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Science Learning Game (SLG) Based on Augmented Reality Enhances Science Literacy and Critical Thinking Students Skills

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Abstract: Science literacy is the ability of individuals to understand, evaluate, and apply scientific knowledge in everyday problem-solving, while critical thinking is the ability to analyze, evaluate, and make decisions based on evidence and logic. This research is based on several issues in SDN Sentul2 Kota Blitar in grade 6 post-Covid 19. This research aims to produce a product used as a learning tool in Grade 6, namely Science Learning Game (SLG) Media based on Augmented Reality to Improve Science Literacy and Critical Thinking Skills in Grade 6 Students in Kota Blitar. This research and development (R&D) study uses the ADDIE (analysis, design, development, implementation, and evaluation) model. The instrument used is a questionnaire. The research data analysis results show that the developed media can improve critical thinking skills, as evidenced by comparing the Pre-test results at 72.21% with the Post-test results at 93.57%. This media can also enhance science literacy, as indicated by the increase between the Pre-test results at 74.28% and the Post-test results at 92.14%. The implication is that the science literacy and critical thinking abilities of students in Indonesia still need improvement, which can be achieved by considering the use of instructional media. With positive results in pre-test and post-test scores, this media has the potential to enhance science literacy and critical thinking skills in students.

Keywords: Augmented Reality; Critical thinking; Science learning game; Science literacy

Introduction

Literacy encompasses the activities of reading, writing, and speaking to build, combine, and evaluate meaning (Frankel et al., 2016). This falls within the purview of school management's responsibilities because literacy can empower children to become skilled in reading, writing, understanding, reacting to, and cultivating an awareness of the favorable or detrimental consequences of contemporary information technology usage (Nurasiah et al., 2017). Therefore, this research is crucial to depict the implementation of a culture of literacy, particularly scientific literacy, in elementary schools.

Scientific literacy is the ability to use scientific knowledge in an effort to solve problems (Toharudin et al., 2011). Furthermore scientific literacy is essential for students to master, as it relates to how students can Comprehending the challenges related to an environment, public health, economics, and other aspects confronting a contemporary society heavily dependent on technology, progress, and scientific innovations is essential (Jamaluddin et al., 2019).

According to the opinion of (Nurasiah et al., 2017; Ayuningtyas et al., 2023) Someone having scientific and technological literacy is characterized by their ability to solve problems using scientific concepts acquired through education at their respective level (González-Gómez & Medvecky, 2022), understanding the technology products in their surroundings and their impacts, being able to use and maintain technology products, and being creative in creating simplified

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technological outcomes, enabling students to think critically when making decisions based on values (Derby et al., 2020).

Critical thinking is crucial for students to cultivate a mindset and skills towards a subject. Santrock (2011) also asserts thinking entails the manipulation, management, and transformation of information within memory. Critical thinking is frequently employed to create concepts, engage in reasoning and critical thought, make decisions, foster creative thinking, and address problems (Khairani & Aloysius, 2023). Through the ability to think critically, students will develop characters that align with the goals of education, especially in the current curriculum (Su & Zhong, 2022).

Based on observations of post Covid-19 learning activities in elementary schools, several methods are still being used, such as sending assignments through WhatsApp (WA), which involves completing tasks in workbook packages, leading to student boredom (Sukarmin & Sani, 2023). The learning process remains suboptimal because teachers have limited technological proficiency (Rui & Badarch, 2022). Many students rely on their parents and others because they find the tasks assigned by teachers during online sessions to be challenging and have not been adequately explained, relying solely on electronic media through smartphones (Vermeulen et al., 2017).

Similarly, in face-to-face learning, many teachers still rely heavily on lecturing methods, which leads to student boredom (Hussein et al., 2020). One-way teaching approaches result in student dissatisfaction, causing their motivation To effectively participate in the learning process, it is important to remain engaged and attentive (Fatih, 2018). Therefore, this class teacher also utilizes teaching aids/Science Kits intended for utilization. during face-to-face teaching (Yi-Ming Kao & Ruan, 2022). The school possesses these media, but media belonging to the school cannot be recycled (Brüggemann et al., 2023).

Based on the findings above, the researcher aims to develop an effective learning media, particularly for the subject of Science, specifically focusing on the solar system topic. The supporting tool in question takes the form of learning media. According to Fatih (2021) the presence of learning media can be used to stimulate students' learning enthusiasm, especially when it includes a simulation of the learning material (Leaver & Corin, 2019). Therefore, the creation of this media takes the form of interactive and innovative media by utilizing technology.

This learning media will use Augmented Reality (AR), which overlays Integrating digital layers of information into the physical environment enhances reality by superimposing computer graphics onto the real world (Wang, 2017; Billinghurst, 2002). AR is a technology that situates intricate digital content within the physical surroundings, offering students an authentic and immersive viewpoint (Hwang et al., 2016; Serio et al., 2013). The utilization of AR technology allows them to partake in genuine learning encounters and investigate the actual environment (Radkowski et al., 2015), resulting in numerous beneficial outcomes, particularly for young students (Ibáñe & Delgado-Kloos, 2018; Wu et al., 2013). The existence of augmented reality that can display real illustrations aligns with the opinion of Sari et al. (2023) where realistic learning media can facilitate the delivery of learning materials and make them easier for students to understand (Al-Asadi & Faris, 2022).

In terms of learning, AR can serve as a motivator and a tool to enhance comprehension by incorporating extra visual senses, thereby enriching the learner's real-world experience (Bujak et al., 2013; Cheng & Tsai, 2013; Ibáñe & Delgado-Kloos, 2018). It can also encompass different degrees of immersion and engagement to encourage children's active involvement in the learning process (Saadon et al., 2020). Through AR, they can actively participate in lessons and experiment with real-time visualizations (Lepouras, 2021). Observing the dynamic properties of the phenomena currently under examination can train students to think critically and enhance their literacy skills, particularly within the realm of science, through their actions (Akçayır et al., 2016).

Findings in the journal 'Computers & Education' titled "Ten years of augmented reality in education: A meta-analysis of (quasi-) experimental studies to investigate the impact" The meta-analysis clearly demonstrates that AR technology has had a positive impact on all three learning outcomes, particularly with a larger average effect size observed for performance-related outcomes (Chang et al., 2022). Furthermore, here are the findings from the meta-regression analysis indicating that treatment duration is a significant factor likely associated with the variation in the impact of AR in education. Furthermore, the use of AR according to Vari et al. (2023) to enhance language or social science learning is more likely to be linked with increased learner responses, including heightened learning motivation or improved attitudes, in contrast to AR's utilization in science education (Pelargos et al., 2017). However, unfortunately, the study has not yet identified whether augmented reality can be used to improve students' science literacy and critical thinking (Fatih, 2023a; Alyousify & Mstafa, 2022).

The previous research by Rokhman & Ahmadi (2020) titled "Pengembangan Game Edukasi si Gelis Berbasis Augmented Reality untuk Meningkatkan Kosakata Bahasa Inggris Siswa The research findings, as suggested by the title, reveal that during the evaluation

phase of this educational game, it underwent feasibility testing by two media experts and two subject matter experts. The outcome was an average feasibility score of 90.6%, signifying an excellent rating.

Additionally, this educational game has proven to be highly effective in enhancing the English vocabulary skills of second-grade students. In an application test involving 20 students, it resulted in an average improvement of 32 points in class scores. An educational game si Gelis (Genius English) An educational game. 'Genius English' can serve as a supplementary learning tool for 2nd-grade elementary school students. However, this research has also not revealed that AR can be used to enhance students' science literacy and critical thinking (Fatih, 2023a). Therefore, through this study, it is hoped to provide insights regarding AR in the field of education, specifically in terms of students' science literacy and critical thinking (Kerr & Lawson, 2020).

From the explanation provided, this research has two main objectives: to design a science learning game (SLG) based on augmented reality, with a focus on the solar system material, and to test whether the use of augmented reality-based science learning games can improve students' science literacy and critical thinking. Although some previous studies have highlighted the positive impact of implementing augmented reality in learning, unfortunately, they have not addressed the impact of augmented reality on enhancing students' critical thinking skills and scientific literacy. As a distinctive feature, this research will examine the implementation of augmented reality in science education to enhance students' critical thinking abilities and scientific literacy.

Method

The choice of utilizing the ADDIE development model in this research was determined based on the perspective that the ADDIE development model is a simple and easy procedural model for creating a product for both short-term and sustainable research. Additionally, the characteristics of the ADDIE development model, compared to other development models include the presence of two evaluations: summative evaluation (an overall evaluation at the end of the research) and formative evaluation (evaluation at each stage). The research procedure adheres to the ADDIE development model, comprising five distinct stages: analysis, design, development, implementation, and evaluation (Yulia et al., 2023).

Data collection in the field was carried out by adopting two methods, namely test and non-test approaches. The data collection approach involved testing (pre-test and post-test) to assess students' critical thinking skills when the Augmented Reality-based Science Learning Game (SLG) media was implemented for 6th-grade students in Blitar City on the topic of the solar system, with assessment aspects including basic clarifications and suppositions and integration. The test instrument was found to be valid with a calculated r_{value} of 0.747 and had instrument reliability with Cronbach's Alpha of $r_{11}(0.793) > 0.6$, which falls into the Excellent category.

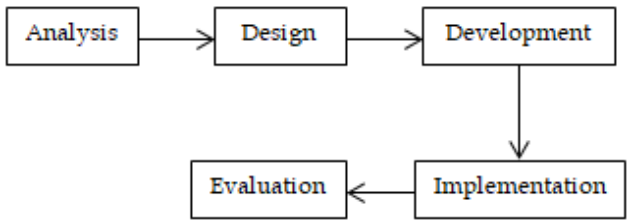

Figure 1. ADDIE Model Development Stages Chart

Non-test data collection techniques included: Interviews related to obstacles that emerged during the online learning process during the COVID-19 pandemic with 6th-grade teachers in Blitar City, and product testing conducted in 6th-grade classes in Blitar City; Questionnaires were used to assess the improvement in science literacy skills, including aspects of science attitudes such as supporting scientific inquiry, interest in science, and responsibility towards environmental resources. The validity of the science literacy instrument had an r_{value} of 0.7926, indicating validity, and the instrument's reliability had an r_{11} (0.886) > 0.6, which falls into the reliable category.

The data collection in this research employed two methods: test and non-test. The researcher used test data to measure students' critical thinking about media development as equation 1.

$$P = \frac{\sum R}{N} \times 100\% \quad (1)$$

Description:
P: Percentage Score
∑R: Sum of Answers provided by respondents
N: Total maximum score

Then, the percentage results of data analysis are interpreted into categories according to Table 1.

Table 1. Criteria for Quantitative Data

Achievement level (%)	Criteria
76-100	Very Good
51-75	Good
26-50	Fair
> 25	Very Poor

Source: (Sugiyono, 2019).

If the percentage validation result is greater than (>) 81.25%, then the product is considered very suitable according to experts. The developed product is deemed

highly suitable for use as a medium to support students' understanding in school.

Result and Discussion

Result

Results are the main part of scientific articles, containing: final results without data analysis process, hypothesis testing results. Results can be presented with tables or graphs, to clarify the results verbally. This research has resulted in a product, which is an Android Grade 6 elementary school Science Game Learning (SLG) media based on Augmented Reality, focusing on the topic of the Solar System. This media aligns with the curriculum for the second semester of Grade 6th Science according to the 2013 curriculum, following the ADDIE research and development design.

Analysis

In the initial phase of the ADDIE model, the field analysis stage involved gathering information about the learning environment in the 6th-grade class at SDN Sentul 2, Blitar City. This information was obtained through observations and interviews with the teachers. The research outcomes highlighted several crucial observations: the learning process took place in an online format, emphasizing theoretical instruction predominantly; the instructional materials exhibited limited diversity; there was a demand for easily accessible learning resources among students; and a deficiency was identified in appropriate instructional media for online learning, particularly in the field of Science. This gap was particularly noticeable when focusing on the solar system curriculum for 6th-grade students at SDN Sentul 2 in Blitar City.

Design

The design stage is a phase of instructional media design, which includes formulating the objectives for creating instructional media according to students' needs, creating a storyboard as an initial design for the instructional media, collecting design elements in line with the content found in the instructional media, and developing instruments to assess the validity and suitability of the instructional media.

Development

The media development process involves the stage of product creation. In the product creation phase, all components such as content, assessments, images, videos, and music were assembled to create an Android-based Science Learning Game (SLG) Media using the Kahoot application. The instructional media design aligned with the previously designed storyboard. The design output was exported as a file extension, making it convenient for the execution of the instructional media. The appearance of the Augmented Reality-based Science Learning Game (SLG) can be seen in figures 2-4.

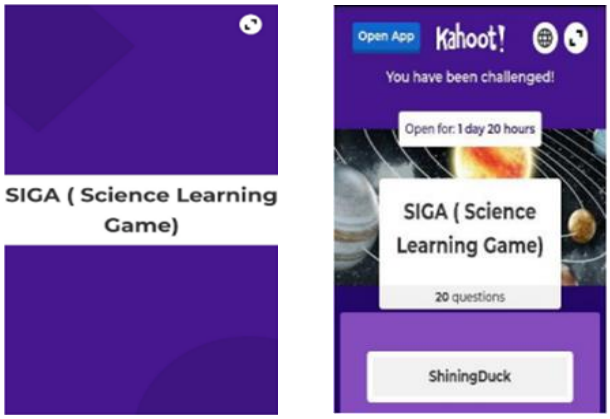

Figure 2. Intro SLG

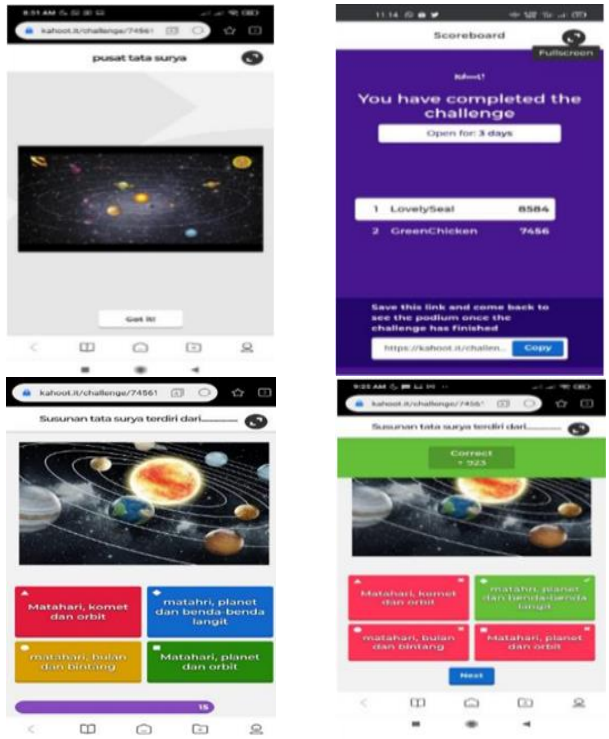

Figure 3. SLG content display

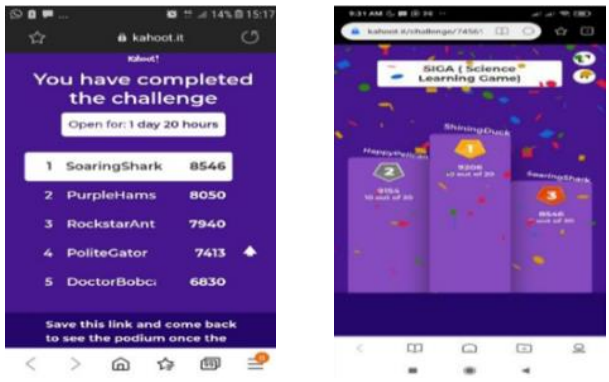

Figure 4. SLG end cover display

Implementation

In the implementation stage of the "SLG" instructional media that had been developed, it was introduced to the 6th-grade students at SDN Sentul 2, Blitar City, on June 19, 2023. The media testing was conducted online, allowing students to use the media independently from their homes. Before starting, a Kahoot instructional media link was distributed to the students within the 6th-grade class group at SDN Sentul 2, Blitar City.

The researcher demonstrated the instructional media to the class group with the permission of the homeroom teacher. Before playing the instructional media game, students were given instructions on how to use it. Afterward, students were encouraged to utilize the instructional media and attempt the assessments embedded within it. Subsequently, students were asked to complete a respondent questionnaire consisting of 10 statements to provide feedback on their learning experience using the "SLG" instructional media. The purpose of this media development testing was to assess the validity and suitability of the "SLG" instructional media.

The results of the students' critical thinking ability were assessed with 28 respondents and 10 questions, using two phases consisting of a Pre-Test before using the media and a Post-Test. The Pre-Test results showed that the total score obtained by students was 205, while the expected score was 280. Therefore, the analysis before using the instructional media yielded 73.21%, categorized as Fairly Good. Subsequently, the Post-Test total score was 262, compared to the expected score of 280. As a result, the data analysis after using the instructional media showed a score of 93.57%, categorized as Very Good.

Following the Pre-Test and Post-Test results, a normality test was conducted using the Kolmogorov-Smirnov test, with a significance value of Sig. > 0.05, indicating that the residuals were normally distributed (Sugiyono & Susanto, 2015). The result of the normality test showed Sig. (0.200) > 0.05, leading to the conclusion that the residual values were normally distributed.

The students' science literacy response was assessed using two phases: a questionnaire before using the media and a questionnaire after using the media, with 28 respondents. The results of the student responses before using the media showed a total score of 208, compared to the expected score of 280. Therefore, the analysis before using the instructional media resulted in 74.28%, categorized as Fairly Good. Furthermore, based on the Pre-Test assessment results of the respondents with a total score of 258, compared to the expected score of 280, the analysis of the instructional media's suitability yielded 92.14%, categorized as Very Good.

The graph showing the results of the implementation of the media on students' science literacy and critical thinking abilities can be seen in Figure 5.

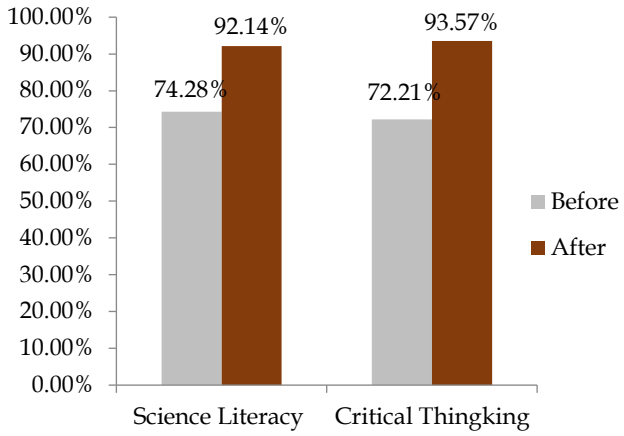

Figure 5. Results of the augmented reality-based Science Learning Game (SLG) product testing on students

Discussion

The product developed is augmented reality-based SLG (Science Learning Game) Learning media with solar system material in science learning. Augmented Reality (AR) is a technology that allows the integration of digital information, such as images, sounds, and animations, into the user's physical environment, creating an experience that unites the real world with virtual elements for the purpose of interaction and increased understanding (Ilafi et al., 2023). The advantages of this 3D augmented reality-based media include a higher level of interactivity, optimal effectiveness of use, wide implementation capabilities, affordable manufacturing costs, simple use of object models, and ease of operation (Kristina et al., 2023).

This media has the potential to be a suitable learning tool in the context of teaching science, because it is equipped with features in SLG media in the form of Quizzes and exposure to learning-related material according to the answers to questions in each Quiz and at the end of the media the value of the results/ranking of players in the SLG Game is displayed. SLG (Science Learning Game) Learning Media with solar system material uses image manipulation effects, audio-visuals and examples of making designs with the Kahoot application. The existence of this media makes students more interested in learning. According to Setyawan et al. (2019) augmented reality can increase students' interest in learning because it provides a more interactive, immersive, and entertaining learning experience, which makes the subject matter more interesting and relevant to students.

The final product of SLG learning media is an *.exe extension file, which will make it easier for users to use learning media. The material in the learning media includes understanding the solar system in accordance with the learning KD accompanied by images and video examples of learning materials. Learning media contains material presented in the form of text, images, animations and design video tutorials using the Kahoot application to make it easier for students to understand the material and increase student creativity. The field test was conducted by researchers on 19 June 2023. The implementation of this media test is carried out online so that students can run the media independently in their respective homes. Before students play the learning media game, instructions are first given in the learning media game. After that students are invited to use the learning media and try to do the evaluation contained in the learning media.

After the product test is carried out, the next stage is to measure the level of science literacy and critical thinking of students. Based on the recapitulation table of product trials in improving students' scientific literacy, the pretest percentage is 74.28% which is in the Good Enough category. Then based on the posttest results got a percentage of 92.14% which included the Very Good category. While the results of the trial on students' critical thinking skills obtained a pretest score of 73.2% which is included in the Quite Good category. Then the posttest score is 93.5% which is included in the Very Good category.

Based on these findings, it can be said that the augmented reality-based SLG learning media has undergone validation and can be applied as a valid learning tool in learning to improve science literacy and critical thinking of grade 6 elementary school students. This is because the media developed contains aspects of science literacy and critical thinking which are media that can be used online.

The way to maximize the improvement of students' critical thinking and science literacy is to make them construct their own thinking through online learning (Alfi et al., 2016; Kimianti & Prasetyo, 2019). In addition to enhancing students' critical thinking and science literacy, independence in learning can be fostered (Lestari 2020). According to Utamingsih et al. (2023), interactive media can be used to promote students' independence in learning. Therefore, the SLG media is developed with innovative and creative principles.

In addition, this product is also an innovative and fun media, so that it can attract enthusiasm from students in learning. A good learning media that is able to make students enthusiastic in learning (Hadiprayitno et al., 2021; Fatih, 2023b). Therefore, it is expected that this Augmented Reality-based Science Learning Game (SLG) media can stimulate students' learning enthusiasm in the post-Covid-19 period.

Conclusion

Based on the analysis of the research findings presented, it can be concluded that the development of media for 6th-grade elementary school has resulted in a product known as Science Learning Games (SLG) based on augmented reality. Furthermore, it was found that there was an improvement in student responses between the pre-test and post-test in terms of critical thinking and science literacy. This suggests that the Science Learning Games (SLG) media can be effectively used to enhance the critical thinking and science literacy abilities of 6th-grade students in Blitar City's elementary schools. However, it's important to note that this research is limited to the topic of the solar system within the 6th-grade science curriculum. Therefore, it is hoped that future research will explore the development of augmented reality-based media for other subjects.

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Author Contributions

The author's role in this research as an implementer in the research is expected to contribute to the development of science in the fields of learning technology and natural science literacy. In addition, it helps students in increasing critical thinking in elementary science learning.

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Conflicts of Interest

The authors declare no conflict of interest.

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