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Enhancing Vocational Students' Critical Thinking Skills in Society 5.0 with Flipbook and Augmented Reality Learning Media

Zenita Sabitri[1], Danny Meirawan[1], Sri Rahayu[1] *

[1] Building Engineering Education Study Program, Universitas Pendidikan Indonesia
Jl. Dr. Setiabudi No. 229, Isola, Sukasari, Bandung City, West Java, Indonesia-40154

**Corresponding author: srirahayu@upi.edu*

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Abstract

The era of Society 5.0 demands that human resources possess critical thinking skills in response to rapid changes in the field of education, with Vocational High Schools (VHS) playing a central role in shaping students to be critical and creative. To achieve optimal results, further breakthroughs in the use of educational technology are needed, such as the implementation of Augmented Reality (AR)-based flipbooks in the vocational school environment. This study aims to evaluate the level of critical thinking skills among vocational school students. The method used in this study is a quasi-experimental design with descriptive quantitative data analysis. This research was conducted with 64 tenth-grade students at a vocational school in Bandung. The instruments used to obtain data included critical thinking skills tests. The data analysis technique used was descriptive quantitative analysis to evaluate the improvement of students' understanding and critical thinking skills. The research data was tested using normality test, homogeneity test, independent test, and N-Gain. Research data indicates that the use of AR-based flipbooks significantly enhances student comprehension, with an N-gain value of 0.6 observed in the experimental class. Consequently, it can be concluded that the implementation of AR-based flipbooks effectively improves students' critical thinking abilities in VHS, offering substantial promise for developing more interactive and efficient learning technologies for future education.

Keywords: Augmented Reality, Critical Thinking, Flipbook, Media, Vocational School.

1. Introduction

In the era of Society 5.0, technological advancements and human resource skills bring significant benefits, particularly in the context of education [1]–[3]. Students' access to various devices such as computers, laptops, and smartphones enables them to engage in more interactive learning formats [4]–[6]. Interaction in the educational process is considered crucial, where media acts as a mediator for delivering information [7], [8]. These media serve as tools and materials that can be applied in both software and hardware forms [8], [9]. The presence of this connecting technology makes the media more influential by integrating various learning resources and facilitating more dynamic and effective interactions between educators and students. Moreover, digital technology holds immense potential, especially in today's educational context [10]–[12]. The success of the implementation of a learning process is inseparable from several factors involved in it [13]–[15]. Several factors influence the dynamics of the teaching-learning process [16]. Within the framework of learning, there are several interconnected aspects, such as the role of teachers, the role of students, teaching materials, learning methods, learning media, and assessment of learning outcomes [17], [18]. All these components are interrelated and influence each other [19].

In the implementation of the Merdeka Curriculum for Vocational School, ,there is a subject called Basic Program Foundations aimed at training students to be proficient in analyzing building materials and developing problem-solving skills [20]–[22]. Considering the variation in learning styles in each class, especially in subjects that emphasize building science, responses to the material can vary [23], [24]. This situation highlights the importance of adopting diverse teaching methods according to the

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characteristics of each class [25]–[27]. Teaching about the fundamentals of the program, which includes concepts of green building and environmentally friendly building materials, can also enhance students' critical thinking skills in Vocational School [28]–[30]. This subject can stimulate students' critical thinking skills in analyzing materials used in construction.

Critical thinking skills become an essential key in understanding material when students are faced with situations that require them to solve problems [31]–[33]. The importance of training critical thinking skills is emphasized because this ability is not a natural talent [33]–[36]. Although critical thinking skills are possessed from the outset, they still require continuous practice because without practice, these skills will not develop into solid abilities [37], [38]. Critical thinking involves a series of skills, such as identifying sources of information, evaluating their reliability, considering the relevance of information to existing knowledge, and drawing conclusions based on critical considerations [39], [40]. Critical thinking is a process of rational, reflective, and responsible thinking in making accountable decisions [41], [42]. Individuals who can think critically have practical and creative abilities to formulate appropriate questions, access relevant information, filter information, and present logical arguments to support information and accountable conclusions [43], [44]. Enhancing critical thinking skills in basic program subjects can be achieved by engaging students in exercises that encourage the use of higher-order thinking skills (HOTS) [45]–[47].

One strategy to enhance students' critical thinking skills is by utilizing interactive learning media [48]–[50]. The implementation of interactive learning media, such as flipbooks supported by Augmented Reality (AR) technology, can aid in developing students' critical thinking abilities [51], [52]. With AR, students can directly analyze the form and material of buildings from the projected visualization [53]–[55]. This interactive learning media not only plays a role in sharpening critical thinking skills but also enriches students' communication, collaboration, and creativity abilities [56]–[58]. Based on the perspectives of several previous researchers, it can be concluded that the use of interactive media encourages active participation of students in seeking solutions to problems or cases they encounter, enabling them to overcome these challenges [59].

Although technology has been widely used in educational contexts, such as the use of learning media like PowerPoint, modules, and the like, not all implementations have reached an optimal level [15]. Previous research indicates that conventional learning media have limitations in enhancing student engagement and understanding. For instance, [60] found that using PowerPoint in education only marginally improves material comprehension and does not significantly impact students' critical thinking abilities. Similarly, [61] showed that e-modules can increase student engagement, but the enhancement of critical thinking skills remains limited. Furthermore, research by [62] indicates that instructional videos have a positive effect on enhancing conceptual understanding but are less effective in developing analytical skills [63] found that the use of digital textbooks can improve the accessibility and availability of learning materials but does not significantly impact students' learning outcomes. Lastly, [64] suggest that the use of game-based learning apps can enhance learning motivation, yet its effects on improving critical and analytical thinking skills still require further research.

Therefore, innovation in the form of virtual-based learning media, such as flipbooks supported by Augmented Reality (AR), is necessary to maximize meeting students' needs in developing their skills in line with technological advancements in the era of Society 5.0. Flipbook as a simple interactive media has the potential to enhance students' learning motivation [65]. On the other hand, Augmented Reality (AR) is a technology that enables the projection of virtual objects into the real environment [66], [67]. This study focuses on the implementation of flipbooks with AR as a learning tool in vocational schools, especially in Vocational School, considering that Vocational School students require critical thinking skills that are essential in the Society 5.0 era. The novelty of this research lies in the innovative integration of flipbooks and AR technology, which has not been widely applied in the context of vocational education. The main objective of this research is to evaluate the effectiveness of this learning media and measure students' critical thinking abilities in vocational schools. The benefit of this research is to present an alternative interactive learning media in the form of flipbooks that can be applied in the learning process in vocational schools, while enhancing or identifying critical thinking abilities through the use of flipbooks with augmented reality.

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2. Method

This study was conducted at one of the Vocational School located in Bandung and known as the Center of Excellence Vocational High School. Participants in this research were students of the tenth grade who were enrolled in the Construction Engineering and Property program with elements of green building technology and materials in the Basic Program of Expertise subjects, the learning materials of which were covered in flipbooks with Augmented Reality (AR) developed. The total number of participants in this study is as many as 64 students. A total of 32 students were assigned to the experimental class, while another 32 students were assigned to the control class.

This study adopted one of the experimental methods, namely quasi-experiment (Non-equivalent Group Pretest Posttest Design), using both control and experimental groups to assess the extent of improvement in students' critical thinking abilities, as depicted in Figure 1 [68], [69]. The quasi-experimental method was used to allow for a comparison between two learning media, namely flipbooks with AR and conventional media like powerpoint, in order to identify the effectiveness of each medium in enhancing students' critical thinking skills.

NR_1	O_1	X	O_2
NR_2	O_3		O_4

Figure 1. Non-Equivalent Group Pretest Posttest Design

This stage begins with piloting the test instrument as many as 20 items of instrument in class X.1 to enhance the quality of the questions, including validity to measure question accuracy, reliability to assess the quality of question measurement, difficulty level to determine the difficulty level of the questions, and discriminative power to differentiate students based on their abilities.

The tested question instrument was then utilized by the researchers as a tool to measure students' critical thinking abilities through pre-tests and post-tests. The pre-test was conducted to evaluate the students' abilities in the control class (X.2) and the experimental class (X.3). The experimental class was then subjected to treatment by implementing flipbooks with AR, while the control class did not receive any specific treatment. Before applying the treatment to both classes, the researchers conducted a homogeneity test to ensure that the students in the control and experimental classes had the same variance. Afterward, the students were tested with post-tests in both the experimental and control classes to measure the difference in the level of critical thinking abilities. The data collection technique used was a test, aimed at assessing critical thinking abilities focusing on analyzing sustainable building, green building, and green materials possessed by students in the control and experimental classes. The research began with the use of tests to measure students' critical thinking abilities in the control class (X.2) and the experimental class (X.3).

The experimental research data analysis includes two critical tests: the normality test and the homogeneity test. The normality test is conducted as the first step in statistical data processing to determine whether parametric or nonparametric statistical methods will be used. This test aims to ascertain whether the collected data are normally distributed. The data are considered normally distributed if the significance value (Sig. p) is greater than or equal to 0.05, indicating that the data follow a normal distribution with a 5% error rate [70].

Following the normality test, the homogeneity test is performed to ensure that the variances of the two groups being compared are equal. This is crucial to confirm that any observed differences between groups are not due to variability differences in the data. The homogeneity test helps determine whether the assumptions for parametric statistics have been met. If the Sig. (p) value is ≥ 0.05, it means the data is homogeneous (uniform). Conversely, if the Sig. (p) value is < 0.05, it means the data is not homogeneous (not uniform) [70].

The next step in the analysis involves conducting an independent test to assess the difference in values between the control group and the experimental group. This test is essential to determine whether there is a significant difference between the two groups, which is central to analyzing the effectiveness of the intervention conducted in the study. The results of this test provide a foundation for further evaluation of the effectiveness of the educational media used. After the independence test, the N-Gain test formula developed by Melzer in 2002 is conducted to measure the improvement and effectiveness of using the flippbook with augmented reality (AR) compared to conventional learning media. The N-

Gain results can be interpreted in terms of achievement levels based on percentage into four effectiveness categories: less than 40% as "very ineffective," 40-55% as "ineffective," 56-75% as "quite effective," and more than 76% as "very effective." [71]. All testing processes are carried out using SPSS version 27 software.

3. Result and Discussion

Researchers utilized unity software in conjunction with Vuforia to develop an Augmented Reality (AR) Flipbook. This application is compatible with Android devices running version 7 or later, supporting AR features. The AR Flipbook comprises two main menus: the Flipbook menu, which contains text, audio, and video materials, and the Augmented Reality menu, which projects 3D content into the real world. Additionally, there are menus for Information, Credits, and Exit, as illustrated in Figure 2. The AR Flipbook has been evaluated for feasibility by subject matter experts, including a Basic Programming teacher from one of Vocational High School Bandung and an architecture lecturer from UPI. Furthermore, the application was tested by two media experts, including a lecturer from the educational technology program and a lecturer from the Multimedia program at UPI. The application was also tested by 30 respondents from class X.1 students, yielding excellent usability results.

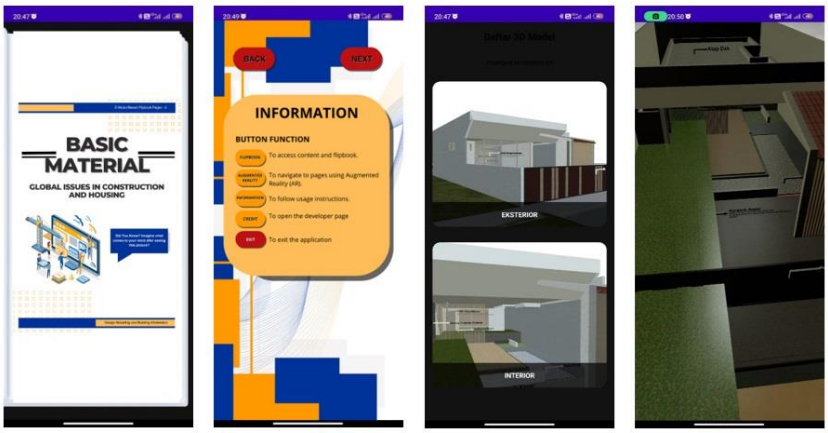

Figure 2. Display of Flipbook Application with AR

In this study, testing is required to evaluate questions that can measure students' improvement in critical thinking abilities. Therefore, a trial test was conducted involving class X.1. The purpose of this trial was to assess the quality of the test items from various aspects such as validity, reliability, difficulty level, and distinguishing power of the questions.

The validity of the test items was measured using the Pearson Product-Moment Correlation formula [72]. The test instrument for pretest and posttest consisted of 20 items given to 30 students in class X. Validity of this instrument was assessed by comparing the calculated correlation value (r-value) with the correlation value in the criteria table (r-table) [73]. If the significance value of the test results is < 0.05, then the instrument is considered valid; conversely, if the significance value is > 0.05, then the instrument is considered invalid. The test results showed that the calculated t-value (0.362) exceeded the critical value, which ranges from 0.356 to 0.661, indicating that the 20 items used can be considered valid. Validity of test instruments results can be seen in Table 1.

Table 1. Validation of Test Instruments

Total		
N	Pearson Correlation	Sig. (2-tailed)
30	0.587**	0.001
30	0.502**	0.005
30	0.356	0.054
30	0.446*	0.014
30	0.587**	0.001
30	0.535**	0.002

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30	0.431*	0.017
30	0.448*	0.013
30	0.489**	0.006
30	0.488**	0.006
30	0.643**	0
30	0.482**	0.007
30	0.643**	0.000
30	0.448*	0.013
30	0.552**	0.002
30	0.533**	0.002
30	0.465**	0.010
30	0.552**	0.002
30	0.489**	0.006
30	0.661**	0.000
30	1	

Next, a reliability test of the test items was conducted, measured using the Cronbach Alpha formula. Reliability measurement refers to the criteria stated in Table 2. This reliability test establishes that if the r-Alpha value is positive and exceeds the r-table value, then the test items are considered reliable; conversely, if the r-Alpha value is negative and smaller than the r-table value, then the test items are considered unreliable. The research results indicated a reliability value of 0.926, which falls into the category of very high reliability as shown in Table 2.

Table 2. Item Reliability

Cronbach's Alpha	N of Items
0.926	20

To evaluate the difficulty level of the test items, the level of difficulty formula detailed in Table 3 was used. To ensure optimal measurement of students' critical thinking abilities, the test items should fall into the moderate to difficult difficulty categories, in line with cognitive levels C4 (analyzing), C5 (evaluating), and C6 (creating) according to the revised Bloom's taxonomy by Anderson. The research results showed in Table 3 that out of 20 test items, 16 items were categorized as moderate, while 4 items were categorized as difficult, with a difficulty range between 0.33 to 0.60.

Table 3. Level of Difficulty Test

Recapitulation Level of Difficulty Test					
No.	Mean	Classification	No.	Mean	Classification
1	0.53	Moderate	11	0.60	Moderate
2	0.60	Moderate	12	0.53	Moderate
3	0.37	Difficult	13	0.60	Moderate
4	0.37	Difficult	14	0.53	Moderate
5	0.53	Moderate	15	0.57	Moderate
6	0.37	Difficult	16	0.33	Difficult
7	0.60	Moderate	17	0.53	Moderate
8	0.53	Moderate	18	0.57	Moderate
9	0.47	Moderate	19	0.47	Moderate
10	0.40	Moderate	20	0.60	Moderate

Lastly, a item distinguishing power test was conducted to prove that the answer choices were in the good category. The research results indicated that the item distinguishing power of the test items used ranged from 0.356 to 0.643. Assessment of the Item Distinguishing power category is stated as moderate if the coefficient falls within the range of 0.3 to 0.39, and it is considered good if the coefficient

falls within the range of 0.4 to 1.00 [74]. From these results in Table 4, it can be concluded that out of the 20 test items used in this study, 19 items were categorized as good and 1 item was categorized as fairly good.

Table 4. Item Distinguishing Power Test

Recapitulation of Distinguishing Power Test					
No.	r_{Count}	Category	No.	r_{Count}	Category
1	0.587	Good	11	0.643	Good
2	0.502	Fair	12	0.482	Good
3	0.356	Good	13	0.642	Good
4	0.446	Good	14	0.448	Good
5	0.587	Good	15	0.552	Good
6	0.535	Good	16	0.533	Good
7	0.431	Good	17	0.465	Good
8	0.448	Good	18	0.552	Good
9	0.489	Good	19	0.489	Good
10	0.488	Good	20	0.611	Good

After the test instrument was evaluated, researchers could utilize the instrument to measure students' critical thinking abilities through pre-tests and post-tests. The pre-test aimed to assess the initial abilities of students in both the control class (X.2) and the experimental class (X.3). Subsequently, the experimental class received a special treatment involving the use of flipbooks with Augmented Reality (AR), while the control class continued to use conventional teaching media without any special treatment. After the treatment was administered, students in both groups were given post-tests to measure changes in their levels of critical thinking abilities.

As shown in Table 5, the significance value of the normality test for the pretest in the control class is 0.083 and for the pretest in the experimental class is 0.200. For the posttest, the significance value for the control class is 0.081 and for the experimental class is 0.200. These results indicate that the data from both classes meet the normality test requirements, with significance values greater than 0.05. Therefore, it can be concluded that both groups have a normal data distribution.

Table 5. Test of Normality

Class		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	Df	Sig.	Statistic	df	Sig.
Pretest	Control	0.145	32	0.083	0.972	32	0.550
	Experiment	0.127	32	0.200*	0.962	32	0.317
Posttest	Control	0.146	32	0.081	0.938	32	0.064
	Experiment	0.119	32	0.200*	0.952	32	0.166

As shown in Table 6, the test values from the homogeneity test range from 0.176 to 0.770. This range indicates that both classes can be considered homogeneous according to the homogeneity requirements, as these values fall within the accepted limits for data homogeneity.

Table 6. Test of Homogeneity of Variance

		Levene Statistic	df1	df2	Sig.
Pretest	Based on Mean	0.086	1	62.000	0.770
	Based on Median	0.094	1	62.000	0.761
	Based on Median and with adjusted df	0.094	1	61.235	0.761
	Based on trimmed mean	0.093	1	62.000	0.761
Posttest	Based on Mean	1.872	1	62.000	0.176
	Based on Median	1.642	1	62.000	0.205
	Based on Median and with adjusted df	1.642	1	61.886	0.205

Based on trimmed mean	1.735	1	62.000	0.193

Based on Table 7, it is evident that the independence test value for the pretest in both the control and experimental classes is 0.776. This indicates that there is no significant difference in abilities between the two classes before the treatment was given. Conversely, the independence test value for the posttest in the control and experimental classes is 0.000. This result indicates a significant difference in abilities between the two classes after the treatment, suggesting that the intervention provided had a different impact on each class.

Table 7. Independent Samples Test

	t-test for Equality of Means			
	T	Df	Sig. (2-tailed)	Mean Difference
Pretest	-0.286	62.000	0.776	-0.93750
Posttest	-6.697	62.000	0.000	-18.59375

Furthermore, the results of the pre-test and post-test in Table 8 and Figure 3 indicate that the control group had a lower N-gain score compared to the experimental group. The control group achieved an N-gain score of 0.098, categorizing as low, while the experimental group attained an N-gain score of 0.6, categorized as moderate. Based on the criteria for interpreting N-Gain values, the use of Flipbook with AR as a learning medium has proven effective in enhancing students' critical thinking skills.

Table 8. Result of N-Gain

Class			Statistic	Std. Error
N-Gain_Percent	Control	Mean	9.8076	5.02276
	Experiment	Mean	60.7594	4.00506

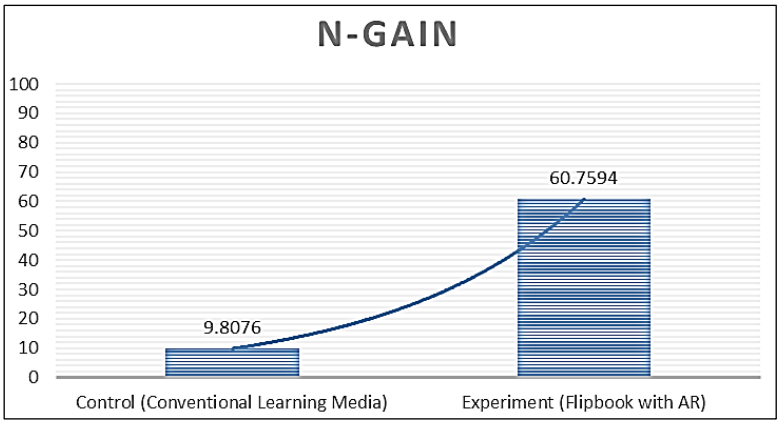

Figure 3. Grafic of N-Gain

This comparison indicates that the implementation of Flipbook with augmented reality (AR) as a learning media significantly impacts the improvement of students' critical thinking skills. With higher N-gain scores, the experimental class demonstrates that this learning approach can be more effective in stimulating the development of critical thinking skills compared to the conventional method applied in the control class.

The results of this study indicate a significant increase in students' critical thinking skills following the implementation of flipbook learning media with augmented reality (AR). This improvement reflects the effectiveness of using AR technology in supporting a more interactive and enganging learning experience.

Previous studies have also examined the effectiveness of various conventional learning media such as PowerPoint and e-modules. For instance, a study conducted by [60] showed that the use of PowerPoint in teaching can enhance students' understanding of the material, but it does not significantly affect critical thinking skills. Meanwhile, research by [61] found that e-modules can increase student

engagement and understanding of the material, but the improvement in critical thinking skills remains limited. Compared to these conventional learning media, flipbooks with augmented reality provide better results in enhancing students' critical thinking skills. This may be due to AR's ability to present material visually and interactively, which can stimulate students' analytical and critical thinking more effectively than static presentations like PowerPoint or electronic modules. Thus, it can be concluded that the utilization of Flipbook with AR as a learning medium has been proven effective in enhancing students' critical thinking skills. These findings provide strong support for the development and implementation of interactive learning technologies in the educational context, particularly in enhancing critical thinking aspects among students. It emphasizes the importance of integrating technology into the learning process to broaden the scope of learning and enrich students' learning experiences.

4. Conclusion

This study confirms the success of the experimental class implementing Flipbook with augmented reality (AR) in achieving a significant improvement in student comprehension. This is evidenced by a much higher increase in critical thinking aspects in the experimental class compared to the control class. This improvement demonstrates the effectiveness of Flipbook with AR in enhancing student comprehension. Tangible evidence is seen in the comparison of critical thinking aspects, where the experimental class shows a much higher percentage than the control class. This striking difference provides a clear picture of the positive impact of using Flipbook with AR on student comprehension progress, particularly in developing critical thinking skills. These findings underscore the potential of innovative teaching methods like Flipbook with AR to revolutionize and optimize the learning experience, paving the way for more engaged and proficient learners. This study shows that the use of advanced technology in education can provide significant benefits in the learning process, enhancing the quality of education and helping students achieve better learning outcomes.

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