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Development of games-based learning media "Eco Quest: guardian of the element" on the subject of climate change and global warming for class X high school

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Abstract
This study aims to develop "Eco Quest: Guardian of the Elements" as an educational tool to enhance students' understanding of climate change and global warming concepts. The learning medium utilizes a game-based learning approach to make learning physics concepts engaging and interactive. This media aims to help students grasp complex concepts and foster a greater interest in physics. The research follows a research and development (R&D) methodology, explicitly employing the ADDIE model. The study involved 35 tenth-grade high school students as participants. During the development stage, validation data was gathered from media experts, including lecturers, to assess the effectiveness of the developed media. Pretest and posttest results revealed a 23-point improvement in student comprehension, with an N-Gain score of 37%. Overall, the "Eco Quest: Guardian of the Elements" learning tool has proven effective in enhancing students' understanding of climate change and global warming concepts. However, further research is recommended to investigate the long-term effects of this medium on students' attitudes, knowledge, and behavior regarding these issues.

Keywords: genially, instructional media, game-based learning

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I. Introduction

Physics is a branch of science that explores the universe, encompassing matter, energy, and their interactions. Climate change and global warming are essential topics within physics and pertain to natural phenomena that significantly impact Earth. These issues represent two global challenges that require urgent understanding and action. Over the next thirty years, life on Earth will be affected by climate change and global warming [1]. As future generations will directly experience these effects, high school students must understand these phenomena. However, teaching this material often presents challenges, particularly in conveying complex, engaging, and easily understandable information to students.

The complexity of climate change and global warming concepts can make them difficult for students to grasp. Students develop skills to analyze natural phenomena using logical and mathematical reasoning through physics education. However, explaining intricate ideas verbally can be challenging. At the secondary education level, there is a need for engaging and effective learning media on climate change and global warming, which is the primary focus of this research. Conventional learning tools frequently need help to present complex concepts in ways that are both interactive and interesting, often resulting in limited concept mastery among

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students [2]. Mastery of fundamental concepts is critical to learning physics [3]. Students need to understand key concepts within any physics context [4], [5], as effective material delivery by teachers facilitates the development of strong physics foundations [6]. Consequently, designing innovative and engaging learning media—such as game-based learning tools—can enhance educational effectiveness.

Game-based learning has shown significant potential in science education, especially in introducing and discussing complex concepts [7]. This approach involves designing engaging, student-centered activities to meet educational objectives and enrich the learning experience [8]. Studies have shown that digital game-based learning can enhance students' motivation and academic performance, as they are more likely to retain information that sparks tremendous enthusiasm [9], [10]. Furthermore, a study by [11] indicated that implementing game-based learning improves students' comprehension and engagement with subject matter.

One medium for creating game-based learning experiences is Genially, a free, internet-based platform that enables interactive learning and accommodates visual, auditory, and kinesthetic learning modalities [12]. In this study, researchers developed a game-based learning tool called "Eco Quest: Guardian of the Elements" using Genially. This educational game, inspired by the concept of the Jumanji game, challenges students to complete various tasks related to climate change and global warming. To succeed in these tasks, students must apply their knowledge and skills, fostering a deeper understanding of complex physics concepts and enhancing their interest in physics.

Given the escalating reality and severity of climate change and global warming, this research holds significant importance. With rising incidences of natural disasters, shifting extreme climate conditions, and threats to biodiversity, it is vital for students to cultivate an awareness of environmental issues. Such knowledge will be crucial in shaping their future behavior and decision-making. This study addresses the need for more effective learning tools to educate students on environmental challenges, particularly those related to climate change and global warming.

II. Methods

This study utilizes a research and development methodology using the ADDIE model initially developed at Florida State University. Guided by constructivist theory, this model centers on the “learning process,” which includes learning content, instructional methods, and evaluation [13]. The ADDIE model applies to curricula that teach knowledge, skills, or attitudes [14]. In addition, this model supports the creation of a more effective, dynamic, and supportive learning infrastructure, thus improving the overall learning process [15]. The application of the ADDIE model is not limited to textbook development; it can also be used to design and produce course content. Therefore, this study adopts a research and development approach using the ADDIE model to develop “Eco Quest: Guardian of the Elements.”

Product Development Steps

The ADDIE model consists of five stages in creating learning media: Analysis, Design, Development, Implementation, and Evaluation. Each stage includes processes of revision and evaluation and is further divided into smaller, interconnected components. These five stages are interdependent and cannot be separated. The ADDIE model is based on the belief that learning should be student-centered, with development that incorporates innovative, authentic, and inspiring concepts [16].

1. **Analysis**
   The first stage is the Analysis stage, during which data is gathered before creating the learning media [17]. At this stage, observations are conducted in the school environment and classroom, including the learning process, learning outcomes analysis, and learning objectives related to climate change and global warming topics. Additionally, the selection of appropriate media for this material is determined.
2. **Design**
   The second stage, the Design stage, involves designing the learning media product [18]. Planning begins with identifying the necessary materials, including icons, content boundaries, questions, layout, game buttons, instructions, and learning tools such as lesson plans. Comprehensive learning tools help teachers implement the media effectively in the classroom.
3. **Development**
   The third stage is the Development stage. After the design phase, the next step is to create the product [18]. During this stage, material and media experts—lecturers or teachers—complete a questionnaire to

validate the content and suitability of the media [19]. For the learning media "Eco Quest: Guardian of the Elements," validation data was obtained exclusively from media experts, including lecturers and teachers. The learning media "Eco Quest: Guardian of the Elements" was developed using the Genially platform in Jumanji-style game mode. This media engages students with game elements, encouraging learning about climate change and global warming. The media interface consists of three main sections. The first section displays the name of the learning media, "Eco Quest: Guardian of the Elements," along with a start button, as shown in Figure 1.

Figure 1. Display of the Learning Media Name "Eco Quest: Guardian of the Element"

Instructions for playing the learning media "Eco Quest: Guardian of the Elements" are shown in Figure 2. The gameplay for "Eco Quest: Guardian of the Elements" is as follows: This game can be played individually or in groups, with each group consisting of 3-4 participants. Each group selects an animal icon to represent them in the game, and the first group to reach the center circle wins. Players click the dice on the left to roll and generate a number, then move their chosen animal along the path according to the roll. Players must answer a question correctly when landing on a space marked with a black and white circle. If they cannot answer, they may choose a help card. A correct answer keeps the icon in place; otherwise, it must move three steps back.

Figure 2. Information display on how to play the learning media "Eco Quest: Guardian of the Elements"

The appearance of the learning media "Eco Quest: Guardian of the Elements" resembles the game of Ludo, but the gameplay mechanics are different, as shown in Figure 3.

Figure 3. Display of Learning Media "Eco Quest: Guardian of the Element"

4. **Implementation**
   The fourth stage is the Implementation stage. "Eco Quest: Guardian of the Elements" was tested in a class of tenth-grade students at a private high school in Bandung City. This trial assessed students' responses before and after using the learning media [15]. During this stage, students participated in the trial, completed questionnaires [18], and answered questions. The technical implementation began with students answering 15 pretest questions and learning and playing "Eco Quest: Guardian of the Elements." Afterward, students completed 15 post-test questions and a student questionnaire.
5. **Evaluation**
   In the ADDIE research and development method, the final stage is the Evaluation stage. This phase assesses whether the developed product meets the specified requirements. The primary goal of evaluation is to measure the achievement of the development objectives [20]. This stage serves as a process for improving the research on the feasibility of the learning media that has been created. It also provides the basis for revisions, ensuring that the research and media can be refined to produce better results, making them more useful and efficient for learning.
   Typically, quantitative data analysis in this stage evaluates the product's effectiveness using pretest, posttest, and student questionnaire data sheets [21].
   The complexity of each model stage depends on the outcomes of the previous stages, which can be shortened or expanded as needed. For project-based research, it is essential to complement the instructional design process by implementing a series of repeatable steps for describing, organizing, and completing the work. The complexity of the results determines how many processes are applied at each stage.

Participants

This research was conducted at a private high school in Bandung City. Participants included media experts, physics teachers, and students. The subjects of the study were 35 tenth-grade high school students. The pretest and posttest each consisted of 15 questions on climate change and global warming. This research used feedback and suggestions from media experts, teachers, and students to make improvements, ensuring that the final product was of higher quality. Additionally, three physics teachers from Bekasi, Tasikmalaya, and Bandung provided their assessments from a teacher’s perspective by completing a questionnaire via Google Forms.

Research Instruments

To assess the quality of the learning media "Eco Quest: Guardian of the Elements," calculations will be based on statements measured numerically. This quality assessment relies on media validation results and feedback from media experts and teacher questionnaires [21]. Additionally, empirical feasibility will be evaluated based on student questionnaires regarding the learning media [22] and test questions used during the limited trial (pretest and posttest). The evaluation will be conducted using Google Forms to facilitate the process for teachers.

Three main criteria for evaluating learning media are content, software engineering, and visual communication [23]. For "Eco Quest: Guardian of the Elements," only two criteria will be used: software engineering and

visual communication. A total of 14 indicators will be assessed, starting with software engineering (ease of access, ease of use, accuracy in selecting media for development, clarity of instructions, durability of the media, appropriateness of the question sequence, and compatibility with various hardware) and visual communication (type and font size, layout design, color selection, readability of text, appropriateness of writing layout, communicativeness (alignment with the intended purpose), and creativity of ideas). In evaluating the media "Eco Quest: Guardian of the Elements," each response to the indicators will be scored using a Likert scale from 1 to 5 [24]. Information on the Likert scale used to measure these indicators is provided in Table 1.

Table 1. Likert scale description

Likert-Scale	Likert-Scale Description
5	Very good
4	Good
3	Enough
2	Not Good
1	Very Not Good

The data obtained were then analyzed using percentages. The formula used to calculate the percentage of validation results from media experts and teachers is as follows:

$$\text{Percentage of Achievement} = \frac{\text{total score obtained}}{\text{total score expected}} \times 100\%$$

Based on the calculation results, the percentage of achievement is then categorized according to Table 2.

Table 2. Percentage categories [25]

Likert-Scale	Likert-Scale Description
81 – 100	Very good
61 – 80	Good
41 – 60	Enough
21 – 40	Not Good
0 – 20	Very Not Good

The results of this data will be analyzed to describe and draw conclusions based on the 14 indicators. To provide an overview of improvements after using "Eco Quest: Guardian of the Elements" in the learning process, researchers collected pretest and posttest scores to calculate the Average Normalized Gain (N-Gain). An increase in learning outcomes is used to measure the effectiveness of the treatment or learning method in promoting understanding of the concepts [26].

The calculation of the Average Normalized Gain (N-Gain) follows the concept outlined in [27], using the equations (1) and (2).

$$\langle g \rangle = \frac{\%\ \text{Gain}}{\%\ \text{Gain}_{\max}} \tag{1}$$

$$\langle g \rangle = \frac{\%\ \text{Post test} - \%\ \text{Post test}}{100 - \%\ \text{Pre test}} \tag{2}$$

$\langle g \rangle$ is the average normalized gain, Gain is the average gain obtained, while $\text{Gain}_{\max}$ is the average maximum gain.

The Average Normalized Gains (N-Gain) category can be seen in Table 3.

Table 3. Average N-Gain Category

Average N-Gain Value	Category
$\langle g \rangle \geq 0.7$	High-g
$0.3 \leq \langle g \rangle < 0.7$	Medium-g
$\langle g \rangle < 0.3$	Low-g

III. Results and discussion

The learning media "Eco Quest: Guardian of the Elements" uses the Genially website as the game platform. The development of this learning media is based on an analysis of student needs and the characteristics of climate change and global warming material. The material on climate change and global warming in physics education has contextual characteristics that students directly experience. Additionally, this material often needs more mathematical formulas, making it tedious for teachers to present. Therefore, the learning process must be designed to be more engaging.

Digital game-based learning has long been recognized as an effective medium for educational and training purposes [28]. The primary benefit of game-based learning is that it enhances problem-solving, communication, analytical thinking, teamwork, negotiation, socio-cultural awareness, logical thinking, and critical thinking [29], [30]. The extent to which these skills are practiced depends on the design of the game and the learning objectives. One key advantage of game-based learning is the active interaction it promotes among students [31]. In the game, students are challenged to answer questions, make decisions, and think critically. They can learn from failure and continue trying until they achieve their goals.

The learning media "Eco Quest: Guardian of the Elements" has been tested with validation from media experts and teachers, using two assessment criteria identified by [32]: software engineering and visual communication.

Data from Media Expert Assessment Results

At the development stage of the learning media "Eco Quest: Guardian of the Elements," researchers gathered validation data from media experts, including lecturers, to assess the media that had been created. The assessment conducted by the media experts focused on two criteria: software engineering and visual communication. The results of the media expert evaluation are shown in Table 4.

Table 4. Media Expert Test

Aspect Assessment	Percentage	Category
Software Engineering Aspect	100%	Very Good
Visual Communication Aspect	100%	Very Good

Based on the percentage categories according to [25] in Table 4, the results of the media expert evaluation indicate that the software engineering aspect received a score of 100% (very good category), and the visual communication aspect also received a score of 100% (very good category), resulting in an average score of 100%. This places the learning media in the "very good" category.

It can be concluded that "Eco Quest: Guardian of the Elements" is very easy to access and use. The researchers were highly accurate in selecting the media for development, and the instructions provided were very clear. Since the media is digital, it is very durable and lacks physical form. Additionally, the sequence of questions is well-organized, and the media is compatible with various devices, including laptops and smartphones.

Furthermore, in developing "Eco Quest: Guardian of the Elements," the researcher made excellent choices in font type and size, layout placement of buttons, and color selection. The text is highly readable, appropriately aligned with the layout, and very communicative (in line with the intended purpose). The media is also highly creative in its design. Therefore, according to media experts, the learning media "Eco Quest: Guardian of the Elements" is very high quality and suitable for classroom learning.

Teacher Assessment Results Data

At the implementation stage, researchers obtained trial results through a teacher questionnaire that assessed the suitability of the "Eco Quest: Guardian of the Elements" media. This assessment focused on two criteria: software engineering and visual communication. The results of the teacher assessment are shown in Table 5.

Table 5. Media Validity Test (Teacher)

Aspect Assessment	Percentage	Category
Software Engineering Aspect	91%	Very Good
Visual Communication Aspect	96%	Very Good

Based on the percentage categories [25], the teacher's interpretation of the validity test scores, as seen in Table 5, shows that the software engineering aspect received a score of 91% (very good category) and the visual communication aspect received a score of 96% (very good category).

Among the 14 indicators, for the software engineering aspect, the highest score was achieved for ease of access and media durability, both at 100% (very good category), while the lowest score was for the accuracy of selecting development media, which received 80% (good category). For the visual communication aspect, the highest scores were obtained for layout design selection, color selection, suitability of the writing layout, and creativity of ideas, all at 100% (very good category). The lowest score was for the communicative aspect (suitability to the desired goal), which received 87% (very good category).

There are several suggestions for further development of the learning media. One issue noted is that moving objects within the game can be difficult on some devices because they appear very small. Therefore, it is recommended that teachers and students use laptops for optimal use of the media.

Student Questionnaire Results Data

After completing the pretest and posttest, students completed a questionnaire to provide feedback on their experience while learning through the "Eco Quest: Guardian of the Elements" media. The results of the student questionnaire are shown in Table 6.

Table 6. Student Questionnaire Results

Statement	Percentage
Liked the learning activities using QCards and the Eco Quest game	95%
With today's learning, students feel that they understand the material on climate change	84%
With today's learning, students feel that they understand the material on global warming	86%

Based on Table 6, which presents the results of the student questionnaire, it is evident that 95% of students enjoyed the concept of learning using the "Eco Quest: Guardian of the Element" media. In addition to studying, students appreciated the opportunity to play with their group of friends while learning about climate change and global warming. During the learning process, students examined the problems presented in the game and provided solutions related to them. They then answered various questions based on the technicalities of the game in "Eco Quest: Guardian of the Element." As a result, 84% of students reported understanding the climate change material, while 86% demonstrated understanding the global warming material.

Pretest and Posttest Score Results

To determine the improvement after using "Eco Quest: Guardian of the Element," the pretest and posttest scores were processed to calculate the Average Normalized Gain (N-Gain). The students' pretest and posttest results are shown in Figure 4.

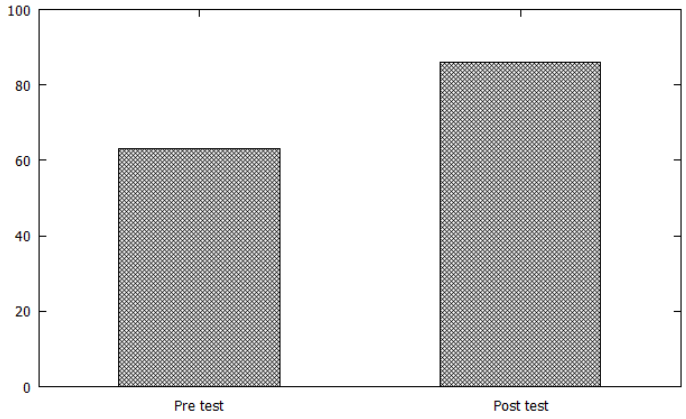

Figure 4. Pretest and Posttest Scores

According to Figure 4, the average pretest score for 35 students was 63 points, while the average posttest score was 86, reflecting a 23-point increase in the average score. Using the formula prepared by [26], an N-Gain value of 0.37 was obtained, indicating that developing the "Eco Quest: Guardian of the Element" learning media on climate change and global warming material resulted in a moderate increase. Although the N-Gain is only 0.07 higher than the low category, this represents a positive development. Based on the feedback, students are not accustomed to playing while learning, as learning and playing are often seen as separate activities. However, during the implementation of this research in the classroom, students appeared very curious, enthusiastic and engaged in the learning process.

This aligns with findings from [31], who used the snakes and ladders game in social studies learning. Their research showed that, in addition to improving students' understanding, it also significantly increased students' learning motivation, achieving a very high level of motivation. Similarly, [33] used the Genially web game media to help students enhance their writing skills. While playing, students not only improved their vocabulary knowledge but also their writing skills. Based on these findings, researchers recommend incorporating game-based learning activities into the classroom to foster greater student engagement and skill development.

IV. Conclusions

The learning media "Eco Quest: Guardian of the Element" is a digital game-based tool designed to improve students' understanding of climate change and global warming. This media has been validated by media experts, teachers, and students. The results of these validation tests show that the learning media is suitable for use in the classroom. According to the validation test from media experts, the learning media received excellent scores in software engineering and visual communication. However, some suggestions for improvement were provided, particularly regarding the ease of moving objects on specific devices. It is recommended that teachers and students use laptops for better usability.

From the student questionnaire, 95% of students enjoyed using the game for learning. Additionally, 84% of students reported understanding the material on climate change, while 86% understood the material on global warming. The pretest and posttest results indicated a 23-point improvement in student understanding, with an N-Gain value of 37%.

Overall, "Eco Quest: Guardian of the Element" effectively enhances students' understanding of climate change and global warming. While it has demonstrated effectiveness in improving students' comprehension of these topics, further research is necessary to evaluate the long-term impact of the game on students' attitudes, knowledge, and behavior related to environmental issues. Future studies could involve continued observation of students over an extended period to determine if their increased understanding persists and influences their daily behaviors.

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