which natural signs have long been used as non-technological early warning system (Brown et al., 2020; Logayah et al., 2022; Prokop & Fančovičová, 2023; Ramadhan et al., 2019).

The gaps highlight the need for innovative game-based learning designs that integrate biological knowledge with interactive decision-making processes to foster students' problem-solving skills in disaster contexts specially in biology course. Based on this gap, this study aims to develop a disaster mitigation board game that integrates animal and plant behavior indicators to enhance students' problem-solving skills in a valid, practical, and effective manner. This development is expected to contribute to increased problem-solving skills in the context of disaster education.

2. Materials and Methods

2.1 Types of research

This study applies a research and development (R&D) approach using the ADDIE model (Branch, 2010). The research aims to develop an educational board game for disaster mitigation that integrates animal and plant behavioral indicators as natural signs for disaster awareness. The integration of these biological indicators is expected to enhance students' understanding of ecosystem response and promote proactive behavior in disaster preparedness. The study employs both qualitative and quantitative data. Qualitative data consists expert validation feedback include media and material validation and user responses during trial phase. Quantitative data comprise the results of pre-test and post-test assessment measuring student's problem-solving skills related to disaster mitigation. The ADDIE model possesses a systematic and flexible structure that ensures the media development process remains well-directed, tested, and adaptable to real classroom conditions, particularly in learning contexts that do not rely on digital technology.

2.2 Research and developments steps

This study employed a design following the ADDIE model, which consists of five stages include analyze, design, develop, implement, and evaluate (Figure 1). This model was selected because it allows continuous refinement of the product based on feedback and evaluation result at each stage, ensuring the media's quality, relevance, and effectiveness in achieving learning objectives.

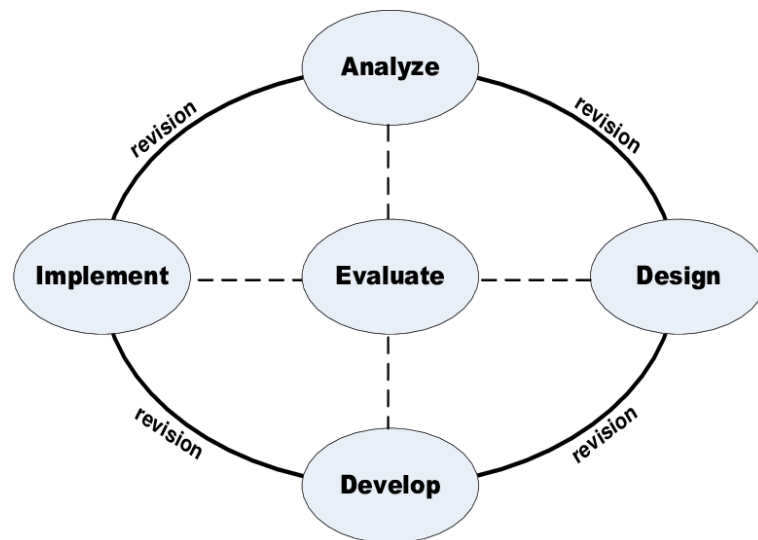


Figure 1. ADDIE model stages

2.2.1 Analyze

The analyze stage was conducted through observation and interviews to find out the existing problems. A needs analysis was conducted to identify the requirements of both students and teachers regarding the development of disaster mitigation learning media. In addition, a curriculum analysis was conducted to ensure alignment between the developed media and the applicable curriculum. This analysis focused on identifying relevant learning objectives, competencies, and content related to biodiversity and disaster mitigation within the Islamic senior high school curriculum. The analysis also examined the learning needs related to disaster preparedness and environmental awareness. Data were collected through observations and interviews conducted with students 11th and 12th grade students at Islamic Senior High School Annur Bululawang who had received biodiversity content to obtain direct insights into the current learning conditions and expectations for media development.

2.2.2 Design

The design stage involved planning and creating the concept of the board game. This process included designing the disaster mitigation materials based on animal and plant behavioral indicators by literature reviews, integrating the materials into the gameplay, sketching the visual layout of the media, printing the prototype, and preparing the necessary instruments such as the problem-solving assessment sheet, media and material validation sheets, and student response questionnaires.

The concept of the board game is showed in [Figure 2](#). The type of disasters, biological indicators, and mitigation strategies were operationalized into structured game components to support problem-solving processes. The disasters included volcanic eruptions, landslides, volcanic earthquakes, forest fires, and flash floods, each represented by specific biological indicators derived from observable animal behavior and plant responses. Animal-based indicators included abnormal movements such as wildlife descending from mountainous areas and unusual migration patterns, while plant-based indicators included leaf wilting discoloration, and root exposure. These indicators were scientifically grounded as early warning signs of environmental disturbances. In the game design, the biological indicators were translated into three main types of cards: (1) biological indicator cards, (2) disaster cards, and (3) mitigation cards. During gameplay, players interpret indicator cards to predict potential disasters and match them with appropriate mitigation strategies when disaster cards are revealed.

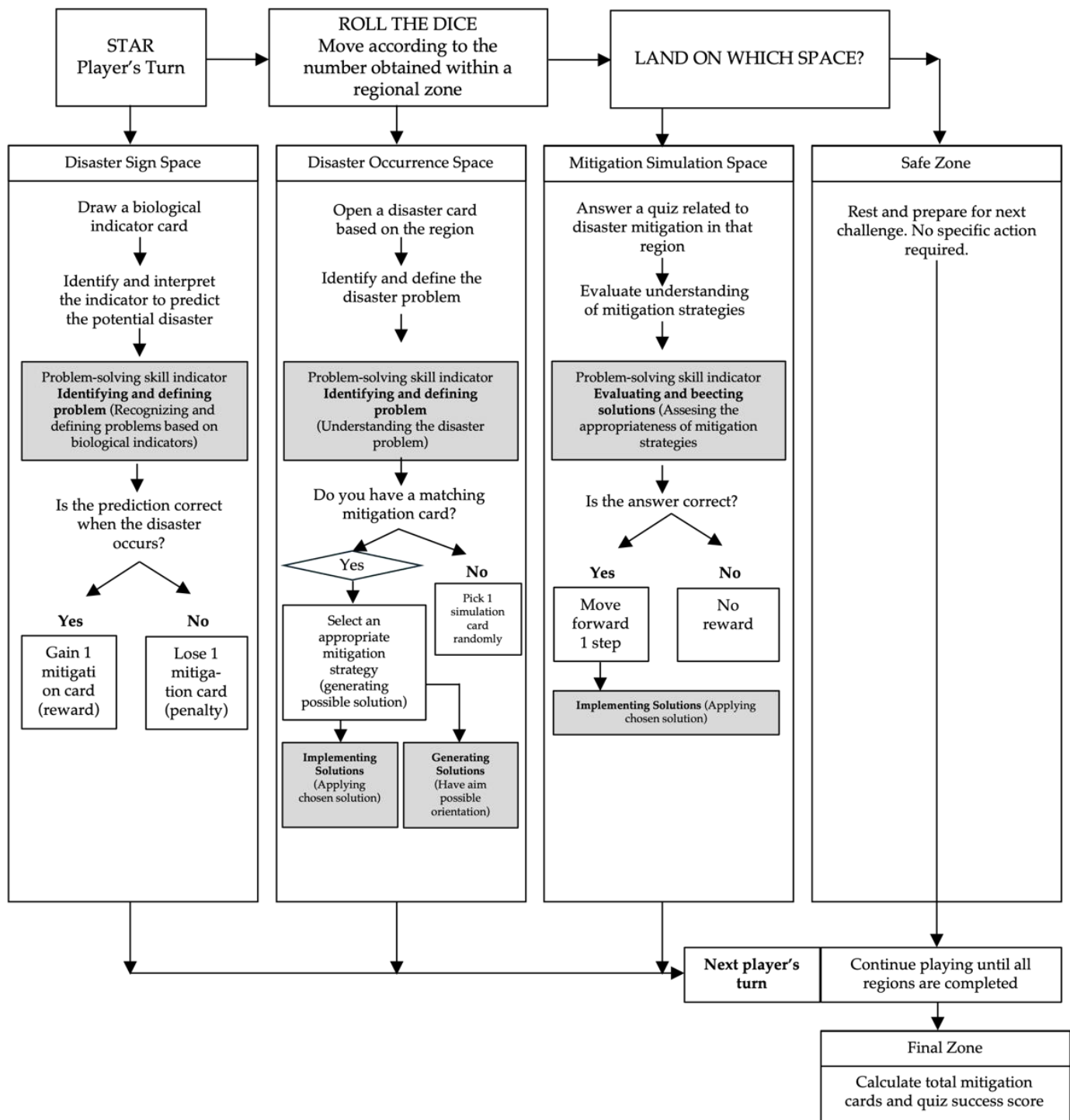


Figure 2. Flowchart of integration of problem-solving skills indicators concept in board game

2.2.3 Develop

In the development stage, the gameplay mechanics were systematically developed to integrate biological indicators, particularly plant and animal-based indicators into the problem-solving process. Players interact with the game through structured stages aligned with problem-solving skills. At the initial stage, players draw biological indicator cards representing observable plant and animal responses, such as leaf wilting, leaf discoloration, or animal behavior in which wildlife descends from mountainous areas into residential zones. These indicators function as contextual cues that guide players to identify and define potential disaster problems.

Subsequently, players interpret the indicators to predict the type of disaster that may occur. In the next stage, when a disaster scenario is presented, players are required to

generate and select appropriate mitigation strategies based on their prior interpretation. If players possess relevant mitigation cards, they may apply them directly, otherwise they must propose a suitable one according to the disaster context. The mechanism ensures that biological indicators function not merely as informational elements but as analytical tools that guide players through the stages of problem identification and definition, solution generation, evaluation and selection of solutions, and the implementation of solutions within the gameplay context.

The board game and its accompanying materials were validated by experts in terms of content accuracy and media design. Student responses were also collected to evaluate the attractiveness and practicality of the media. Revisions were made based on comments and suggestions from validators. Validators of this learning media consisted of media and content expert validators. In this research and development study, the content expert was a lecturer from the Biology Department, holding at least a master's degree and having a minimum of five years of teaching experience in the field of local wisdom-based education and biodiversity. The content expert was responsible for validating the appropriateness and relevance of the content integrated into the development game. Thus, the media expert was a lecturer from the Biology Education Department at Universitas Negeri Malang, holding at least a master's degree and possessing a minimum of five years of teaching experience in the development of digital learning media. The media expert was responsible for validating the quality and feasibility of the development media.

2.2.4 Implementation

The implementation stage was carried out through a limited trial involving one class of 21 students at Islamic Senior High School of Annur Bululawang. During this stage, pre-test and post-test assessments were administered to measure students' problem-solving skill before and after using the developed board game. The indicators of problem-solving skill that are assessed are according to Greenstein (2012) and consist of (1) identifying and defining problems, (2) generating solutions, (3) evaluating and selecting solutions, and (4) implementing solutions.

2.2.5 Evaluate

The effectiveness of the developed board game was analyzed using the results of the pre-test and post-test. Effectiveness was determined from pretest-posttest results analyzed using the *t*-test, tests of normality and homogeneity were carried out to ensure that the data met the required statistical assumptions.

2.3 Research Instrument

The research instruments in this study employed expert validation questionnaires and consist of media expert validation and material expert validation sheets, Course Outlines (Modul Ajar), and problem-solving skills tests. Problem-solving skill instrument employed pretest-posttest open-ended questions. The problem-solving skill indicator according to Greenstein (2012) consists of (1) identifying and defining problems, (2) generating solutions, (3) evaluating and selecting solutions, and (4) implementing solutions. The instrument validity test showed a Pearson correlation coefficient range of 0.658-0.920, indicating high validity. Meanwhile, the reliability test yielded a reliability of 0.845, indicating high reliability. The test was administered at the beginning of the learning session and a posttest at the end.

2.4 Data collection and Data Analysis Techniques

Data collection was conducted from July-October 2025. The instruments in this research include in-depth discussion, media validation, observation, and documentation studies. The in-depth discussion was conducted with biology and geographical experts. Validation of media and material experts was obtained from validator lecturers.

Validation scores were then interpreted and categorized according to predetermined criteria. Validation criteria use Likert scale, the Likert scale is as follows: a score of 5

indicates “very valid”, a score of 4 indicates “valid” a score of 3 means “fairly valid”, a score of 2 means “less valid”, and a score of 1 means “very invalid”, then compared with the criteria by Tegeh et al. (2014) in Table 1.

Table 1. Validation criteria

Percentage (%)	Qualification	Explanation
90-100	Very good	No revisions
75-89	Good	Slight revision
65-79	Enough	Revised sufficiently
55-64	Less	Many things have been revised
1-54	Very less	Repeated making the product

Source: Tegeh et al. (2014)

The practicality scores conducted by students in using board game while learning. The score was collected then interpreted and categorized according to predetermined criteria. Practicality criteria use Likert scale, the Likert scale is as follows: a score of 5 indicates “very valid”, a score of 4 indicates “valid” a score of 3 means “fairly valid”, a score of 2 means “less valid”, and a score of 1 means “very invalid”, then compared with the criteria by Tegeh et al. (2014) in Table 2.

Table 2. Practicality criteria

Percentage (%)	Qualification	Explanation
90-100	Very good	No revisions
75-89	Good	Slight revision
65-79	Enough	Revised sufficiently
55-64	Less	Many things have been revised
1-54	Very less	Repeated making the product

Source: Tegeh et al. (2014)

Data were processed using paired sample t-test using SPSS 25 for Mac, measure the Cohen’s d using Social Science Statistic website, and n-gain analysis to determine the improvement in students’ problem-solving skills after the learning intervention. Effectiveness was determined from pretest-posttest results analyzed using N-Gain score formula. The N-Gain score formula is in Formula 1.

$$g = \frac{\text{posttest score} - \text{pretest score}}{100 - \text{pretest score}} \tag{1}$$

The results of the data analysis are interpreted and concluded based on the criteria for the effectiveness of the learning media. These criteria reflect the alignment between the theoretical framework and the development of the instructional media. The effectiveness criteria are presented in Table 3.

Table 3. The n-gain effectivity criteria

Percentage (%)	Qualification
$\langle g \rangle \geq 0.7$	High effectiveness
$0,3 \leq \langle g \rangle < 0.7$	Moderate effectiveness
$\langle g \rangle < 0.3$	Low effectiveness

Source: Latri et al. (2021)

3. Results

3.1 Analyze

The analysis was conducted through interviews with one three teachers at senior high schools in Malang, Indonesia. The data and information obtained from the interview

included the media commonly used by teachers in the learning process, students' characteristics and learning styles, and the relevant topics that could be integrated into the boardgame. Based on the interview results, it was found that students generally demonstrated curiosity and enthusiasm in contextual and problem-solving based activities. Learning related to disaster mitigation and environmental adaptation was often delivered through learning process. Teacher also stated that students would benefit from interactive and game-based learning media that could visualized real situations and promote problem solving skills.

The material considered for integration in the board game included concepts from biology, particularly the behavioral adaptations of animals and plants as natural disaster indicators. These concepts are aligned with high school biology curriculum, especially in topics related to ecosystem, environmental changes, geography, and biodiversity. The expected learning outcomes of this material are that students can identify animal and plant behaviors that indicate environmental changes, analyzed potential natural disasters based on these indicators, and propose appropriate mitigation strategies through collaborative problem-solving during the game play.

3.2 Design

The design stage consisted of material and product design. The selected content was further integrated with concepts of animal and plant behavioral indicators that can sign the environmental disturbances or potential natural disasters. Meanwhile, the product design involved creating a board game prototype that integrates biological concepts with disaster mitigation scenarios. The design process began with the development of a storyboard outlining the games flow, including objectives, player roles, rules, scoring system, and challenges cards. The media developed was named as "Wild Warning". The storyboard was realized into a 2D layout design using Photoshop and Canva applications to produce visual elements, icons, and board structures that support an engaging learning experience.

3.3 Develop

The prototype developed have passed the validity process. The purpose of media dan material validation is to ensure the feasibility, content accuracy, and effectiveness of the learning media before it is implemented for students. The product developed was validated by media and material expert. The result of media expert validation is shown in [Table 4](#). Thus, the material expert validation is shown in the [Table 5](#).

Table 4. Media expert validation results

Aspect	Maximum score	Score achieved	Percentage	Category
Content suitability	25	24	96%	Very good
Display suitability	25	23	92%	Very good
Presentation suitability	25	23	92%	Very good
Language suitability	15	15	100%	Very good
Total			95%	Very good

Based on the [Table 4](#), the results of the media validation indicated an overall average score of 95%, which is categorized as very good. The content suitability aspect obtained score of 96%, indicating that the material is accurate, relevant, and aligned with the intended learning objectives. Both display suitability and presentation suitability received 92%, reflecting that the visual design, organization, and presentation effectively support learners' engagement and comprehension. The language suitability aspect achieved 100%, indicating that the language used is clear, communicative, and appropriate for the target users. These results confirm that the learning media gained the validity criteria in content, presentation, visual design, and language as valid and appropriate for use in educational design.

This finding demonstrates that the learning media developed is highly suitable for classroom implementation with no significant revisions required. The revision of the learning media was carried out based on suggestions and comments from the media expert validator. The revisions were minor and not significant, involving adjustments to make the box structure sturdier and reduce its overall size.

Table 5. Material expert validation results

Aspect	Maximum score	Score achieved	Percentage	Category
Truth and accuracy	20	18	90%	Very good
Relevance and integration	25	25	100%	Very good
Usefulness	25	25	100%	Very good
Total			97%	Very good

Based on the Table 5, the results of the material validation obtained an overall average score of 97%, which categorized as very good. This indicates that the developed learning media is highly valid and appropriate for use in the learning process. The truth and accuracy aspect obtained a score of 90%, suggesting that the content presented is scientifically accurate. The relevance and integration aspect achieved a perfect score of 100%, showing that the material is highly relevant to the learning objectives and well-integrated with the school’s curriculum. Thus, the usefulness aspect also reached 100%, this indicates that the learning material provides substantial benefits for students in understanding and applying the concepts learned.

The revisions of the material aspect, based on suggestions and comments from the material expert validator, included the addition of QR codes linking to source material and the answers to quiz questions on the mitigation simulation cards. Several illustrations were also improved to better reflect real-life conditions, such as (1) making the image of fish mortality appear more natural, (2) enhancing the depiction of strong winds to look more realistic, and (3) adding initials or disaster-related clues on the natural sign cards.

Table 6. Student’s practicality results

Aspect	Maximum score	Score achieved	Percentage	Category
Interest in board game	30	27.9	93%	Very good
Understanding the material	30	27	90%	Very good
Display	30	28.2	94%	Very good
Total			92.33%	Very good

Based on Table 6, the results of the student’s practicality obtained result 93% of interest in board game aspect, 90% in understanding the material aspect, and 94% in display aspect. Thus, the practicality results show the percentage of readability product is 92,33% categorized as very good. The functional addition of board game emphasizes students’ ability to recognize disaster indicators through animal and plant behaviors. This feature enhances environmental awareness and decision-making skills, making the learning process more interactive and contextual. Some comments and suggestion from students are as follow.

“I really enjoy learning with the disaster mitigation board game because it’s fun and expand my knowledge about natural signs. However, some explanations feel too brief, so adding clearer examples or visuals would help us understand better.” #students1

“Some cards could include more detailed information about natural signs and adding some explanations or illustration on the cards would make the learning more effective. However, the game broadens our knowledge and is quite challenging for us.” #students2

“Learning through the game was exciting, especially because the challenges made us curious and deepened our understanding, particularly about biological concepts.” #students3

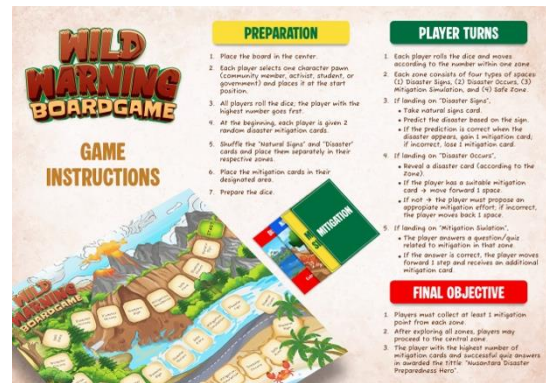
“The rules were a bit confusing at first, so clearer instructions or a short tutorial for students before playing would improve the experience.” #students4

Following the stages of media validation, material validation, and practicality testing, the board game learning media was refined based on the feedback and results obtained from the validation and practicality evaluations. The final product of the board game consisted of several components that showed in [Table 7](#).

Table 7. Final product of the boardgame

Elements	Revised design
Game board	 <p>The board game board is titled "WILD WARNING BOARDGAME". It features a central path winding through a landscape with mountains, a volcano, a river, and a beach. The path is divided into various zones: "Safe Zone", "Disaster Occurs", "Disaster Sign", "Mitigation Simulation", and "Disaster Sign". A "START" button is located at the top right, and a "Central Zone" is marked on the beach. A lighthouse is visible on the left side of the board.</p>
Challenge cards (1) Mitigation cards	 <p>Two green "MITIGATION" cards. The first card lists two points: 1. Immediately move away from the coast and avoid activities in coastal areas. 2. Educated coastal communities to recognize animal behavior as a "Non-technological early warning system". The second card states: "Communities are prohibited from conducting activities such as grass harvesting and mining near the mountain warning system".</p>
(2) Mitigation simulations cards	 <p>Two yellow "MITIGATION SIMULATION" cards. The first card discusses the study of signs and sign systems and includes a QR code. The second card asks "Why do wild animals descend into residential areas before a volcanic eruption occurs?" and also includes a QR code.</p>
(3) Disasters cards	 <p>Two red "DISASTER" cards. The first card shows an illustration of a house being destroyed by a fire, labeled "Forest Fire". The second card shows an illustration of a body of water with excessive algae, labeled "Eutrophication".</p>
(4) Animal and plant indicators cards	 <p>Two blue "NATURAL SIGNS" cards. The first card shows illustrations of a tiger and a bird, representing animal indicators. The second card shows illustrations of a bird and a fish, representing plant and animal indicators.</p>

(5) Rules paper



(6) Player roles



(7) Box



3.4 Implementation

The implementation stage was conducted through a limited trial involving 21 students from one class of two class 10th grade at MA Annur Bululawang. This trial represents an initial evaluation of the developed media in an authentic classroom setting. During the implementation, students participated in both pretest and posttest assessments to evaluate their problem-solving skills before and after using the disaster mitigation board game. The results indicated an improvement in students' problem-solving skill across all indicators based on Greenstein (2012), which include (1) identifying and defining problems, (2) generating solutions, (3) evaluating and selecting solutions, and (4) implementing solutions.

3.5 Evaluation

The developed disaster mitigation board game integrating animal and plant behavioral indicators was declared feasible after validation and practicality test and subsequently implemented in a limited trial to evaluate its effectiveness in enhancing students' problem-solving skills. The effectiveness was measured through written pre-test and post-test assessment based on Greenstein (2012). The results showed a significant improvement in students' problem-solving skill after using the board game (Table 8). The detailed results of the problem-solving skills test are presented in Table 9.

Table 8 indicates that the average score of problem-solving skill indicators increased. The highest improvement was found in identifying and defining problems (83%), followed by generating solutions (67%). Table 9 shows the results of the N Gain value analysis $\langle g \rangle$ is 0.704, it is mean that the score in limited trial was highly effective. Students demonstrated greater accuracy and creativity in identifying natural warning signs through animal and plant behaviors, as well as enhanced reasoning when formulating

appropriate disaster response actions. The findings indicating that the integration of animal and plant behavioral indicators effectively supported the development of problem-solving skills in disaster mitigation learning. Thus, the products' effectiveness is shown on the results by comparing the pretest and posttest results if the students during the limited trial process. The test is carried out with paired sample t-test with statistical analysis software. The normality and homogeneity test result of pretest and posttest are shown in [Table 10](#), thus the result of problem-solving skill is shown in [Table 11](#).

Table 8. Student's problem-solving skills test each indicator

Indicator	Pretest	Posttest	Improvement
Identifying and defining problems	52,38	91,67	83%
Generating solutions	45,24	82,14	67%
Evaluating and selecting solutions	41,67	67,86	45%
Implementing solutions	40,48	67,86	46%

Table 9. Student's problem-solving skills test

Test	Assessment Average Result	N Gain Value	Category
Pretest	47.43	0.704	High effectiveness
Posttest	84.48		

Table 10. Normality and homogeneity test

Test	Normality	Homogeneity
Pretest	0.050	0.295
Posttest	0.267	0.200

Table 11. Paired sample t-test result

t	df	Sig. (2-tailed)	Cohen's d
-12.131	20	<0.001	2.65

[Table 8](#) shows that both pretest and posttest data were normally distributed ($\text{sig}>0.05$) and had homogenous variances ($\text{sig}>0.05$), therefore a paired sample t-test was conducted to determine the effectiveness of the learning media developed. [Table 9](#) shows a significance of 0.001 ($\text{sig}<0.05$) and Cohen's d of 2.65 it is show that the development of board game integrated animal and plant behavioral had effect to students' problem-solving skills with very large effect. This result demonstrates that the learning media is not only facilitates understanding of disaster concepts but also strengthens students' ability to identify problems, generate solutions, and make decisions based on environmental cues.

The significant difference between pretest and posttest results suggests that the boardgame provides an effective, engaging, and contextualized learning media to foster students' problem-solving skill in disaster mitigation education. Before using the disaster mitigation board game, students tended to rely on theoretical explanations with limited contextual understanding of natural warning signs. After the implementation, students showed higher curiosity and active participation as they analyzed disaster indicators represented through animal and plant behaviors. This interactive learning experience encouraged critical thinking and reflection on real-life disaster scenarios, allowing students to connect biological knowledge with practical mitigation strategies.

4. Discussion

Educational games can use a storyline to engage students deeply, allowing them to learn through her narrative experience. Non digital games for education purpose involve various mechanics, shapes, elements, and size of media (Cardinot et al., 2022; Martí-Parreño et al., 2016). The effectiveness of the board game may not solely derive from its

game format, but also from interaction between visual design, contextual content, and student engagement. For instance, game layout, color contrast, and symbol representation as highly effective in supporting learning motivation (Koskinen et al., 2023). Lu and Hanim (2024) said visual and interactive media play an essential role in increasing students' engagement and comprehension. The incorporation of visual cues related to animal and plant behaviors enhanced the contextual understanding of environmental patterns (Fadilah et al., 2020), making abstract disaster concepts easier to grasp through experiential learning (Rahman et al., 2024).

The quality of the physical design, including material quality and structural strength also highlighted as an important factor, both the board game components and its storage box were also considered important aspects of product design (Samarasinghe et al., 2021). A durable and well-structured material ensures the media's longevity and practicality for repeated classroom use. A well-designed product enhances usability and sustainability in classroom setting. Validators emphasized that the physical strength of the product supports its sustainability as a learning medium, providing ease of use, safety, and aesthetic durability for learners (Ji & Lin, 2022) as more engaging compared to conventional tools. This suggest that the perceived practicality may not always directly correspond to actual learning effectiveness.

The use of relevant and validated images was considered highly supportive in improving students' conceptual understanding (Huang et al., 2022). Appropriate visual representations help clarify the meaning of scientific phenomena, bridge abstract concepts into concrete understanding, and minimize potential misconceptions among students (Wichmann & Geirhos, 2023). This finding aligns with Edelson et al. (2021), the validity of learning materials is achieved when the content accurately represents scientific concepts and relates to students' daily experiences. Following the validation process, several improvements were made to the media, particularly in refining clarity of visual representations and strengthening the alignment between natural behavioral indicators and disaster contexts.

The integration of natural behavioral signs and corresponding images into the game not only enriches biological knowledge but also encourages students to interpret environmental phenomena as early indicators of natural disasters (Demiray et al., 2025; Lin et al., 2024). Similar studies have also shown that disaster mitigation board games can effectively enhance students' understanding and preparedness. Chew et al. (2023) and Rahman et al. (2024) found that the disaster mitigation board game increased students' awareness and understanding of disaster response strategies through experiential learning. Interactive board games on earthquake and flood mitigation successfully improved students' conceptual comprehension and collaborative problem-solving skills (Robinson et al., 2021; Tsai et al., 2021). These findings support the validity of integrating behavioral and environmental indicators into learning materials to promote active engagement and deeper understanding of disaster mitigation concepts. Visual clarity and contextual alignment were made to contributed better student comprehension. It is important to consider that the improved outcomes may also be influenced by instructional guidance provided during implementation phase, not solely by media itself.

Learning media should be user-friendly and capable of stimulating students' curiosity and participation (Navas, 2025). The game provided a fun and challenging learning experience while deepening their understanding of natural warning signs (Kuo et al., 2023). Students response on the developed media indicate that the board game successfully creates a meaningful and enjoyable learning environment (Chen et al., 2021; Samarasinghe et al., 2021). The integration of real-life disaster indicators through animal and plant behaviors enables students to connect scientific concepts with authentic contexts (Appiah-Adjei et al., 2025; King & Henderson, 2018), thus improving their comprehension and retention. However, the novelty of this media lies in its incorporation of biological early warning indicators, specifically animal and plant behavioral responses into a disaster mitigation board game. This approach provides a contextual and accessible form of disaster education, particularly in areas with limited access to advanced

technology. The media facilitates students' preparedness by training them to recognize natural early warning signs and respond appropriately to potential disaster risks (Wu et al., 2023). Gamification and interactive learning environments enhance motivation and conceptual engagement by increasing emotional involvement and curiosity (Hellín et al., 2023; Tu & Lee, 2025). Game-based learning fosters active participation and cognitive immersion (Adipat et al., 2021), allowing students to learn through challenge (Bado, 2022), feedback (All et al., 2021), and exploration (Kuo et al., 2023).

Board game effectively facilitates conceptual understanding and skill development (Radzi et al., 2020; Yonwilad et al., 2025). A high N-gain value indicates that the instructional intervention successfully enhances students' learning outcomes compared to their initial knowledge (Sari et al., 2025). The improvement was evident in across all indicators of problem-solving skill, with the most significant gains observed in identifying and defining problem and generating solutions, while relatively lower improvements were found in evaluating and selecting solutions and implementing solutions. The significant increase in identifying and defining problems indicates that the board game helps students recognize and interpret disaster-related cues. Through repeated exposure to contextual scenarios involving biological indicators students become more sensitive to early warning signs and better able to formulate problem statements accurately. Well-designed educational games can foster situated learning (Ge & Ifenthaler, 2018), where students apply knowledge in contextually rich environments that mirror real-life problem situations (Appiah-Adjei et al., 2025). Assapun and Thummaphan (2023) and Chen et al. (2021) found that interactive game-based learning enhances cognitive engagement, analytical reasoning, and decision-making abilities. Likewise, the improvement in generating solutions shows that the board game encourages students to propose diverse mitigation strategies and think creatively. As educational tool the board game based on ecological content help to foster critical thinking through the development of a winning strategy in game (Martindale et al., 2024). Students learned to connect biological concepts such as animal migration, leaf closure, or unusual plant blooming with natural disaster cues, thus strengthening their reasoning and adaptive response skills.

Integrating animal and plant behavioral indicators provides a distinctive cognitive benefit because it requires students to interpret dynamic environmental data and infer causal relationships between living organisms and natural phenomena (SP et al., 2024). Tawfik and Gatewood (2022) argued that problem-solving skills are strengthened when learners engage in authentic, ill-structured problems that demand the application of scientific reasoning. The contextual and inquiry-based nature of this board game encourages players to observe, hypothesize, test, and reflect key cognitive stages in developing higher-order thinking (Booker & Mitchell, 2021). Educational games promoting scientific literacy and environmental awareness enhance learners' motivation and long-term conceptual retention (Sun et al., 2025). The significant difference found in the test results suggests that the integration of animal and plant behavioral indicators in a disaster mitigation board game provides not only cognitive enrichment but also ecological and contextual learning benefits. The students' exposure to realistic natural signs trained their ability to link biological phenomena with disaster mitigation strategies, fostering scientific reasoning, environmental awareness, and collaborative problem-solving (Rahman et al., 2024). While findings indicate that the board game has significant potential in enhancing problem-solving skills, the effectiveness of the media could be influenced by multiple interacting factors. Future research is needed to compare this with other instructional methods and examine long-term impact.

5. Conclusion

The disaster mitigation board game integrating animal and plant behavioral indicators was declared valid, practical, and effective as an innovative learning media. This findings is indicate that the developed product is feasible for classroom implementation and has a significant potential to enhance students' problem-solving skills in disaster mitigation topic. This suggests that integrating biological behavioral

indicators into game-based learning can support meaningful understanding and skill development. The implementation was conducted on a limited sample size and within a specific educational context, which may affect the generalizability of the findings. This study only focused on short-term learning outcomes, without examining long-term retention. Future research is recommended to involve a broader population, explore long-term impacts, and develop digital or hybrid versions of the board game to improve accessibility and engagement.

Funding statement

This research received internal funding in Universitas Negeri Malang scheme early youth lecturer research by contract number 24.2.247/UN32.14.1/LT/2025.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

CRediT authorship contribution statement

A. Wibowo: conceptualization, supervision, writing original draft, and writing-review & editing. **E. Fitriana:** resources instrumentation, writing original draft, and writing-review & editing. **D. A. Anggarani:** conceptualization, collecting data, data analysis, and revision. **A. Daniarsih:** methodology, writing original draft, and writing-review & editing. **M. D. Novaldi:** developing and revision the media, writing original draft, and writing-review & editing., **H. Sa'diyah:** project administration, writing original draft, and writing-review & editing. **N. Kusmahardika:** conceptualization, writing original draft, and writing-review & editing.

Declaration of the use of AI

The authors used Open AI's ChatGPT to review and enhance the clarity of the writing. After using ChatGPT, the author reviewed and edited the content as needed and took full responsibility for the publication's content.

Data availability statement

The data that support the findings of this study are available on request from the corresponding author, [initials, AW]. The data which contain information that could compromise the privacy of research participants are not publicly available due to certain restrictions.

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