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Development of Gamification-Based Learning Media on Environmental Change Topics for Senior High School Students

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Abstract: This study aims to develop a gamification-based learning medium and to examine the feasibility of its use in teaching environmental change topics for senior high school students. A quantitative approach was applied using the Research and Development (R&D) method with the ADDIE model, which consists of the analysis, design, development, implementation, and evaluation stages. The research subjects were 35 tenth-grade students of SMA Negeri 3 Banda Aceh. The research instruments included validation sheets completed by media and subject-matter experts, as well as a student response questionnaire using a Likert scale ranging from 1 to 5. The validation results indicated that the developed media achieved a very high level of feasibility, with a score of 98.9% from the media expert (excellent category) and 86.4% from the material expert (very valid category). The student trial results showed scores of 91.43% for learnability, 88.00% for efficiency, 86.71% for interaction, 80.38% for errors, and 83.43% for satisfaction, all of which fell into the excellent category. In addition, content feasibility reached 90%, language feasibility 90%, presentation feasibility 88.46%, and graphic feasibility 91.57%, resulting in an overall feasibility score of 84.78% in the very feasible category. The average score of students' test answers within the application reached 91.09. Therefore, the gamification-based media *Savior of the Earth* is considered feasible as an interactive learning tool for environmental change material.

Keywords: Environmental change; Gamification; Learning media

Introduction

Education at all levels primary, secondary, and higher inevitably involves thinking processes. These thinking abilities are influenced by various factors, one of which is individual cognitive skills. In the context of developing human resources in Indonesia, graduates from schools to universities are not only required to possess vocational skills, but also strong thinking abilities so that they can contribute as a productive and innovative generation. However, in practice, the learning process often does not provide sufficient opportunities for students to understand the phenomena they encounter in everyday life (Erna Muliastrini et al., 2019). Students are also still rarely active in asking questions or expressing opinions during the learning process (Juriah & Zulfiani, 2019). This condition makes it difficult for them to connect their existing knowledge with the subject matter being studied (Putri et al., 2014). This situation is becoming increasingly apparent in learning related to environmental change, which is currently an urgent issue. Climate change, pollution, and the loss of biodiversity are global challenges that require a good understanding from the younger generation so that they are able to make responsible decisions and actions.

Biology, as one of the subjects in senior high school, examines various life phenomena, including environmental change. Biology learning will be more effective when presented through enjoyable methods, encouraging active participation and stimulating students to think, making the material easier to understand. The development of today's education system also encourages changes in teaching strategies and the use of learning media. The approach that was previously teacher-centered has gradually shifted toward a student-centered approach. Teachers no longer act as the sole source of information, but as facilitators, mediators, and companions who create a conducive learning environment for knowledge construction. However, the shift from teacher-centered to student-

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centered learning has not yet fully occurred, as students rarely ask questions or express opinions during the learning process. As a result, learning is still focused on the teacher as the main source of information, which does not optimally support the development of students' abilities. In fact, students are inherently creative and innovative, and this potential must be fully developed through the learning process(Juriah & Zulfiani, 2019).

In education, innovative approaches are needed to attract students' attention and increase their learning motivation. The appropriate use of learning media can help students understand learning materials more easily. Learning media are tools, methods, or facilities used in the learning process to help deliver information or instructional content effectively. According to (Septiani et al., 2024), learning media function as a bridge between teachers and students in the learning process, allowing the material to be received in a more accessible, engaging, and interactive way. Such media may include visual, audio, or multimedia forms that combine various modes of communication.

Before designing the development of learning needed in the field, it is essential to conduct a needs analysis. A needs analysis helps evaluate existing programs, and if deficiencies are found, it can serve as a basis for determining what students require and introducing relevant changes. In the context of the Merdeka Curriculum, some of the demands placed on teachers include acting as facilitators, mastering appropriate technology, and delivering material in a structured manner using technology. In addition, the implementation of the Merdeka Curriculum emphasizes the integration of the Pancasila Student Profile, which includes values such as devotion to God Almighty, diversity, mutual cooperation, independence, critical reasoning, and creativity.

Under the Merdeka Curriculum, the education system is expected to produce students with critical, creative, and innovative thinking skills, as well as communication and collaboration competencies. In addition, skills in searching, managing, and presenting information, as well as the ability to use technology, are highly needed (Hidayati & Wijayanto, 2024). To achieve this, the use of technology in the teaching and learning process is essential so that learning becomes more engaging and effective. Teachers need to adjust their strategies and teaching methods to the characteristics of 21st-century learners, who rely heavily on technology, especially the internet, to support learning.

The material analysis shows that: (1) environmental change material includes spatial concepts that affect life; (2) the material is informative in nature, thus requiring attractive learning media such as games or visualizations in the form of images, tables, and videos to make it easier to understand; (3) environmental change material discusses environmental pollution, environmental change data, its causes and impacts on life, and the formulation of solutions to environmental problems in the surrounding environment.

A survey involving biology teachers and 30 students revealed that 60% of students still find this material difficult and less interesting, due to textbooks that lack illustrations and incomplete content. As a result, the teaching and learning process becomes slow, and the teacher has to repeat the material. To overcome this problem, more attractive and comprehensive learning media or resources are required.

Student characteristics, especially visual learning styles, are an important factor to consider. Based on interviews, students tend to have a visual learning style, meaning they understand material more easily through visual elements such as images, videos, and graphics. Therefore, learning media that match this learning style are needed to support the learning process. Currently, biology teaching methods are still dominated by lectures assisted by videos and PowerPoint presentations. Gamification-based learning has never been implemented. Therefore, the development of more interactive and supportive learning media is necessary.

The needs analysis indicates that 80.4% of students are interested in visual learning media in the form of an application that includes videos, materials, questions, and images in an integrated, attractive, and easily accessible format. Most students are also more interested in learning through applications equipped with game elements, making learning more enjoyable and the material easier to understand.

Based on these findings, the survey results show that the majority of students have a visual learning style and are more interested in interactive application-based learning media that include videos, materials, questions, and images. The current teaching method is still dominated by lectures supported by videos and PowerPoint. Therefore, it is necessary to develop more interactive learning media that are aligned with students' characteristics.

One medium that has proven to be effective is gamification. Gamification integrates game elements into the learning context to create an enjoyable and interactive learning experience. By using gamification-based media, students are expected to more easily understand scientific concepts and their impact on the environment.

Previous studies have shown that gamification can improve student engagement and learning outcomes across various subjects, including science (Lutfi et al., 2021). However, studies that specifically examine the use of gamification-based media in environmental change topics are still limited. Therefore, this study aims to investigate how gamification-based learning media on environmental change can influence students'

understanding and awareness of the environmental issues they face.

This study emphasizes that gamification does not mean developing an actual game, but rather developing a special medium to apply the concept of gamification more effectively. The use of game-based learning applications is intended to encourage students to solve problems in specific subjects through completing exercises and simulations contained in the application. Therefore, this gamification-based learning media is expected to facilitate students' understanding of the learning material, especially on the topic of environmental change. Thus, this study is expected not only to contribute to the development of effective learning strategies, but also to increase environmental awareness among students, enabling them to become agents of change within society.

Method

This study employed a quantitative approach to analyze data objectively through numerical measurement. The data were obtained using standardized instruments and were statistically processed to produce measurable and generalizable findings. The type of research used was Research and Development (R&D) with the ADDIE development model (Analysis, Design, Development, Implementation, Evaluation) as proposed by (Lee & Owens, 2004) in (Shelton & Saltsman, 2006).

The study was conducted at SMA Negeri 3 Banda Aceh, located in Banda Aceh City, Aceh Province. The research took place in the second semester of the 2024/2025 academic year, from March to June 2025. The research sample was selected using purposive sampling, consisting of a subject-matter expert and a learning media expert who are lecturers from Syiah Kuala University, as well as students of class X IPA 2 at SMA Negeri 3 Banda Aceh, totaling 35 students.

Data were collected using questionnaires. The questionnaires in this study aimed to measure user experience based on Nielsen's (1993) five usability indicators: learnability, efficiency, memorability, errors, and satisfaction. These were completed by the media expert, the subject-matter expert, and the students as a basis for evaluating the quality and usability of the media. Furthermore, the quantitative data obtained from the evaluation questionnaires were analyzed using descriptive analysis techniques. The results of the descriptive analysis can be presented in the form of tables, graphs, or charts (line, bar, or pie charts).

In this study, data collection was carried out through a questionnaire technique focusing on testing the validity of the gamification-based learning media. The instruments used included a material validation assessment sheet, a media validation assessment sheet, and a student trial questionnaire. The material validation questionnaire was developed based on guidelines from the National Education Standards Agency (Badan et al., 2012), while the media validation questionnaire was designed to measure the usability of the media based on five main aspects of usability according to Nielsen et al. (1993).

Result and Discussion

Development of Gamification Based Learning Media

The learning media developed in this study is a gamification-based learning medium named "*Savior of the Earth.*" This medium was designed by integrating a web platform and an application into a single, flexible, and easily accessible system. The learning media can be used anytime and anywhere through various digital devices without the need for downloading, and it can still be operated under offline conditions. The media contains learning content on environmental change, integrated with eight gamification elements: challenges, points, content unlocking, badges, game rules, levels, tasks, and time limits.

The learning media includes several menus, such as learning objectives, interactive materials, challenge-based games, quizzes, evaluation tasks, and learning reflection. Students can directly participate in challenges, answer questions, and submit assignments through this platform. The following is a detailed description of the gamification-based learning media used in this study.

1) Opening Page

The opening page of the learning media was designed with an interactive and user-friendly interface. On this page, students are required to enter three main identities name, class, and school before starting the learning process. This display aims to create a personalized experience so that students feel involved as part of the educational game they are undertaking. The "Start" button serves as the gateway to the learning content, which will then guide students to explore various educational features in a gamified format. The appearance of the opening page is shown in Figure 1.

Figure 1. Opening Display of the Gamification-Based Learning Media

2) Main Page

The main page serves as the primary adventure map and acts as the central navigation hub within the learning media. This interface is designed in the form of an exploration map, illustrating a journey across educational islands, thereby strengthening the elements of gamification and adventure in the learning process. On this page, students will find various main features represented by icons and signboards located at different points on the map, as shown in Figure 2.

Figure 2. Main Page Display

On this page, several menus are available, including, 1) Information, which provides a general explanation of the learning media and the learning objectives. 2) Profile, which displays user information such as name, class, and school that have been previously entered. 3) Settings, which provides technical sound settings. 4) FYI (For Your Information), which presents additional information, unique facts, and scientific knowledge related to environmental issues. 5) Start, the main menu for accessing the core learning activities related to environmental change. In addition, this section also includes a game that contains quiz questions that must be solved. 6) Reflection, which is used to record students' understanding and difficulties after completing the learning activities. 7) Evaluation, which contains assessment questions to measure students' final understanding independently. 8) Developer Profile, which contains information about the individual who developed this gamification-based learning media. 9) Exit, which is used to close the application or return to the initial page.

The map design provides an immersive and interactive learning experience, where students feel as if they are exploring a world full of challenges while learning. Visual elements such as mountains, forests, oceans, ships, and lighthouses reinforce the thematic atmosphere of "savior of the Earth," which becomes the main mission in this learning media.

3) Material Display

The learning material in this media presents the topic of environmental change, which is part of the Grade X senior high school curriculum. The selection of this material is based on the results of the needs analysis. Therefore, the material is presented in a visual and narrative form through an attractive combination of images and text, as shown in Figure 3.

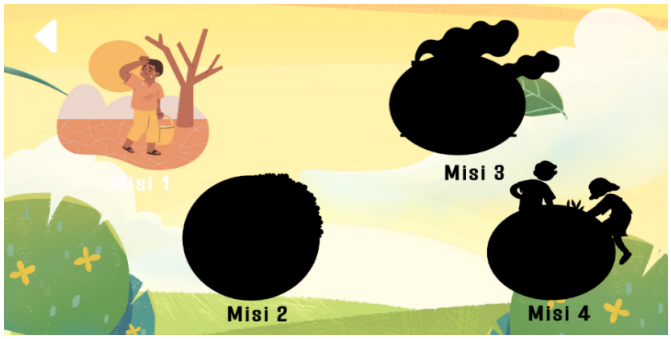

Figure 3. Material Menu Display

In the material menu, students are unable to access the next level until they successfully complete the available missions, ensuring that the learning process takes place in a gradual and structured manner. Each section of the material is accompanied by challenges in the form of interactive quizzes that must be completed before moving on to the next stage. The display of the material menu on each mission can be seen in Figures 4, 5, 6, and 7.

Figure 4. Material Menu and Quiz for Mission 1

Figure 5. Material Menu and Quiz for Mission 2

Figure 6. Material Menu and Quiz for Mission 3

Figure 7. Material Menu and Quiz for Mission 4

The material and quiz menus in this media are designed using a sequential, mission-based approach that must be completed by students in order. The content is visualized in an engaging way to increase students' attention and learning interest in the topic of environmental change.

4) Test Menu Display

One of the important features in this learning media is the test menu, which functions as a learning evaluation tool. This menu can be accessed after students have completed all learning challenges. The first screen that appears is a final motivational page that welcomes students with an appreciative message, and in order to access the test, students are required to enter a password as a form of validation. For more details, this can be seen in Figure 8.

Figure 8. Initial Page of the Test Menu

The password on the test menu is designed to prevent students from committing academic dishonesty by viewing the test questions in advance. After entering the correct password, students are directed to the test regulations page, which contains the technical guidelines for completing the assessment through the application. This page ensures that students understand the procedures and rules before starting the test, so the evaluation process can be carried out in an orderly and fair manner.

Figure 9. Test Question Page

Upon entering the test stage, students will see a question page display equipped with a timer in the upper corner as a reminder of the remaining working time. There are four answer choices that assess students' ability to interpret data, evaluate scientific information, and draw evidence-based conclusions. In addition, a question navigation panel is located on the right side of the screen, allowing students to jump to a specific question number. The "Previous Question" and "Next Question" buttons are provided to move between questions sequentially. The "Submit Test" button must be clicked after all questions have been answered. The students' scores will be displayed immediately after they complete the test.

Validation and Trial of Gamified Learning Media

The media expert validator provided an assessment based on five usability aspects: learnability, efficiency, ease of interaction, error tolerance, and user satisfaction. The results of the media expert's evaluation are presented in Table 1.

Table 1. Media Validation Results

Aspect	Number of Statements	Number of Questionnaire Scores	Highest Score	Peecentage for Each Aspect	Grade	Adjective Rating
Learnability	4	19	20	95%	A	Excellent
Efficiency	4	20	20	100%	A	Excellent
Kemudahan Interaksi	4	20	20	100%	A	Excellent
Errors	3	15	15	100%	A	Excellent
Satisfaction	4	20	20	100%	A	Excellent
Total	19	94	95	98,9%	A	Excellent

Based on the data in Table 1, the learning media obtained an overall score of 94 out of a maximum of 95, with a validity percentage of 98.9%. All aspects received a "very valid" rating. This indicates that the media has excellent quality in terms of ease of use, navigation efficiency, user interaction, error tolerance, and user satisfaction. Next, subject matter experts conducted assessments based on four main aspects, namely content suitability, language, presentation, and graphics. The assessment results can be seen in Table 2.

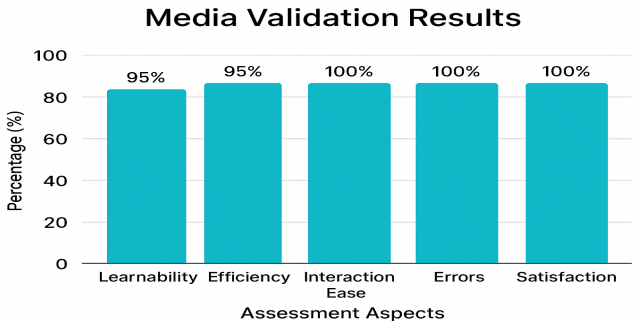

Figure 10. Media Validation Results Diagram

Table 2. Material Validation Results

Aspect	Number of Statements	Number of Questionnaire Scores	Highest Score	Peecentage for Each Aspect	Qualification
Content suitability	6	25	30	83,3%	Valid
Language suitability	7	30	35	85,7%	Highly Valid
Presentation suitability	5	22	25	88%	Highly Valid
Graphic suitability	4	18	20	90%	Highly Valid
Amount	22	95	110	86.4%	Highly Valid

The assessment results show that the learning media obtained a total score of 95 out of a maximum score of 110, with an average validity percentage of 86.4%. The content aspect was categorized as valid, while the other three aspects, namely language, presentation, and graphics, were categorized as highly valid. Based on the overall validation results, the learning media is declared highly valid for use as a supporting medium in improving the science literacy of high school students on the subject of environmental change. For more details, see the Figure 11. The gamification-based learning media was then tested on students. The media testing phase was conducted as an effort to determine the feasibility of gamification-based learning media from the user's perspective. The results of the students' assessment of the learning media are presented in detail in Table 3.

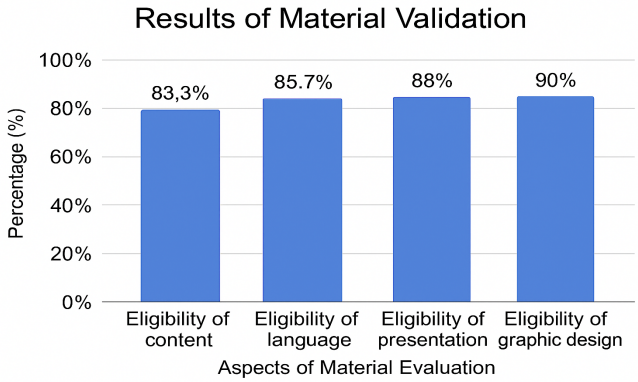

Figure 11. Material Validation Results Diagram

Table 3. Results of the Media Feasibility Test

Aspect	Number of Statements	Number of Questionnaire Scores	Highest Score	Peecentage for Each Aspect	Qualification	Category
Usability aspect with System Usability Scale qualification						
Learnability	4	640	700	91.43%	Excellent	Very good
Efficiency	4	616	700	88.00%	Excellent	Very good
Ease of Interaction	4	607	700	86.71%	Excellent	Very good
Errors	3	422	525	80.38%	Good	Good
Satisfaction	4	584	700	83.43%	Excellent	Very good
Aspects of BNSP with Akbar qualifications, 2013						
Content suitability	6	945	1.050	90.00%	Highly Recommended	High Quality Material
Language suitability	7	1.109	1.225	90.53%	Highly Recommended	Communicative
Presentation suitability	5	774	875	88,46%	Highly Recommended	Systematic & Coherent
Graphic suitability	4	641	700	91,57%	Highly Recommended	Interesting & Consistent
Amount	41	6.338	7.475	84.78%	Highly Recommended	Ready to Use Media

The results of the learning media feasibility test were analyzed using two approaches, namely the National Education Standards Agency (BNSP) criteria referring to (Akbar, 2013) and the System Usability Scale (SUS) criteria for usability aspects. Based on the table of test results for students, the usability aspect, which consists of learnability, efficiency, ease of interaction, errors, and satisfaction, obtained a percentage above 80%. According to the SUS qualifications, the aspects of learnability (91.43%), efficiency (88.00%), ease of interaction (86.71%), and satisfaction (83.43%) were categorized as Excellent, which means that the media is very good in terms of ease of learning, speed of use, interaction, and user satisfaction. Meanwhile, the errors aspect scored 80.38%, which is still in the Good category, indicating that the media is relatively free from errors but still has minor improvement potential.

For aspects assessed based on BNSP standards, namely content suitability, language suitability, presentation suitability, and graphic suitability, all received scores above 88%. According to (Akbar, 2013) criteria, this is categorized as Very Suitable, so it can be concluded that the material, language, presentation, and graphic display of the media meet very good quality standards.

Overall, this gamification-based learning media achieved a total percentage of 84.78%, which is categorized as media ready for use in learning. This shows that the media has met the content and presentation aspects according to BNSP standards and has a level of usability that is excellent according to SUS, so it is believed to provide an effective, efficient, and enjoyable learning experience for students.

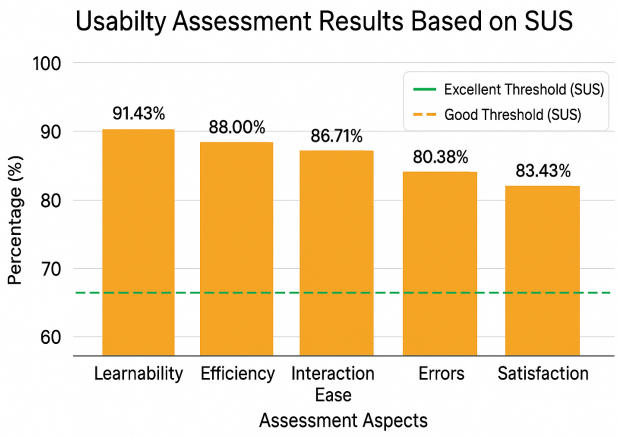

Figure 12. Diagram of Learning Media Test Analysis Results

In this study, usability was evaluated to ensure that gamified learning media were not only visually appealing, but also easy to use, efficient, and provided an enjoyable learning experience for students.

The results of the analysis show that learnability scored 91.43% and was categorized as Excellent according to the SUS interpretation. This indicates that learners can quickly learn how to use the media without requiring complicated guidance. The efficiency aspect also scored 88.00% (Excellent category), which means that learners are able to complete learning tasks quickly and effectively through this media.

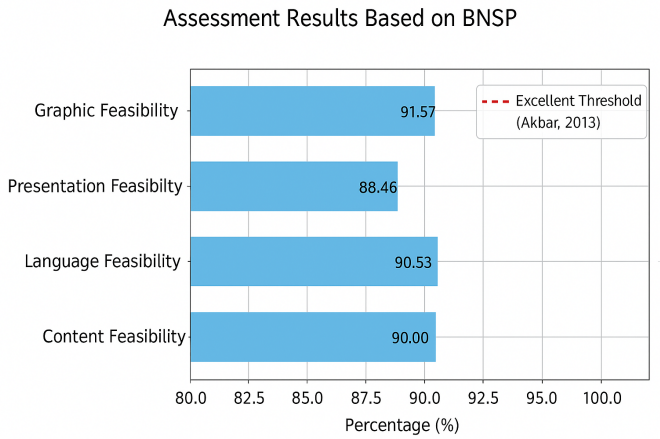

Figure 13. Diagram of Learning Media Test Analysis Results

In terms of ease of interaction, the media scored 86.71% (Excellent category), indicating that the navigation, buttons, and features within the media are easily accessible and understandable to users. The errors aspect received a score of 80.38%, which falls into the Good category. This indicates that the media is relatively free from technical errors, although there is still potential for minor improvements to minimize further errors. The satisfaction aspect received a score of 83.43% (Excellent category), indicating that users are satisfied and enjoy using the media, which can increase their motivation to learn.

The learning media developed showed very high scores in all of these aspects. The high scores in learnability and efficiency indicate that the media is easy to learn and enables users to complete tasks quickly and effectively. The errors aspect shows that the media has minimal potential for user mistakes, while the perfect score in satisfaction confirms that users feel pleased and comfortable when interacting with the media. Therefore, these results strengthen the conclusion that the gamification-based learning media developed is not only valid in terms of content, but also has usability quality that meets theoretical standards, making it feasible for implementation in learning activities to optimally support student engagement. This finding is in line with previous research stating that media with good usability can enhance learners' experiences and learning outcomes (Cowley, 2006). These results not only confirm the theoretical quality of the media's usability, but also provide a strong foundation for evaluating its impact on the learning process.

In terms of efficiency, the media helps students access learning materials quickly and in an organized

manner. The intuitive interface and simple navigation make learning time more effective. Teachers can also integrate this media into their lesson plans without requiring extensive adjustments, thus supporting the efficiency of the teaching process in the classroom. From the perspective of user satisfaction, students reported a more enjoyable learning experience. The visual elements, interactions, and challenges embedded in the media create an interactive learning atmosphere and reduce boredom. These findings support the view of (Adhari et al., 2024) that usability aspects play an important role in creating a positive learning experience.

The high scores obtained in this analysis are closely related to the students' enthusiasm when using game-based educational media. Fun interactions, interactive features, and challenges that encourage competition make the learning process more interesting and less monotonous. Gamification-based media provide students with the freedom to explore material independently while completing various educational challenges. As explained by (Byusa et al., 2022), the use of games in learning has been proven to increase learning motivation, student interaction, and conceptual understanding because students are actively and emotionally involved in the learning process.

This media also presents challenges in the form of questions or quizzes, which function as obstacles that must be overcome by students. Correct answers increase the score, while incorrect answers direct students to review the material again. This pattern encourages students to be more focused and to strive for a deeper understanding of the material. According to (Shaheen et al., 2023), effective gamification-based media can build meaningful learning experiences because it involves students in active interaction, reflection, and decision-making that leads to problem solving.

In addition, the ease of operating the application makes students feel comfortable and experience no difficulty in accessing the learning features. The application is designed with relevant gamification elements such as points, challenges, badges, time limits, game rules, and levels, and is also equipped with features that support independent learning. The use of educational game-based media has also been shown to improve learning effectiveness, especially in the context of online and blended learning(Wardoyo et al., 2020). Based on this discussion, it can be concluded that this gamification-based learning media has a good level of usability in supporting the learning process.

Furthermore, this is supported by the students' responses when answering the questions contained in the gamification media. The results of the students' answers in responding to the questions in the media are presented in Table 4.

Table 4. Students' Response Results to the Questions in the Media

Name	Class	Score
Aditiya Yudhistira	X-2	96
Azelia Giovani	X-2	96
Delisha Aisyi Rizona	X-2	96
Fadveoka Wastu Lesmana	X-2	84
Fairuz Ramadhan	X-2	96
Hasya Anabila	X-2	88
Haura Aflia Qabila	X-2	96
Haura Mazaya	X-2	96
Jusye Qobil Faiza Syah	X-2	96
Luthfia Syakira Efendi	X-2	96
Mazaya Arsi Aurindi	X-2	84
Mazaya Arsi Aurindi	X-2	92
Mira Aqilla	X-2	76
Muhammad Aufan	X-2	84
Muhammad Darrel Syahputra	X-2	96
Muhammad Joesef Aldri	X-2	96
Muhammad Khairul Nafis	X-2	84
M. Kenatra Rizki Pratama	X-2	96
Muthia Ajera Setyawan	X-2	84
Nabila Husna	X-2	96
Nadifa Reza	X-2	88
Naila Shabihah	X-2	92
Nailul Huda Ulama	X-2	92
Nazifa Qaira	X-2	92
Nazifa Qaira	X-2	96
Neisya Aira	X-2	88
Nisqika Dara	X-2	96
Niskha Dara Faiba	X-2	84
Qaisa Nabila	X-2	88
Rafania Leidy Anggraini	X-2	88
Rafka Fiky Ramadhan	X-2	92
Rafka Fiky Ramadhan	X-2	96
William Tsuraya Abdul Khoir	X-2	96
Yasmin Nurul Riyanti	X-2	88
Zahrahul Aini	X-2	84

Out of 35 participating students, 17 achieved near perfect scores close to 96, indicating very strong analytical and scientific interpretation skills. Meanwhile, only one student received the lowest score of 76. Overall, this score distribution illustrates that the implementation of questions through gamified media was effective in helping students understand environmental issues scientifically.

Conclusion

Based on the identified problems, research objectives, and the results of analysis and discussion at each stage of media development, it can be concluded that the gamification-based learning media "Savior of the Earth" was successfully developed for the topic of environmental change in the form of a digital application

that can be accessed offline via both PCs and mobile devices, integrating eight key gamification elements, namely points, levels, challenges, badges, competition, time duration, content unlocking, and game rules. The validation results indicate that the media is highly feasible, with a media expert score of 98.9% (excellent) and a subject-matter expert score of 86.4% (very valid). Furthermore, the usability trial involving Grade X students at SMAN 3 Banda Aceh showed a very good usability level with a score of 84.78%, consisting of learnability (91.43%), efficiency (88.00%), ease of interaction (86.71%), error rate (80.38%), and satisfaction (83.43%). Overall, "Savior of the Earth" is categorized as excellent—easy to use, efficient, with minimal errors, and capable of providing a meaningful and engaging learning experience—indicating that it is very well accepted by the target users.

Author Contributions
The author was responsible for all aspects of this study, including the conceptualization, research design, data collection, analysis, and the preparation of the manuscript.

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