



How does an augmented reality-based pocket book enhance students' critical thinking skills?

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Abstract

Background: Students' low critical thinking skills negatively impact their mathematics learning outcomes. One contributing factor is the insufficient optimization of instructional media.

Aim: This study aims to design instructional media, assess its feasibility and practicality, and evaluate the effectiveness of an augmented reality-based pocket book in enhancing the critical thinking skills of fifth-grade students.

Method: The study adopts the Borg & Gall development model and employs a pre-experimental design with a one-group pretest-posttest approach. Data collection techniques include observation, interviews, questionnaires, tests, and documentation. Initial data analysis involves normality tests, while final data analysis uses mean difference tests and N-Gain tests.

Results: The findings reveal an improvement in students' critical thinking skills, as indicated by the increase in average test scores from 51.5 to 76.6. The N-Gain analysis result of 0.5052, classified as moderate, provides evidence that the augmented reality-based pocket book is effective in enhancing students' critical thinking skills.

Conclusion: The augmented reality-based pocket book proves to be an effective tool for improving students' critical thinking skills, as demonstrated by the significant increase in average test scores and n-gain values.

INTRODUCTION

The contemporary educational landscape, the development of critical thinking skills among students is increasingly recognized as a crucial objective (Fitriani et al., 2022; Palavan, 2020). Critical thinking is essential for effective problem-solving and decision-making, particularly in subjects like mathematics, where analytical and logical reasoning play a significant role (Basri et al., 2019; Putri et al., 2023; Wahyudi et al., 2022). However, despite its importance, several studies reveal that many students exhibit low levels of critical thinking skills, negatively impacting their academic performance, especially in mathematics (Dahlia & Panjaitan, 2024; Yoma et al., 2018; Yulianto et al., 2024). One of the primary factors contributing to this deficiency is the lack of optimized learning media that engage students in meaningful and interactive learning processes. Traditional teaching methods often fail to stimulate students' critical thinking abilities, necessitating the integration of innovative technologies to enhance the learning experience.

Augmented reality (AR) technology has emerged as a promising tool in educational settings due to its ability to create immersive and interactive learning environments (Avila et al., 2021; Fernández-Enríquez & Martín, 2020). AR can overlay digital information onto the real world, providing students with enriched learning experiences that foster deeper understanding and engagement. The potential of AR to transform educational practices and

improve learning outcomes has been widely recognized in recent research. The combination of AR implemented in pocket book media presents an intriguing opportunity. Pocket books are essential as they provide concise and portable learning materials, allowing students to study anytime and anywhere (Juniarti et al., 2021; Sirait & Lubis, 2023). Additionally, pocket books enable students to quickly access information and review lesson materials independently, which is highly beneficial for reinforcing their understanding and learning skills. An augmented reality-based pocket book is expected to be an innovative solution in enhancing students' critical thinking skills.

Numerous studies on the development of pocket book media have been conducted, demonstrating various educational benefits. For instance, pocket books have been developed to enhance mathematical logic skills (Sirait & Lubis, 2023), problem-solving abilities (Juniarti et al., 2021), critical thinking skills (Wiyono et al., 2023), and motivation (Istiana et al., 2024). The approaches in pocket book development are diverse, including those based on Android platforms (Nurmala, 2022), using mind mapping (Istiqomah & Setiadi, 2024), and incorporating QR codes (Mustika et al., 2022). Despite the many innovations in pocket book development, there has yet to be research specifically focused on developing augmented reality (AR)-based pocket books. Therefore, this study aims to fill that gap by developing an augmented reality-based pocket book to enhance students' critical thinking skills.

METHODS

Design

This study employs a Research and Development (R&D) design, adopting the Borg & Gall development model. This model is chosen for its suitability in designing educational products that are systematically tested in the field before being widely implemented. The study utilizes a pre-experimental method with a one-group pretest-posttest design, where measurements are taken before and after the intervention to assess the effectiveness of the augmented reality-based pocket book.

Participants

The subjects of this study are fifth-grade students in Pekalongan, during the second semester of the 2023/2024 academic year. Participants include all fifth-grade students, as well as teachers and experts to evaluate the feasibility of the media, including content experts, media experts, and language experts. A small-scale trial involves several students representing the population, specifically 2 high-achieving students, 2 average-achieving students, and 2 low-achieving students.

Instruments

The research instruments consist of various data collection tools, including observations, interviews, questionnaires, tests, and documentation. Essay tests are used to measure students' critical thinking skills, based on Ennis' critical thinking indicators. Validation instruments by content, media, and language experts, along with teacher and student response questionnaires, are used to assess the feasibility and practicality of the augmented reality-based pocket book.

Data Analysis

Data analysis is conducted in two stages. The first stage involves analyzing the initial data using normality tests to ensure the distribution of pretest and posttest data. The method used is pre-experimental with a one-group pretest-posttest design, which involves conducting an initial test before the intervention and a final test after the intervention. Data collection techniques in this study include observations, interviews, questionnaires, and documentation.

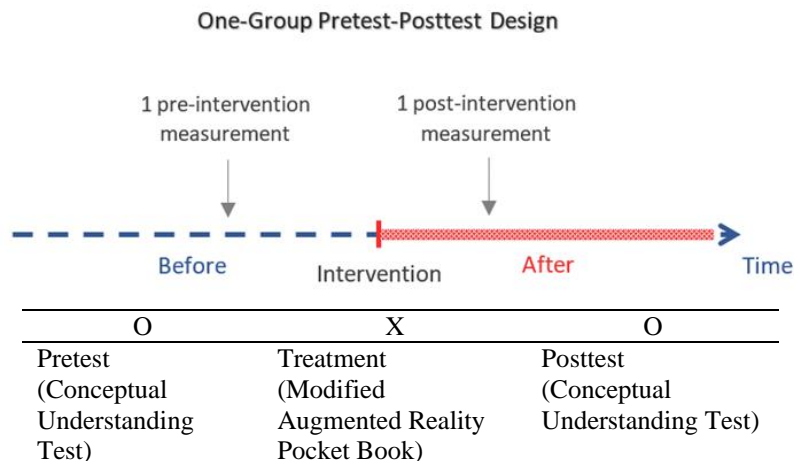


Figure 1. Desain one-group pretest-posttest

The second stage involves analyzing the final data using mean difference tests and the N-Gain test to evaluate the effectiveness of the media in enhancing students' critical thinking skills. The N-Gain score is calculated to determine the improvement in critical thinking skills, with the results interpreted based on low, medium, and high categories.

RESULTS AND DISCUSSION

The outcomes of this research and development are presented in three main sections corresponding to the research questions: (1) the design of the augmented reality-based pocket book; (2) the feasibility and practicality of the augmented reality-based pocket book; (3) the effectiveness of the augmented reality-based pocket book in enhancing the critical thinking skills of fifth-grade students.

Product Design

Designing an Augmented Reality-based Pocket Book requires a preliminary needs analysis. In this context, the researcher used observations, interviews, needs questionnaires, and documentation. Observations during mathematics lessons, particularly in geometry, revealed that students tend to memorize formulas without understanding the underlying concepts. This was evident when students attempted geometry problems by directly writing formulas without analyzing the problem's shape. This finding aligns with interviews conducted with the fifth-grade teacher, who stated that the students' critical thinking skills in mathematics were not optimal, leading to less than satisfactory learning outcomes.

Based on the media needs questionnaire, teachers expressed a desire for media that could assist in enhancing students' critical thinking skills and should include 3D projections to help construct students' manipulation skills. The media should be concise, clear, and easy to

understand. Similarly, the student needs questionnaire indicated a preference for engaging and succinctly packaged media to avoid boredom. Hence, the researcher chose to develop an Augmented Reality-based Pocket Book.

The data obtained from the media needs questionnaire was then used to design the product. The AR-based Pocket Book was designed and aligned with Van Hiele's theory of geometric learning. The researcher was interested in developing the media's writing system based on Van Hiele's theory, as it specifically addresses geometry content and is tailored to the students' cognitive development stages (Lita et al., 2020; Rahmadita et al., 2022). This approach helps students understand concepts and consequently improves their critical thinking skills, leading to better learning outcomes.

The development of the augmented reality-based pocket book in this study involved: (1) creating a pocket book focusing on geometry elements in mathematics, specifically prisms and cylinders; (2) using Canva to design the book's content and Unity Vuforia to design the AR scanning application; (3) the appearance of the AR-based Pocket Book includes a book containing special marked images that can be scanned using the ARPIBUNG application, which then displays a 3D projection of the scanned images.

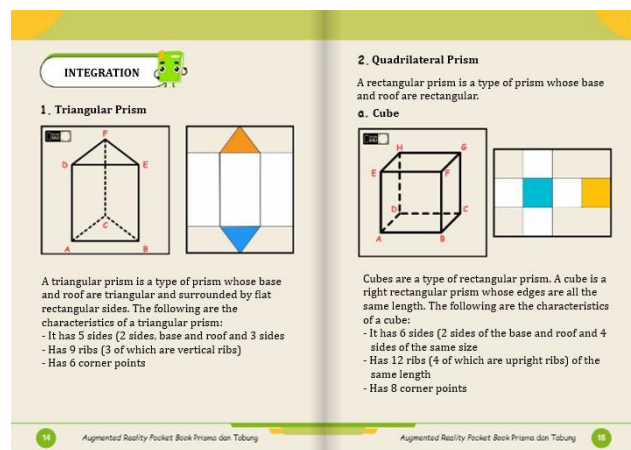


Figure 2. Pocket Book View



Figure 3. Augmented Reality Application Display



Figure 4. 3D Projection View in Application

Feasibility and Practicality of the Product

The feasibility and practicality of the Augmented Reality-based Pocket Book have been tested by subject matter experts and evaluated for practicality by teachers and students. The experts involved in this research included content experts, media experts, and language experts. The feasibility tests were conducted to gather suggestions and feedback from competent experts to ensure that the Augmented Reality-based Pocket Book is suitable for use in mathematics learning activities. Below are the percentages of the feasibility assessment results by the experts regarding the augmented reality-based pocket book.

Table 1. Media Feasibility Assessment Results

Validator	Validation Instrument	Number of Items	Ideal Score	Obtained Score	Percentage (%)	Category
Content Validator	Content Validator	18	72	65	90,27	Very Feasible
Media Validator	Media Validator	24	96	91	94,79	Very Feasible
Language Validator	Language Validator	17	68	64	94,11	Very Feasible
Average Score					93,05	Very Feasible

Based on Table 1, the feasibility assessment results by content, media, and language experts show percentages of 90.27%, 94.79%, and 94.11%, respectively, with all criteria rated as very feasible. These assessments indicate that the Augmented Reality-based Pocket Book is highly suitable for testing with students.

Following expert validation, the next step was to conduct product trials to determine practicality based on small-scale/limited trials using teacher and student response questionnaires. The results of the teacher response questionnaires in the small-scale/limited trial yielded an average index percentage of 88.75% with a very practical criterion. The student response questionnaires showed an average practicality index percentage of 93.67%, also with a very practical criterion. This aligns with previous research by Rizal Nurrul (2021), where the development of AR-based pocket book media received an average teacher response of 88% and student response of 83% (Nurrul, 2021). Additionally, research by Winarni (2023) on AR-based pocket book development for solid geometry obtained a teacher response of 85.33% with a very practical criterion and a student response of 86.15% with a very practical category (Winarni et al., 2023).

Product Effectiveness

The effectiveness of the Augmented Reality-based pocket book in enhancing students' critical thinking skills can be determined through the students' learning outcomes on pretest and posttest scores. The pretest scores were obtained before the students were taught the solid geometry material using the Augmented Reality-based Pocket Book. The posttest scores were obtained after the students received the solid geometry lessons with the Augmented Reality-based Pocket Book.

Table 2. Hasil Large Group Cognitive Learning Outcomes

Action	Number of Students	Average Score	Number of Students Passing	Percentage
Pretest	26	51,5	5	19,23%
Posttest	26	76,61	20	76,92%

Based on Table 2, it is evident that the average pretest score was 51.5, while the average posttest score was 76.61, indicating a difference of 25.11 points between the pretest and posttest scores. In the pretest, only 5 out of 26 students (19.23%) scored above the minimum competency criteria (KKM), whereas in the posttest, 20 out of 26 students (76.92%) exceeded the KKM. This demonstrates a significant improvement in students' critical thinking skills, as measured by their learning outcomes before and after the intervention using the Augmented Reality-based Pocket Book.

Tabel 3. Normality Test of Pretest and Posttest Scores

	Statistic	df	Sig.
Critical Thinking Pretest Scores	,941	26	,139
Critical Thinking Posttest Scores	,957	26	,335

Based on the normality test results, the normality test for the pretest scores has a significance value (sig.) of 0.139, and the normality test for the posttest scores has a significance value of 0.335. The criteria for normality testing state that the data can be considered normally distributed if the significance value is greater than 0.05. Conversely, if the significance value is less than 0.05, the data are considered not normally distributed. According to Table 3, the normality test result for the pretest scores is $0.139 > 0.05$, indicating that the data are normally distributed. Similarly, the posttest scores show a normality test result of $0.335 > 0.05$, confirming that the data are also normally distributed. Given this, it can be concluded that both pretest and posttest scores are normally distributed, allowing the use of parametric statistical techniques for further analysis.

Table 4. Results of the Mean Difference Test

		t	df	Sig. (2-tailed)
Pair 1	Critical Thinking Pretest and Posttest Scores	-11.193	25	<0.001

Based on the table of mean difference test results, the criteria for testing indicate that if the Sig. value is less than 0.05, there is a significant difference between the pretest and posttest learning outcomes. The data shows a Sig. value of $0.001 < 0.05$, indicating a significant difference between the pretest and posttest results. Thus, it can be concluded that there is a

significant improvement in learning outcomes after the intervention with the Augmented Reality-based Pocket Book.

Table 5. N-Gain Test Results

Category	Value
Pretest	51,5
Posttest	76,61
Average Difference	25,11
N-Gain	0,5052
Criteria	Moderate

Learning media can be considered effective if students' learning outcomes show significant improvement or difference. Based on Table 5, the N-Gain results for the pretest and posttest scores indicate a value of 0.5052, categorized as moderate. The N-Gain test results demonstrate the average improvement in learning outcomes for fifth-grade students before and after using the Augmented Reality-based Pocket Book. This improvement can be attributed to the use of the AR-based Pocket Book, which effectively clarifies messages or information by succinctly and flexibly presenting key points of the material. This aligns with Nurrul (2021) assertion that pocket books are flexible media.

The Augmented Reality-based Pocket Book facilitates the translation of abstract concepts by presenting objects realistically, providing students with direct experiences and leaving lasting impressions. According to Edgar Dale's Cone of Experience theory, the more direct experiences students have, the more concrete and profound the knowledge they acquire (Lilian & Amollo, 2023). Deeper knowledge fosters greater curiosity in students, driving them to evaluate their thinking, assess evidence, and make logical decisions, thereby enhancing their critical thinking skills.

Based on the research findings, the development of the AR-based Pocket Book for fifth-grade students is effective as a learning medium and can serve as a supportive tool in mathematics education, particularly in geometry. The AR-based Pocket Book enhances students' understanding of the material, leading to improved critical thinking skills and overall better learning quality.

CONCLUSIONS

Based on the research results, the augmented reality-based pocket book developed proved to be both engaging and effective for learning. The feasibility assessment by expert lecturers indicated that this media is highly suitable for use, with excellent ratings from content, media, and language experts. The practicality of this media was also rated very highly by teachers and students, demonstrating that it is user-friendly and well-received in a learning context. The effectiveness of the media is evident from the improvement in students' critical thinking skills, as shown by a significant increase in mathematics learning outcomes after using the media. The N-Gain test results indicate a significant improvement, suggesting that this media is effective in enhancing critical thinking skills. Overall, the augmented reality-based pocket book has proven to be feasible, practical, and effective in improving students' critical thinking abilities in geometry learning.

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AUTHOR CONTRIBUTIONS STATEMENT

HP played a crucial role in conceptualizing the research idea and collecting data. Additionally, HP was responsible for drafting the manuscript, conducting statistical data analysis, and interpreting the results. NN was involved in project supervision, providing feedback on idea development, data analysis, and manuscript preparation.

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