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Review Article

Augmented reality integrated education game using problem-based learning model to improve critical thinking skills

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Abstract: Limited students' critical thinking skills in learning can be strengthened by using augmented reality technology applications. The main objective of this research is to analyze the problem-based learning model with integrated augmented reality educational games in improving students' critical thinking abilities. This quasi-experimental research used a nonequivalent control group design. The research sample consisted of 60 students from SD Muhammadiyah 09 Surabaya who were selected using purposive sampling. Data was collected by observing the implementation of learning and testing students' critical thinking levels. The data obtained in the research was processed statistically based on research obtained with a significant value of 0.000 < 0.05, confirming that Ho was rejected and H1 was accepted. Thus, the probability value is 0.000 < 0.05, so all coefficients have meaning. Applying the PBL model with integrated augmented reality educational games on critical thinking skills has a significant effect. From the ANOVA test or F-test, Fcount was 45,348 with a significance level of 0.000. This probability is smaller than 0.05, so the learning model to predict the level of participation in learning with a problem-based learning model through educational games integrated with augmented reality influences students' critical thinking skills.

Keywords: augmented reality technology; critical thinking skills; educational games; problem-based learning model

1. Introduction

In the era of technological development that is more modern, it was such a compulsion to fulfill human needs (Lindner et al., 2019). Learning media has affected advanced technology in education (Bursali & Yilmaz, 2019; Joda et al., 2019). Technology allows the teacher to make fun of learning media in the learning process (Fidan & Tuncel, 2019; Yip et al., 2019). The problem often encountered in the learning process was indicated to be sick and tired, so the situation could have been more fun (Dring, 2019; Qin et al., 2021). The learning process for elementary school students focused on learning by playing. The students loved playing using learning media (Aslan, 2021; Chen & Kuo, 2019). Generally, playing was an infallible part of the child's life and integral to establishing a child's attitude. Nowadays, play is used for learning integrated with the developments of technology (Riche et al., 2019; Sahin & Yilmaz, 2020).

Digital plays are audio-visualized in the form of an application, and the play is called a game nowadays (Huang et al., 2017; Lee et al., 2020). There are so many forms of games for educational purposes that are used for the learning process. In this era, it is not impossible to utilize games for learning media that affects fun and practical situations (Law & Heintz, 2021; Martín Gutiérrez et al., 2015). Learning media was used to clear up the presence of messages to avoid being verbally dominant and overcome the limit of space, time, and sensory ability (Liu et al., 2015; Prit et al., 2020). Learning media used and implemented for elementary students must be based on the potential and ability developed by the teacher as the facilitator (Farrow, 2019; Soetrisno & Yoku, 2019). Elementary school students rely on productive educative games by giving them space to express themselves (Lestari et al., 2018; Setyawan, 2019).

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Implemented learning processes must be constructive and focused on something other than the students rather than the teacher. Internal and external factors influence the learning process's success (Ayçiçek, 2021; Sapeni & Said, 2020). The internal factors, such as learning results, consisted of interest, motivation, attention to learning, and readiness to learn, then the external factors, such as teacher teaching method, classroom (facility), classmates, and media of technology (Anderson et al., 2021; Montepara et al., 2021). The learning process that must be attempted is digitalization with technology. Developed digital media nowadays is mobile augmented reality (AR) (Al-Ismaily et al., 2021; Garzón et al., 2020). Augmented Reality was one technology in multimedia that combined the digital object with the natural world; in other words, it was such a combination of digital objects with the natural world that the implementation used a camera as the media (Servant-Miklos, 2019a, 2019b). Then, it gave the user a preview of the combination of the natural world and cyber-world observed in the same place (Barth et al., 2019; Oranç & Küntay, 2019; Theodoropoulos & Lepouras, 2021).

Learning media through augmented reality (AR) is a combination of objects in the virtual world that are applied to the real world in two-dimensional or three-dimensional forms so that they can be touched, seen, and heard (Hussain et al., 2019; McCarthy & Uppot, 2019). The augmented reality-assisted media referred to in this case is through educational games (Andersen et al., 2019; Balan et al., 2019; Liu et al., 2019). Learning through educational games is assisted by Android-based augmented reality, which is implemented in the learning process (Roopa et al., 2020; Ting et al., 2021). Using learning media through games assisted by AR technology has great potential in science, which displays attractive visuals and 3D animation and emphasizes more practical and effective learning (Andersen et al., 2019; Aslan et al., 2019; Harun et al., 2020). Learning through games has existed since the beginning of civilization. Recent research shows that playing games contributes to faster reactions and improves students' critical thinking in the learning process (Arulanand et al., 2020; Gholami et al., 2021; Liono et al., 2021).

Critical thinking ability is a natural and reactive way of thinking to determine focus in determining what to believe and do in learning (Ayçiçek, 2021; Sapeni & Said, 2020). Critical thinking ability is one of the life skills that students must have (Huang et al., 2017; Lee et al., 2020). The ability to think critically will help students solve simple or complex problems (Chen et al., 2016; Murano et al., 2021). Critical thinking abilities are abilities a person needs to face various problems in group and personal life (Ngajie et al., 2020; Polat & Aydın, 2020). Optimal student critical thinking ability requires interactive classes and more emphasis on the student center (AlMarwani, 2020; Kavenuke et al., 2020). Improving students' critical thinking ability through educational game media assisted by augmented reality according to the needs of elementary school students (Dekker, 2020; Tang et al., 2020).

Learning carried out in elementary schools must be oriented toward students' abilities so that the learning atmosphere is more enjoyable in the learning process (Diago et al., 2022; Lin et al., 2019). Current educational games are learning to provide a more meaningful atmosphere and motivate students more (Cai, 2021; Richards et al., 2020). Even though teachers are only facilitators in the learning process, and students must be more active, teachers must create a pleasant learning atmosphere to stimulate students to be more active (Kiili et al., 2020; Xin et al., 2020). Various factors greatly influence fun learning activities, including the choice of learning media that is more interesting, interactive, and fun (Tabatabaei et al., 2019; Thongsuwan et al., 2021). Using learning media using augmented reality makes learning easy for students and fun. It can make it easier to increase students' digital literacy (Smith et al., 2019; Suri & Gupta, 2019). Then, the ability to think critically is a child's ability to understand and use analysis of the problems they face (Sandrone & Carlson, 2021; Serpa et al., 2020).

Research discussing critical thinking skills could be more optimal in educational circles (Pritzkoleit et al., 2020; Quandt et al., 2020). Critical thinking emphasizes analytical

skills that solve a problem (Pereira et al., 2021; Phungsuk et al., 2017). Empowering critical thinking skills must be prioritized in the learning process carried out by teachers (Nadolny et al., 2020; Noroozi et al., 2020). Learning innovation using problem-based learning (PBL) as a learning model is known in education today. However, it should be noted that more research is needed to link the PBL model with educational game media integrated with augmented reality (AR) technology because connecting learning models adapted to technological developments is necessary for the current learning process. The PBL learning model, assisted by educational games integrated with augmented reality, which is implemented, aims to empower elementary school students' critical thinking abilities. Because this model is problem-oriented, students will be skilled in finding alternative solutions.

2. Materials and Methods

2.1 Research Design

The research is quasi-experimental on implementing the problem-based learning (PBL) model through educational games integrated with augmented reality technology. The independent variable used in this research is PBL through educational games integrated with augmented reality technology, which is symbolized by.

2.2 Participants

In determining respondents for this research, the Muhammadiyah Elementary School in Surabaya City was first determined as the research setting. Researchers determined the research location at SD Muhammadiyah 09 Surabaya. The research location was chosen randomly through purposive sampling, carried out directly from the population without determining or examining the population structure. The type of sampling that the researcher used was cluster random sampling. Cluster random sampling is a method of taking samples based on a group of individuals and not taken individually or individually. The criteria for respondents in this research were students at SD Muhammadiyah 9 Surabaya. The research subjects used were 60 students who participated carefully in this research. Their average age is 10-11 years from grade 5 (fifth).

2.3 Data Collection

Researchers carried out data collection in October 2020. Before the research began, the instruments were written and submitted to experts for feasibility. The learning model is carried out using an observation sheet instrument consisting of initial activities, core activities, and final activities. Meanwhile, critical thinking abilities are carried out using observation sheet instruments and tests. The research team introduced the idea that teachers were assured that all information collected would be kept confidential. In implementing learning through the PBL model with integrated Augmented Reality educational games, a review was conducted during 2 (two) meetings. Meanwhile, finding critical thinking ability data through observation sheets and tests that refer to indicators builds basic ability, concludes, provides further explanations, and develops strategies and tactics.

2.4 Data Analysis

Data analysis uses descriptive statistics to determine the distribution of independent variables and inferential statistics to test the influence between independent and dependent variables. Descriptive statistics use frequencies and percentages, while inferential statistics use the T-test and one-way ANOVA analysis to assess differences in average values based on the independent and dependent variables. This T-test analysis aims to understand the influence between the problem-based learning model and augmented reality integrated educational games as the independent variable on critical thinking skills as the dependent variable. Previously, the normality test prerequisites were tested as a test on the sample to find out whether the data was normally distributed and a

homogeneity test using the Kolmogorov-Smirnov method via the SPSS software application with the latest version at this time.

3. Results

This research was conducted using a model with elementary school students in Surabaya, coinciding with SD Muhammadiyah 09 Surabaya. The selection of research samples is carried out through techniques of purposive sampling with certain considerations so that researchers can determine sampling by determining special characteristics that are by the research objectives so that they are expected to be able to answer research problems. Specifically, the learning used is a problem-based learning (PBL) model through educational games integrated with Augmented Reality technology to improve elementary school students' critical thinking ability. The stages of learning using models PBL through educational games integrated with Augmented Reality technology at SD Muhammadiyah Surabaya can be described in the following Table 1.

Table 1. Stages of the PBL Model through educational games integrated with AR.

Learning stages	Activities
Student orientation to the problem	The teacher explains the learning objectives, explains the logistics required, poses problems contained in the learning video, and motivates students to be involved in problem-solving activities of their choice through the learning media that has been presented. Students explained that operating educational game media integrated with augmented reality provides a fun learning process.
Organizing students to study	Teachers help students define and organize problem-related learning tasks by using educational game media integrated with augmented reality, which students can use Android in accordance with the material to be delivered. Then, the teacher provides LKPD, which can be used as a reference for students following the lesson.
Guiding individual and group investigations	The teacher encourages students to collect appropriate information from various sources by referring to the educational games used and carrying out experiments to get explanations for solving problems while using educational game media via Android in groups that have been previously formed.
Develop and present results.	The teacher helps students plan and prepare appropriate work, such as reports and educational posters, according to the student's level of understanding and helps students to share assignments with their groups. Then, the results of their work are presented sequentially, and other groups respond and criticize.
Analyze/evaluate the problem-solving process.	The teacher helps students reflect or evaluate the investigations carried out in the learning process with the students' processes. This is to show that students' learning is more meaningful or enjoyable.

Source: (Dring, 2019)

This research's initial analysis is related to the distribution of respondents based on gender and age, which can be explained through the Table 2. in the following learning process.

Table 2. Distribution of Respondents by Gender and Age

Gender	Amount	%
Male	28	46.6
Female	32	53.4
Age		
9-10	23	38.3
11-12	37	61.7

The Table 2. shows that most respondents (46.6%) were men and 53.7% were women. However, if analyzed more deeply, the proportion of women compared to men is 1 2, so this situation shows that there are more women than men. In this study, the ages of respondents were grouped into three parts. Based on this grouping, it turns out that at the age of 9 years to 10 years, the percentage is (38.3%) and at the age of 11-12 years, the percentage is (61.7%). Based on the research results, the description of the gender and age of the respondents shows that they are at the elementary school level. In terms of gender, there are more female students than male students, while the dominant age range is 11-12 years. Then, the implementation of learning can be explained in the following Table 3.

Table 3. Implementation of Learning

Activity	Total Indicator	Implementation			r	Criteria
		1	2	3		
Introduction	6	4,50	4,66	4,83	4,66	Good
Core Strength	16	4,50	4,68	4,81	4,66	Good
Closing	4	4,25	4,50	4,75	4,59	Good

From the Table 3. the implementation of learning with teachers using the PBL model can be stated using good criteria, starting from preliminary, core, and closing activities. In the preliminary activities, the average score was 4.66 with the criteria "good." Implementing this activity using the PBL model with augmented reality integrated educational games received an average score of 4.66 with the criteria "good." Meanwhile, in the closing activity, learning was implemented using a PBL model assisted by educational games integrated with augmented reality, with the criteria obtained being "good." This means that implementing learning using the PBL model with educational games integrated with augmented reality improves critical thinking ability with "good" criteria. Then, it is seen that the data is analyzed using a normality test first, presented in Figure 1.

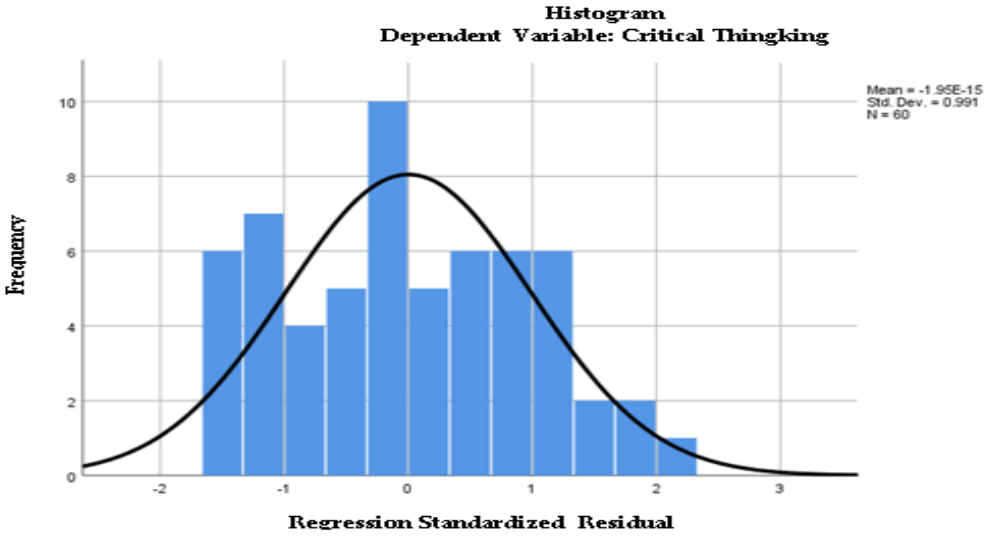

Figure 1. Normality Test histogram graph

Based on these rules, all variables in this study have a normal distribution. The image above is a histogram graph, which is normal if the data distribution forms a bell*(bell-shaped)*, not leaning left or not leaning right. The histogram graph above forms a bell and does not lean to the right or left, so the histogram graph is declared normal. Based on the histogram graph of the residual data normality test above, the data forms a bell curve (symmetrical curve). Thus, the residual data is normally distributed. Thus, the regression model for the influence of the independent variable on the dependent variable has met the data normality requirements. Then, the data forms a normal curve, and most of the bars are below the curve; the variable is normally distributed, can be seen in Figure 2.

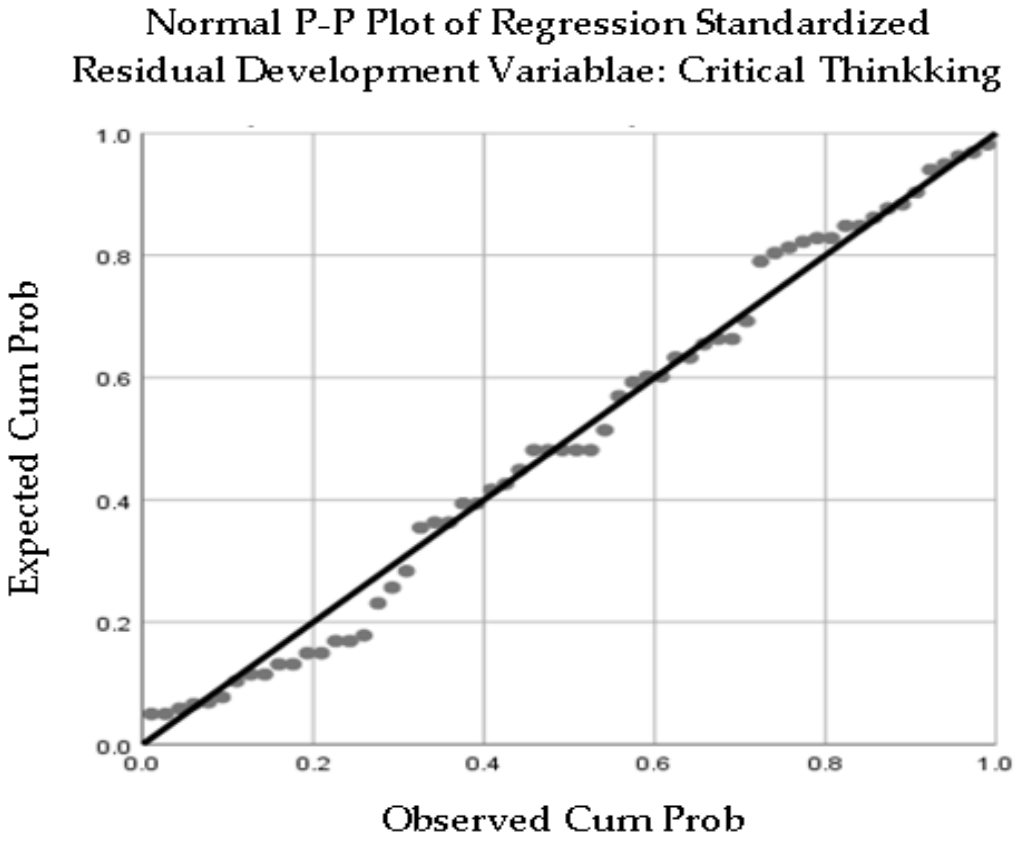

Figure 2. P-P Graph Normality Test Plot

One of the basic assumptions that must be met before carrying out a parametric statistical test is to use a normality test. This test is used to see whether the data that has been collected is distributed according to a normal distribution. From the pretest normality test based on the Q-Q Plot, the visible plots appear to fit lines, so the data is said to be normally distributed. Because the data above the point follows the normal line. Based on the graph above, the interpretation of the Q-Q plot for the value of critical thinking ability is based on a straight line that runs from the bottom left corner to the top right to form a diagonal direction. Based on the graph above, the curve and the points are spread close to a straight line; thus, based on the results of normality testing with the normal Q-Q Plot, it is proven that the critical thinking ability data is normally distributed.

Followed by the regression analysis results related to the Problem-Based Learning model with integrated Augmented Reality educational games on students' critical thinking ability. Before the regression test is carried out, it is first carried out using the multicollinearity test. The multicollinearity test aims to determine whether, in a regression model, a high or perfect correlation is found between the independent variables or the dependent variable. This research test shows that it can be seen by looking at the tolerance value and variance inflation factor (VIF) value, which can be seen in the Table 4.

Table 4. Multicollinearity and coefficients checking

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	27.472	8.922		3.079	.003		
	PBL	.731	.109	.662	6.734	.000	1.000	1.000

a. Dependent Variable: Critical Thinking

Based on the Table 4. the collinearity statistics section, the tolerance values for the variables show that critical thinking is greater than 0.10 and the VIF value is <10.00. This means that it can be concluded that the data shows no symptoms of multicollinearity in the regression model, and the assumptions are met. Then, it can be seen from the criteria heteroscedasticity with indicators H0 that is, there are no symptoms of heteroscedasticity in the regression model and H1, namely, symptoms of heteroscedasticity occur in the regression model. The heteroscedasticity test method used is the Glejser method. The significance value is 0.000. Because the significance value of the independent variable is greater than 0.05, Ho is rejected, which means heteroscedasticity occurs in the regression model.

Results of regression testing by the hypothesis with indicator H0, namely there is no influence of PBL model learning on critical thinking, and H1 It can be stated that there is an influence of PBL model learning on critical thinking with provisions Significant level which can be explained through the following Table 5.

Table 5. Multicollinearity Checking with Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	27.472	8.922		3.079	.003		
	PBL	.731	.109	.662	6.734	.000	1.000	1.000

a. Dependent variable: Critical thinking

The Table 5. shows that the coefficient of determination or R-square value is 0.439 or 43.9%. This number means that PBL model learning assisted educational games integrated with augmented reality towards critical thinking ability of 43,9%. At the same time, the remainder (100%-43,9%=56.1%) is influenced by other variables outside this regression equation or variables not studied (error), the result ANOVA Regression Test presented in Table 6.

Table 6. ANOVA[a] Regression Test

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	491.000	1	491.000	45.348	.000[b]
	Residual	627.984	58	10.827		
	Total	1118.983	59			

a. Dependent variable: Critical thinking
b. Predictors: (constant), PBL

From the ANOVA test in Table 6. the probability value is 0.006 < 0.05, so the whole regression coefficients have meaning. Then, the model of PBL is assisted by an educational game integrated with augmented reality towards critical thinking ability. This section describes the significance level of the ANOVA test or F-test, obtained Fcount 45.348 with

a significance level of 0.000. Because this probability (significance level) is smaller than 0.05, this regression model can be used to predict the level of participation in learning. In other words, implementing the PBL model with integrated Augmented Reality educational games influences students' critical thinking ability. This means that using educational games significantly impacts students' thinking abilities in any situation, the summery presented in Table 7.

Table 7. Summary of F Test Results

Data type	Fcount	F_{table}	Information
PBL Model assisted by educational game integrated with augmented reality and critical thinking	45.348	2.000	45.348 > 2.000 (Influence Exist/ Relation exist)

Results of data analysis about the influence of the PBL model assisted by educational games integrated with augmented reality towards critical thinking ability show the calculated F influence coefficient of 45.348 with a sig value of 0.000. If the calculated F value is compared with the F table, the calculated F is greater than the F table (45,348 > 2,000), and the sig value, if compared with sig $\alpha = 0.05$, then the significant value is smaller than sig α, namely 0.000 < 0.05. As a result of the data analysis, it can be concluded that the hypothesis of this research can be stated that there is an influence of the Problem-Based Learning model with integrated Augmented Reality educational games on students' critical thinking ability regarding acceptance and significance.

Then, the significance value (sig.) in the t-test is 0.000. Because sig. o, so < then conclusions can be known there is the influence of The PBL model assisted integrated Augmented Reality educational game towards students' critical thinking ability. The regression model equation problem-based learning model assisted by educational games integrated with augmented reality on critical thinking ability forms the regression equation Y= 27.472 + 0.731 Problem-based learning model learning assisted by educational games integrated with augmented reality interpretation of regression equation models. If variable Problem-Based Learning Model Learning increases by 1 unit, the value of critical thinking ability will increase by 0.731.

4. Discussion

The results of this research show that the application of The Problem-Based Learning (PBL) model with integrated Augmented Reality educational games has a significant relationship with students' critical thinking ability, according to the results of the data analysis that has been carried out. Based on the histogram graph of the residual data normality test, it can be seen that the data used forms a bell curve (symmetrical curve); it can be stated that the residual data is normally distributed, then the regression model of the influence of the independent variable on the dependent variable has met the data normality requirements (Alabdulakareem & Jamjoom, 2020; Arya Wiratama et al., 2018). From the pretest normality test based on the Q-Q Plot, the visible plots appear to fit lines, so the data is said to be normally distributed. The data above the points follow the standard line, so the critical thinking ability data is normally distributed (Adaptasi et al., 2021; Hakim, 2018). The Normality Test is a test carried out to assess the distribution of data in a group of data or variables, whether the data distribution is normally distributed or not normally distributed (Aprilinda et al., 2020; Haryani & Triyono, 2017).

The table above shows that the coefficient of determination or Rsquare value is 0.439 or 43.9%. This number means that PBL model learning assisted educational games integrated with augmented reality towards critical thinking ability of 43,9%. At the same time, the remainder (100%-43,9%. = 56.1%) is influenced by other variables outside this regression equation or variables not studied (error). The ANOVA test shows that the probability value is 0.006 <0.05, so all regression coefficients have meaning. Results of data analysis regarding the influence model PBL assisted educational game integrated with augmented reality towards critical thinking ability shows the calculated F influence

coefficient of 45.348 with a sig value of 0.000. So, the calculated F is greater than the F table (45,348 > 2,000), and when the sig value is compared with sig α = 0.05, the significant value is smaller than sig α, namely 0.000 < 0.05. From the data obtained, it is clear that the PBL model with integrated Augmented Reality educational games continuously impacts students' critical thinking ability (Meishanti & Roziqo, 2021; Romadhoni & Prasetyo, 2021).

In the current sophisticated era, elementary school students' critical thinking ability must be empowered as an effective way to make students skilled in carrying out the learning process (Areni et al., 2018; Long et al., 2020). Critical thinking ability, quoted from Ennis, is a natural and reactive way of thinking to determine focus in determining what to believe and do (Abbasi et al., 2019; Pour et al., 2020). Critical thinking is a very important ability to support the success of students' understanding so that it will impact student learning outcomes (Wang et al., 2021; Weeks et al., 2021). Therefore, an educator must prepare a thorough and comprehensive plan in choosing a learning model to continuously encourage students to improve their critical thinking ability (Hincapie et al., 2021; Venkatesan et al., 2021). Based on the problems students face, choosing an innovative learning model is a must for teachers, one of which is the PBL model assisted by augmented reality learning media (Albar & Southcott, 2021; Seibert, 2021; Zhou et al., 2020).

Applying the PBL model arises from the concept that students will be better able to explore their critical thinking ability if they are actively involved in solving a problem related to a subject (Bosica et al., 2021; Wedel et al., 2019). This learning model is a learning process that prioritizes students' ability to analyze learning material independently using real problems to face so that students can think critically (Ali-Abadi et al., 2020; Din, 2020). Then, develop problem-solving ability and gain knowledge independently (Blakeslee, 2020; Wong & Kowitlawakul, 2020). On the other hand, this model is also associated with the current development of technological media, namely mobile augmented reality (López et al., 2020; Rababa & Masha'al, 2020). The technological media in question is assisted by augmented reality, designed through educational games that emphasize improving critical thinking ability in the learning process (Bursali & Yilmaz, 2019; Lindner et al., 2019).

Based on the description above, applying the PBL model assisted by Augmented Reality Integrated Educational Games can improve students' critical thinking ability (Dring, 2019; Sahin & Yilmaz, 2020). This research strengthens previous research, namely that applying the Problem-Based Learning model can improve students' critical thinking ability, as carried out by (Aslan, 2021; Montepara et al., 2021). This research also shows that the success of implementing the PBL model assisted by augmented reality-integrated educational games measures students' ability to think critically (Giuliano et al., 2021; Sitti et al., 2013). By implementing the PBL model, teachers can make it easier for students to provide direct experience to students on how to solve everyday problems so that learning will be more meaningful according to the material taught by the teacher classically and externally (Awan et al., 2019; Wijnia et al., 2014). Learning is fun and meaningful when teachers use learning models that suit students' needs (Dring, 2019; Rudek, 2012).

5. Conclusions

Implementing the problem-based learning (PBL) model through educational games integrated with augmented reality technology can improve students' critical thinking ability. This is demonstrated by data analysis regarding the influence of the PBL Berserkan educational game integrated with augmented reality towards critical thinking ability, with the calculated F influence coefficient of 45.348 with a sig value of 0.000. So, the calculated F is greater than the F table (45,348 > 2,000), and when the sig value is compared with sig α = 0.05, the significant value is smaller than sig α, namely 0.000 < 0.05. The data shows that the PBL model with integrated Augmented Reality educational games affects students' critical thinking ability. The learning model to predict the level of participation

in learning with a problem-based learning model through educational games integrated with augmented reality influences students' critical thinking skills.

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