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STEM-AR Based Ecology and Biodiversity E-book Development for Increasing Students' Scientific Reasoning

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Abstract: This research aims to developing STEM-AR-based e-book teaching materials to improve students' scientific reasoning in ecology and biodiversity materials. The development of this research is important as a parameter of 21st-century abilities, which require students to have 4C abilities to face the education era of 4.0. This research method uses Research and Development (R&D). The R&D design chosen was Thiagarajan design consisting of four stages (Define, Design, Develop, and Disseminate) (Thiagarajan, 1974). Class VII students (N = 42) were involved as research subjects who were taken by the purposive sampling technique. Data collection was carried out through scientific reasoning tests, student response questionnaires, and observation sheets. Data processing techniques used paired sample T-tests and then performed the N-gain test. The results of the analysis show that after using the STEM-AR-based e-book, there is an increase in scientific reasoning ability, with an N-Gain value of 63% in the medium category. Testing the effectiveness of teaching materials using the SPSS paired sample t-test showed a result of 0.001, which means that STEM-AR-based teaching materials affect students' scientific reasoning. The descriptive average of scientific reasoning has increased by 40%. In addition, students gave positive responses to teaching materials, which made it easier to understand the material.

Keywords: E-book development; Scientific Reasoning; STEM-AR; Teaching material; 21st-century skill

Introduction

To fulfill the demands of the Industrial Revolution 4.0 and present pandemic conditions, pupils in the twenty-first century must have 4C (Creative, Critical thinking & problem solving, Collaboration, and Communication) skills (Redhana, 2019). Science education, in particular, necessitates the capacity to solve issues, assess information, successfully cooperate with people, work with various new technologies, think critically, creatively, and collaboratively, reason, and produce new ideas and products. (Dole et al., 2015; Lamb et al., 2015).

One of the skills that need to be practiced this century is scientific reasoning skills (Saad et al., 2017). Scientific Reasoning Skills (SRS) commonly referred to as scientific reasoning skills is the ability to search and evaluate findings to produce valid conclusions (Putri, S. A., at al., 2020). According to Damawati & Juanda (2016) reasoning is related to thinking processes in problem-solving and higher-order thinking skills.

A student's skill for scientific reasoning is something that needs to be developed as it is one of the skills that is less honed. This is reinforced according to (DeBoer, 2000; Kambeyo & Csapo, 2018) PISA and TIMSS assessments develop an assessment of students' scientific reasoning and reasoning levels. Indonesia's PISA and TIMSS lag far behind other Southeast Asian countries such as Singapore, Malaysia, and Thailand (Fenanlampir et al., 2019). Thus, improvements are needed both in terms of learning strategies and innovation of teaching materials that can increase student competence in science lessons developed with

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meaningful learning that can direct these skills (Marušić, M., & Sliško, 2012).

STEM is frequently connected with meaningful learning via experimentation and project-based learning to create new goods. STEM projects have been found to improve students' creativity and scientific reasoning while developing hypotheses, conducting experiments, drawing results, and assessing education. (Sternberg et al., 2020). In line with this, several research results have reported that learning with a STEM project approach is proven to be able to increase students' creativity and scientific reasoning (Giang, 2021; Hanif et al., 2019). This is because one of the designs according to Smith et al., (2018) STEM activities provide space for creative thinking and scientific reasoning, where teachers can utilize tools or teaching media as well as appropriate scientific practices to develop students' creative thinking skills and can increase learning effectiveness. In addition, it produces meaningful learning (Tseng et al., 2013). On the other hand, STEM projects must be supported by technology-based instructional tools. Books with Augmented Reality (AR) are one type of technology-based education material innovation. Augmented Reality is a technology that integrates two- and three-dimensional virtual things into a real-world environment and then projects these virtual objects in real-time (Martín-Gutiérrez et al., 2015).

Based on an analysis of the use and needs of teaching materials in schools, a preliminary study conducted by 35 respondents of junior high school/equivalent science teachers revealed that 87.1% still use printed books, 16.1% are new to and use Augmented Reality (AR) in learning, and generally know STEM but have not been optimally applied constrained by infrastructure and teaching materials that are not yet qualified.

Therefore, meaningful and responsive teaching using technology-based teaching materials that support scientific reasoning and project-based innovation is expected to be the solution of this era. Based on opinion (Daryanto, 2010) which states that in the era of technology development like today, teachers need to have skills and confidence in using technology for the delivery of teaching materials. In developing technology-based teaching materials, the Ministry of Education and Culture began to be creative through smart books or electronic books, namely BSE (Electronic School Books). However, BSE books only digitize printed books into PDF format, with the presentation of learning content limited to writing/text and image elements only (Putra et al., 2022).

Based on the explanation of the above problems, scientific reasoning skills need to be developed using a learning approach by teachers to students in terms of learning models, teaching materials, and appropriate and technology-based assessment instruments (Hanushek & Woessmann, 2012). This is in line with the results of bibliometric analysis of articles from 2015-2021 regarding scientific reasoning to improve students' cognitive abilities, creativity, learning strategies, and teaching materials in science learning are still wide open (Khoeriah et al., 2022).

Based on the background description above, the formulation of the problem to be raised is how to develop a STEM-AR-based science learning e-book on ecological and biodiversity material carried out and viewed based on its characteristics, feasibility, and effectiveness to improve students' scientific reasoning.

Method

Research Design

This research method uses Research and Development. The R&D design chosen was Thiagarajan design consisting of four stages (Define, Design, Develop, and Disseminate) (Thiagarajan, 1974). However, this research will only be carried out until the limited trial (dissemination) stage in learning in class VII. The limited trial phase is carried out with a one-group pre-test post-test design technique (Fraenkel wt al., 2009).

Figure 1. 4D Models by Thiagarajan

Participant

The research subjects of grade VII junior high school students amounted to 42 students, participants were taken by purposive sampling technique (Fraenkel et al., 2009) at SMPN 2 Dramaga, Bogor Regency.

Data Collection and Analysis Data

The research instruments used in this study include validation sheets, student response questionnaire sheets, and scientific reasoning question instruments. The data

analysis technique used in this study is a quantitative data analysis technique.
The data analysis techniques used include:

Feasibility Test and Validity of teaching materials

The data is in the form of media and material validation test results by experts and student response questionnaires. The product design developed is assessed by the validator using a validation sheet. The results of the assessment of all aspects are measured with a Likert Scale. The scale was a 5-point Likert type, consisting of grading from Strongly Agree (5), Agree (4), Undecided (3), Disagree (2), to Strongly Disagree (1).

Instrumental test of scientific reasoning: Validity and reliability test, scientific reasoning level test.

The questions use 12 graded multiple-choice questions developed by Wenning and Vieyra (2015). The validity and reliability of the questions are first assessed before they are utilized in the restricted test phase. The scale's dependability coefficient was estimated to be 0,889, and Cronbach's alpha values based on sub-factors were calculated to be 0,845, 0.806, and 0,810, respectively. Each sub-factor's coefficient is more than 0.63, suggesting that the scale is dependable. When the entire correlation values of the scale's items are checked, each item is more than r=30. This is evidence of the item's authenticity. The pre-test and post-test data were then evaluated to measure the level of scientific reasoning using the N-Gain test.

In addition, analysis hypothesis tests were conducted for the research problems.

SPSS software was used to analyze quantitative data. The steps are perform data normality tests on the pre-test and post-test, and Conduct a difference test (t-test) to see the significance of the difference between student pre-test and post-test scores.

Implementation

The usage of STEM-AR-based e-books is done in advance offline/face-to-face. The lesson plan for 22 hours of instruction includes the phases of learning outcomes. STEM projects are carried out through activities. Super STEM is a produced STEM-AR-based e-book with student worksheet references. This is done in addition to promoting students' scientific reasoning, particularly in Ecology and Biodiversity classes. Students work on a STEM project in which they develop a small biome. In this Super STEM project, students are given small biomes and challenged to create two ecosystems enclosed inside one biome using equipment and materials readily available to them. Project STEM is made in groups by following the PJBL-STEM stages are; Launching the problems, Building Knowledge, Solving Problem, Presenting product and Evaluations.

Figure 2. Stages PJBL-STEM

The advantages of the teaching materials developed are that there are AR features as a deepening of student material as shown in Figure 3. Students are directed to scan the available barcodes and then choose a 3D or augmented reality view. This activity allows students to see material objects as if they were real.

In the AR feature display, students can see directly the material on Ecology and Biodiversity as outlined in pictures and videos. In the 21st century, the use of technology is considered one of the solutions to some common problems because technology has affected society widely and has a great demand even in the world of education. Augmented reality is a technology that combines the real digital world and the virtual world. Augmented Reality places computer-generated 3D Objects in real-world environments as if they existed. In addition, according to (Elivera & Palaoag, 2020), AR meets educational needs, because images displayed in AR can be used effectively to convey learning material. Students are expected to more easily understand the material being studied.

Figure 3. AR Feature Display

Result and Discussion

Based on the findings of the preliminary test, a STEM-AR-based e-book was designed in the form of flipbooks that are easy to access, attractive, and have a variety of comprehensive features according to the learning outcomes of the material, especially for class VII SMP. Predetermined learning outcomes can be obtained by practicing scientific reasoning and creativity through the presentation of material made in AR features, STEM practicum stages in Super STEM activities, BISA SAINS, 3M column, and HOTS questions guide. The most important thing is that this e-book is easy to access either via a mobile phone or computer connected to the internet so that students can access it anytime and anywhere. The features in this STEM-AR-based e-book were created in response to an analysis of the needs of students at SMPN 2 Dramaga. The e-book feature developed can be seen from the Figure 4.

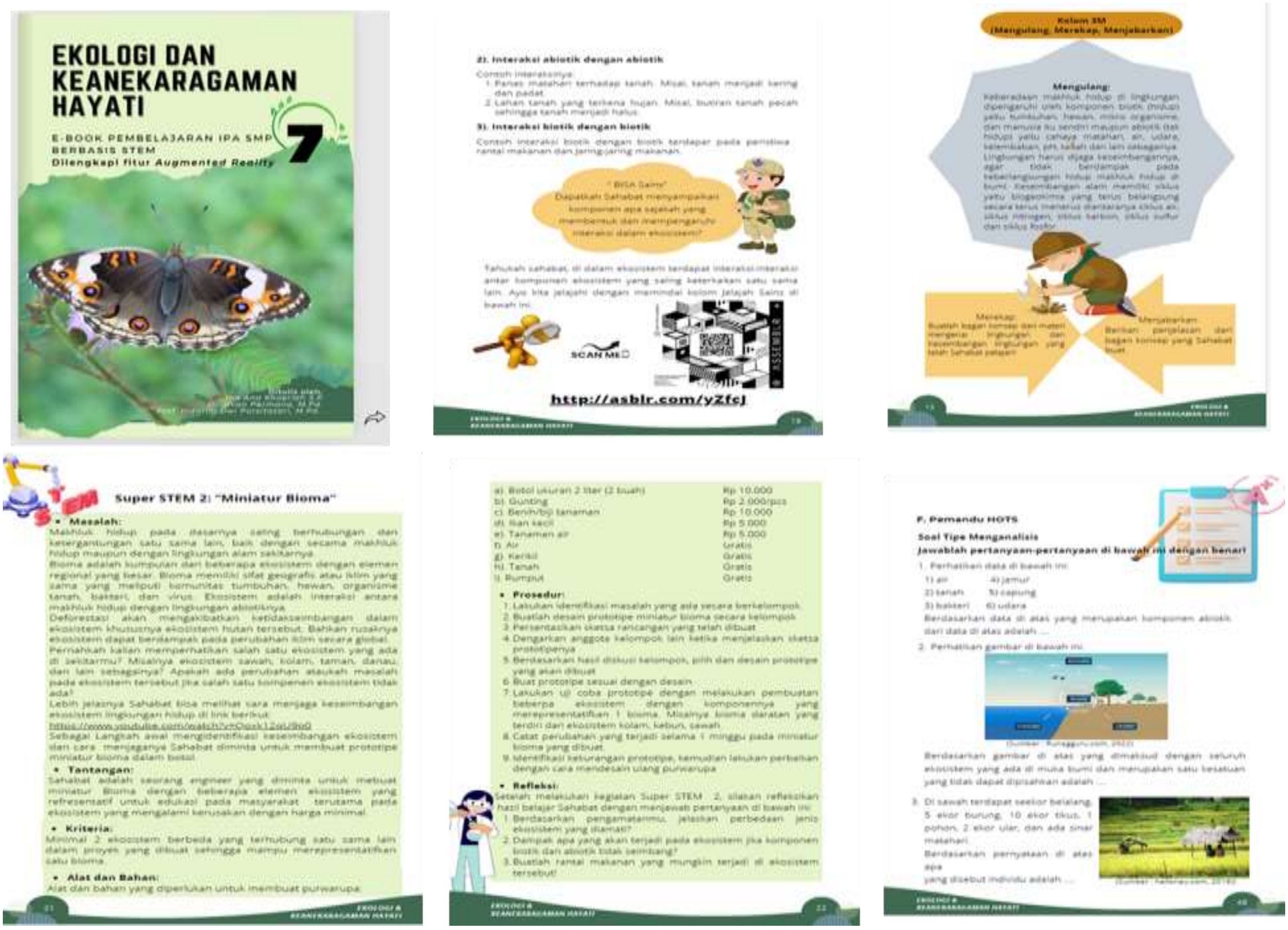

Figure 4. STEM-AR Based E-book Teaching Material Development Features

Table 1. Results of Teaching Material Improvements Based on Expert Judgment

Revised Components	Before Revision	After Revision
Cover (Illustration image and tittle in revision)		

Revised Components	Before Revision	After Revision
Improved table of contents format and page background		
Images corrections as well as information that strengthens the image must be clear		

At the Development stage, there is input from both media experts and material experts as follows in Table 1. After validating the two experts. Recapitulation of the feasibility of the materials and teaching materials developed shows an average percentage of 92.5% with very feasible criteria. This is in line with Kirana (2020) which shows an average percentage of product feasibility of 85.6% which is very feasible. Then it is also in line with research from Fitriani & Rohayati (2019) which shows that the recapitulation results of 84.71% have very decent product criteria. Therefore, the products that have been developed by researchers can be operated as a support for the learning process with the help of technology while the minimum Content Validity Ratio (CVR) value that meets valid criteria according to Lawshe (1975) for a total of 20 respondents is 0.42. The results obtained mean a CVR of 0.98 and a CVI of 0.99 with valid criteria.

Following the validation of the training materials, limited product trials are conducted to assess their effectiveness. The examination of students' written test results, including pre-test and post-test scores, is used to determine the efficiency of learning using STEM-AR-based e-book instructional materials on students' scientific reasoning abilities. A restricted exam was administered to 42 junior high school pupils in grade VII. In general, the N-Gain outcomes of students' scientific reasoning got a score of 0.63 (medium category), with an average score ranging from 36.9 to 76.21. Complete data is shown in Table 2.

Table 2. Student Scientific Reasoning Test Results

Implementation Data	Pre-test	Post Test
Number of Students	42	42
Lowest Score	8	50
Highest Rating	58	96
Standard deviation	11.311	12.050
Average Score	36.9	76.21
N-Gain Score	0.63 (Medium Category)	

Based on Table 2 the increase in post-test scores compared to the pre-test shows that there is an increase in students' scientific reasoning after using STEM-AR-based e-books. The difference in pre-test and post-test values is strengthened by the N-Gain values in the moderate category as shown in Table 2. The results of this study are in line with Remigio et al. (2018) which states that scientific reasoning abilities may be developed and improved via training and practice. STEM practice is carried out in addition to scientific reasoning training and student problem-solving in the notion of Ecology and Biodiversity content. In line with that, Schlottmann (2001) stated that students who have scientific reasoning abilities have very good scores on conceptual understanding.

Furthermore, to determine the significance level of the pretest and posttest, an inferential test was carried out. Pre-test and post-test data for scientific reasoning abilities were analyzed using SPSS with the results shown in Table 3.

Table 3. Inferential Analysis Results via SPSS

Value	Number of Students	Normality Test		Hypothesis Test	
		Value	Description	Value	Description
Pre test	42	0.161	Normal	0.001	Significant
Post test	42	0.143	Normal		

The first step is to perform a preparatory test, namely the normalcy test as a descriptive statistical test, to demonstrate the impact of employing STEM-AR-based e-books on students' scientific reasoning abilities. The Shapiro-Wilk test data is used to assess the normality of the data since the sample size is less than 100. The Sig statistic test value is 0.161 for the pre-test and 0.143 for the post-test based on the results of the normalcy test on the SPSS version 26 data in Table 3. The fact that both data sets are bigger than 0.05 indicates that the data is regularly distributed. The next stage is to put the homogeneity to the test.

Based on the results of the prerequisite tests that were met, a paired t-test was performed which was used to compare the average 'Scientific Reasoning Pretest' and 'Scientific Reasoning Post-test'. The t-count gain is -21.703 and the Sig-value is 0.001. The Sig value is much smaller than the commonly used significance level of 0.05. This shows that the null hypothesis (H_0) is rejected, meaning that there is a difference between pre-test and post-test scores so that STEM-AR-based e-books can be used to increase students' scientific reasoning, especially in Ecology and Biodiversity material.

These findings suggest that STEM-AR-based e-books are a useful tool for improving students' scientific reasoning. These instructional resources foster an interactive and engaging learning environment that fosters critical thinking and problem-solving abilities, both of which are essential components of scientific reasoning. In line with that, Zulkipli et al. (2020) reported that STEM learning has an impact on developing students' scientific reasoning abilities. Apart from that, the results of Giang (2021) research have reported that learning using the STEM project approach has proven to be able to improve students' scientific reasoning.

The N-Gain results illustrate that the application of STEM-AR-based e-books has a significant impact on improving students' scientific reasoning. The N-Gain value for each indicator of scientific reasoning can be seen in Table 4.

Table 4. N-Gain Value of Scientific Reasoning Ability

Indicator		*Pre-test*		*Postest*		N- Gain
	No. Question	Score	Value	Score	Value	
Integrated Ability/C4	1	35	44.94	73	89.58	0.81
	2	41		77		
	3	38		78		
	4	37		73		
Peak Ability/C5	5	41	45.54	70	84.23	0.71
	6	39		69		
	7	38		70		
	8	35		74		
Advanced Ability/C6	9	33	43.45	75	77.68	0.61
	10	37		74		
	11	44		58		
	12	32		54		

Table 4 shows that scientific reasoning ability at the integrated ability stage which is a type of question C4 (analyzing) in bloom taxonomy has the highest N-Gain value among other scientific reasoning indicators, reaching 0.81 in the high category. This is in line with research Ain (2021) which obtained a CRI (Certainly of Response Index) level of C4 higher than the question levels C5 and C6. In addition, this analysis is due to the cognitive level of HOTS type C4 questions being the initial stage after having LOTS abilities (types C1-C3). This is in line with the research of King et al., (2012) explained that HOTS is inseparable from the level of learning, each cognitive level is interdependent. What was previously learned can help optimize higher-order thinking skills. Solving HOTS questions is like climbing stairs. To answer C5 level questions (evaluate) you need to master C4 (analyze), C3 (apply), C2 (understand), and C1 (remember) skills and the same goes for other levels of questions. In response to this, Retnawati et al. (2018) explained that the need to familiarize students with HOTS learning and measurement activities is important for developing ideas or solutions to complex problems.

Students' peaking ability also has a high N-Gain value reaching 0.71 which shows students can answer questions of type C5 (evaluate). While the advanced abilities in the scientific reasoning stage of students are still in the medium category with an acquisition value of 0.61 and is a type of question C6 or creating. Based on these three data, it shows that the type of question C6 is more difficult for students to solve/answer than other types of questions. This can be seen from the acquisition of the value of the type of question C6 which is a sophisticated category in scientific reasoning that has the lowest score. We know that the cognitive level of questions of types C4, C5, and C6 are HOTS types of questions and are classified as difficult and require high-level thinking. This is in line with previous research by Hanifah (2019) which stated that HOTS-type questions that require high-level thinking can train students to think at the levels of analysis, evaluation, and creation. Higher-order thinking cannot be obtained by students automatically through learning (Afandi et al., 2019; Schulz & FitzPatrick, 2016), but is obtained through a process of intentional and repetitive practice (Changwong et al., 2018). Therefore, HOTS question guides and HOTS practice questions in this STEM-AR-based e-book are solutions to stimulate students' HOTS abilities.

Conclusion

The development of STEM-AR-based e-book teaching materials to improve students' scientific reasoning is an innovation that is applied in science learning, especially in the subjects of ecology and biodiversity. STEM-AR-based e-book teaching materials contain qualities that meet the elements or requirements of teaching materials such as language feasibility, presentation feasibility, content feasibility, design and appearance, and pedagogical factors. The resulting e-book teaching resources are based on curricular demands and student characteristics, and can help students improve their scientific reasoning. In addition, STEM activities and HOTS question guidelines can help students improve their scientific reasoning. The STEM-AR-based e-book is substantially effective in increasing students' scientific reasoning with a simple N-Gain score of 0.63. According to the analysis of study data obtained, interactivity, attractive design, STEM practicum and materials in AR can increase understanding and interest in ecology and biodiversity material.

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Authors Contribution

The authors provide equal contribution to this work.

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Conflicts of Interest

The authors declare no conflict of interest.

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