International Journal of Elementary Education
Volume 8, Number 2, Tahun 2024, pp. 354-363
P-ISSN: 2579-7158 E-ISSN: 2549-6050
Open Access: https://doi.org/10.23887/ijee.v8i2.70036

The Positive Impact of Game-Assisted Project Based Learning Model on Students' Critical Thinking Ability in Mathematics Learning

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ARTICLE INFO

Article history:
Received November 09, 2023
Accepted March 12, 2024
Available online May 25, 2024

Kata Kunci:
PjBL, Permainan, Berpikir Kritis

Keywords:
PjBL, Games, Critical Thinking

ABSTRAK

Kecemasan dan kesulitan memahami akan materi pada pembelajaran matematika pada anak berakibat pada penurunan kemampuan berpikir kritis anak. Tujuan penelitian ini yaitu menganalisis penerapan model PjBL murni dan model PjBL berbasis permainan terhadap kemampuan berpikir kritis anak. Penelitian ini merupakan jenis penelitian kuantitatif dengan metode eksperimen. Design penelitian yang digunakan adalah Mathing Pretest Posttest Control Grub Design. Populasi penelitian ini antara kelas 1- 6. Sampel peneltian ini adalah siswa kelas 5 dengan jumlah 32 dibagi kedalam 2 kelas yaitu kelas kontrol dan kelas eksperimen. Metode yang digunakan untuk mengumpulkan data yaitu dengan observasi dan tes. Instrument yang digunakan untuk mengumpulkan data yaitu dengan lembar soal. Teknik analisis data dilakukan dengan uji t dan uji anova dengan menggunakan aplikasi SPSS 25. Hasil analisis yaitu model PjBL murni dan PjBL berbasis permaian keduanya terjadi peningkatan skor sebelum dan sesudah diberikan perlakuan. Komparasi antara model PjBL berbasis permainan dan model PjBL murni menunjukkan bahwa model PjBL berbasis permainan lebih unggul dibandingkan dengan PjBL murni. Kesimpulan penelitian ini adalah kedua model PjBL baik murni maupun berbasis permainan memiliki pengaruh terhadap kemampuan berpikir kritis dan penggunaan model PjBL berbasis permainan lebih unnggul dalam peningkatan kemampuan berpikir kritis dibandingkan model PjBL murni.

ABSTRACT

Anxiety and difficulty understanding the material in mathematics learning in children results in a decrease in children's critical thinking abilities. The aim of this research was to analyze the application of the pure PjBL model and the game-based PjBL model to children's critical thinking abilities. This research was a type of quantitative research with experimental methods. The research design used was Mathing Pretest Posttest Control Group Design. The population of this research was between grades 1-6. The sample for this research is 32 grade 5 students divided into 2 classes, namely the control class and the experimental class. The method used to collect data was observation and tests. The instrument used to collect data was a question sheet. The data analysis technique was carried out using the t test and anova test using the SPSS 25 application. The results of the analysis were the pure PjBL model and game-based PjBL, both of which saw an increase in scores before and after being given treatment. Comparison between the game-based PjBL model and the pure PjBL model shows that the game-based PjBL model was superior to the pure PjBL. The conclusion of this research was that both pure and game-based PjBL models have an influence on critical thinking skills and the use of the game-based PjBL model was superior in improving critical thinking skills compared to the pure PjBL model.

1. INTRODUCTION

The dynamically changing environment means that students must have abilities that are sustainable and can be applied in the real world of students (Amalina & Vidakovich, 2023; Guven & Cabakcor, 2013). Mathematics is an important ability that allows students to obtain accurate explanations of phenomena that occur in the real environment. Including mathematics in students' lives is very important. This is because the role of mathematics can be applied in understanding sustainability sciences such as science, engineering, technology and economics (Amalina & Vidakovich, 2023; Anjum, 2015; Guven & Cabakcor, 2013). Mathematics is considered important because of its usefulness in technologically rich societies and as an important value in educational and career opportunities. However, mathematics is still feared by many students. This fear takes the form of anxiety when studying it because students consider mathematics a difficult science (Guven & Cabakcor, 2013; Iyamuremye et al., 2023; Whyte & Anthony, 2012).

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Students' fear of mathematics subjects becomes urgent which will have an impact on students' low critical thinking abilities. Anxiety and fear of mathematics is said to reduce students' critical thinking abilities, this is because anxiety refers to actual situational stress that is specifically experienced. Research also notes that math anxiety can affect individuals in various ways that can trigger cognitive, affective, or physical reactions. For example, cognitive reactions may involve negative self-talk, and blanking out. Anxiety can also be an affective reaction characterized by disbelief in abilities, fear of appearing stupid, and loss of self-esteem. Physical reactions may be evidenced by a person's sweating, increased blood pressure, heart rate, tension, or nausea (Iyamuremye et al., 2023; Simmons et al., 2023; Whyte & Anthony, 2012). Anxiety in mathematics is a feeling of worry and tension related to mathematics performance or anticipation of student performance in mathematics (Becker et al., 2022; Simmons et al., 2023).

Students' critical thinking skills in mathematics begin with eliminating students' anxiety by adding elements of the learning model as a form of solution of appropriate urgency and methods that are appropriate and fun for children (Evi & Indarini, 2021; Haqiqi et al., 2020; Prameswari et al., 2018; Upadani & Agustina, 2021; Zhou, 2022). A model that can be used to reduce students' anxiety about mathematics uses the project based learning (PjBL) model. The project based learning (PjBL) model is a learning model that focuses on students solving problems or finding solutions with groups that have been grouped (Antika & Nawawi, 2017; Apsari & Wiarta, 2020; Azizah et al., 2018). *Project based learning (PjBL) has been widely used in various subjects. PjBL is more often applied in science, mathematics, technology and social lessons* (Chen.C.H. & YangYC, 2019; Lusiana et al., 2022). This is because PjBL is relevant to students' lives, so this factor tends to increase learning motivation and can attract students' attention about these learning activities (Amini et al., 2019; Dywan & Airlanda, 2020). The benefits of PjBL include improving attitudes towards learning and subject matter. In addition, PjBL helps develop metacognitive skills in students, such as self-regulation and monitoring and supports independent and regulated learning. It is noteworthy that a number of studies show that PjBL is associated with significantly improved academic achievement.

Even though many studies state that PjBL is a learning model that can improve academic abilities and achievements, several studies show the contradiction that PjBL is not optimal and even has the same significance or is not superior compared to other learning models in improving academic achievement results in certain learning. Based on several research results that link the PjBL model with the PBL model, firstly, it can be seen from the effectiveness of the PjBL and PBL models with the help of Kahoot media on student learning outcomes showing the same individual and classical mastery between the comparison of the two models (Anazifa & Djukri, 2017; Lusiana et al., 2022). Second, it can be seen from the use of the PjBL and PBL models that there is no difference in learning outcomes in improving critical thinking. Based on the research results, it shows that critical thinking abilities in 21st century learning skills have a balanced percentage of 14.29% between the two models, namely the PjBL and PBL models. (Inayah et al., 2021; Muhammad et al., 2021; Suradika et al., 2023).

Comparison of PjBL with other models also found that the research results compared the PjBL model and the IBL model in mathematics lessons. The results of this research state that the use of the IBL (Inquiry-Based Learning) model is 39.3% superior compared to PjBL in mathematics learning in Europe (Vidic, 2023). Based on constructive alignment, the results of previous study multilevel model of research on student development such as interdisciplinary skills, reflective behavior, and recognizing disciplinary perspectives show that PBL improves students' interdisciplinary competence more than the PjBL model (Brassler & Dettmers, 2017). Judging from the motivation to improve student learning outcomes, other research results suggest that problem-based learning is superior in providing a greater impact in the academic field compared to project-based and case-based learning (Wijnia et al., 2024).

Although the impact of problem-based learning on motivation is generally positive, interplaying factors such as academic domain and level of implementation require different approaches to utilize effective teaching in increasing motivation for successful learning. One of the uses of effective teaching is project-based collaborative learning and a combination of game elements in the learning model which will be an advantage for teachers in overcoming students' anxiety problems which hinder the critical thinking process and can be an effective supplement for students in simultaneously developing critical thinking skills.

The learning process, when linked and combined with games, can encourage students to increase their attention to lessons. This is because mathematics learning will become more interesting if it is presented with a learning method that uses presentation concepts such as game activities (Arifah et al., 2018; McLaren et al., 2017). Game activities are daily activities carried out by children, so games are attached to children. Therefore, games are one of the learning supports that teachers can choose. Based on the results of students' initial abilities before being given treatment using the PjBL learning model. Critical thinking abilities in mathematics: 73% of students have low critical thinking abilities, 17% have moderate critical thinking abilities, and the remaining 10% have high critical thinking abilities in mathematics. Based

on the results of the initial ability test, it appears that some students have low critical thinking abilities. In fact, critical thinking skills are good for supporting a child's future because they will be used in their future life (Belecina, 2018; Yu & Wan Mohammad, 2019).

The results of this initial identification are supported by observations made, during sports lessons, sports teachers apply games to the lessons. In these learning activities, it appears that children are interested in games. Children look active and happier. This will maximize students' critical thinking abilities when applied in learning activities using the PjBL model. Using games in the PjBL model is considered to be related because both are models that use student activity (Angelina et al., 2023; Suwardika et al., 2022; Winarsih, 2020). Based on several studies regarding the things that underlie critical thinking skills and descriptions of the PjBL learning model and its relationship to games, it appears that learning is interesting with models and techniques that can improve critical thinking skills (Evi & Indarini, 2021; Hodiyanto, 2017). Based on several previous studies, learning using the PjBL model has proven that this model is appropriate for improving students' critical thinking skills (Hari Utomo et al., 2018; Lusiana et al., 2022).

The novelty of this study is integrating the game-based PjBL model in mathematics lessons. Based on these problems and observation results, researchers are interested in conducting research to conduct research that is useful for analyze the effectiveness of a combination of game-based Project Based Learning models in improving students' mathematical critical thinking skills with several objectives. The aims of this research are (1) Analyzing the significance difference between critical thinking abilities before and after receiving learning using the PjBL model, (2) Analyzing the significance difference between critical thinking abilities before and after being given a game base in the PjBL model. (3) Analyze the comparative effect of using the PjBL model with games and without games.

2. METHOD

The effect of using the PjBL model will be seen when a comparison is made between classes treated with the game-based PjBL model and classes without using the game-based PjBL model. To find the influence of the class given the treatment, the research is said to be a quantitative research type with an experimental approach. Experimental research is research that is used to find the effect of certain treatments on others under controlled conditions, in this case controlled conditions (Sugiyono, 2018). The controlled condition is the control class with the Project Based Learning (PjBl) learning model. The design of the research uses the mean difference between the Pretest and Posttest given in the experimental class and can then be compared again with the control class. In this research, the model used as a comparison or control class is the PjBL model without a game base. Critical thinking skills were measured using a pretest before being given the game base and after being given the game base. The following is a research design chart with matching pretest posttest design Table 1.

Table 1. Matching Chart Pre-test Post-test Design

Group	Pre-test	Treatment (X)	Post-test
Experiment Class	A1	X1	B1
Control Class	A2	X2	B2

This research was conducted in two elementary schools, namely SDN Kebonrejo and SDN 2 Glagah. Both elementary schools have the same population, namely there is only 1 class group at all levels between class 1 to class 6. The sample that will be used is class 5 students for the 2023-2024 school year at SDN Kebonrejo totaling 16 students who will be in the experimental class and SDN 2 Glagah totaling 16 students will be the control class.

The methods used to collect data are observation and tests. The instrument used to collect blood is a question sheet. The test technique used in this research aims to measure students' level of critical thinking after being given treatment using the game-based PjBL learning model in the experimental class group and the non-game-based PjBL learning model for the control class. Critical thinking abilities can be measured using Anderson's taxonomy level of cognition at levels C4-C6. Test questions are created for each question by researchers according to the basic competencies in each material. The grid for determining critical thinking ability test questions for students before being validated is shown in Table 2.

Table 2. A Grid of Critical Thinking Ability Test Questions Before Expert Validation

Cognitive Aspect	Description Test questions	Number
C4 (Analyze)	Explain what is meant by the sides of a block and do they have the same size? Give the reason.	1

Cognitive Aspect	Description Test questions	Number
	Compare the shapes of a block and a cube, if the length of the side of the block is 2 times the length of the side of the cube, and the width and height of the block are the same as the sides of the cube, will the two cubes when combined be the same size as the block? Give the reason.	2
	Explain in detail the differences between the formulas for a rectangular pyramid and a triangular pyramid?	3
C5 (Evaluate)	Prove that a cube that is cut will form another shape. What shapes can be formed?	4
	If you want to make a cube by combining 4 rectangular pyramids, what should you do?	5
C6 (Creations)	Make a rectangular pyramid frame	6
	Make a block frame	7
Total		**7**

Before the grid is used to determine the level of critical thinking ability, validation is first carried out. Content validation was carried out by experts, namely grade 5 teachers at elementary schools at SDN Kebonrejo and SDN 2 Glagah. Expert validation showed that the results contained 2 question numbers that were invalid because they were too easy and too difficult for grade 5 elementary school students. The final grid that will be used in this research is in Table 3.

Table 3. Critical Thinking Ability Test Question Grid After Expert Validation

Cognitive Aspect	Description Test questions	Number	Validation
C4 (Analyze)	Explain what is meant by the sides of a block and do they have the same size? Give the reason.	1	Valid
	Compare the shapes of a block and a cube, if the length of the side of the block is 2 times the length of the side of the cube, and the width and height of the block are the same as the sides of the cube, will the two cubes when combined be the same size as the block? Give the reason.	2	Valid
	Explain in detail the differences between the formulas for a rectangular pyramid and a triangular pyramid?	3	Valid
C5 (Evaluate)	Prove that a cube that is cut will form another shape. What shapes can be formed?	4	Valid
	If you want to make a cube by combining 4 rectangular pyramids, what should you do?	5	Not Valid
C6 (Creation)	Make a rectangular pyramid frame	6	Valid
	Make a block frame	7	Not Valid
Total		**7**	**5**

Data analysis used the t test analysis method and ANOVA test using the SPSS 25 application. The t test was used to test the hypothesis. The t test is used to compare or differentiate whether the means of the two groups tested are significantly different or not. The t test is used for paired tests to compare the means of two variables in one group. Then the t test is also used to test the results of the two classes in the class with treatment and the class without treatment. The ANOVA test is a form of statistical testing where researchers can draw conclusions based on inferential or group statistical data.

3. RESULT AND DISCUSSION

Result

This research was carried out with a parametric comparison test using a parametric comparison using dependent comparisons and independent comparisons between the two bases on the PjBL learning model, namely the experimental class using a game base on the PjBL learning model and a control class without a game base on the PjBL learning model. Before deciding to use parametric or non-parametric

techniques, a prerequisite test is carried out, namely using the normality test and homogeneity test. Normality tests and homogeneity tests were carried out using the SPSS 25 program.

The results of the normality and homogeneity test in this study were divided into two, namely normality and homogeneity. Pretest for the two groups namely the experimental class group and control class, and posttest for both groups, namely the experimental class group and the control class. The results of the normality test using the Kolmogorov-Smirnov normality test on the normality values of the pretest groups for both classes show that the data is said to be normal because it meets the requirements of more than an alpha value of 0.05, namely Asymp. Sig. (2-tailed) of 0.118. Likewise with the posttest data for both classes, it is known that the data for both posttest classes is normally distributed with Asymp values. Sig. (2-tailed) of 0.200 is greater than the alpha value of 0.05. Data is said to be homogeneous if the homogeneity test result is greater than the alpha value of 0.05. The results of the homogeneity test show that the data on the pretest value for both groups is greater than the alpha value of 0.05 of 0.876, so it can be concluded that the pretest data for the two groups is declared homogeneous. Likewise, with the posttest class, it is known that the homogeneity test results appear to be 0.538, which is greater than the alpha value of 0.05, so the posttest data is said to be homogeneous. Based on the results, normality and homogeneity have fulfilled the prerequisite elements as parametric data so that the t test and ANOVA test can be carried out to test the hypothesis and draw conclusions from this research..

The paired sample t test is part of the comparative hypothesis test or comparison test. The paired sample t test aims to find out whether there is a difference in the means of two samples that are paired or related. This comparison test was carried out to find out whether the model used had proven significant results between before and after treatment. Comparative tests were carried out in the experimental class using the game-based PjBL model and the non-game-based PjBL model control class. The paired sample t test shows a significance of 0.006, which is smaller than the alpha value of 0.05. So it can be concluded that the pretest and posttest results have significant differences. The results of the paired sample t test for both classes in mathematics learning with the game-based PjBL model and the non-game-based PjBL model can be seen in Tabel 4.

Tabel 4. Paired sampels PjBL Game Based and PjBL non Game Based.

Group	Pre-test	Post-test	Ascension	Sig.	N
PjBL Game base	60.63	81.19	20.56	0.006	16
PjBL non Game base	55.00	72.19	17.19	0.006	16

The increase in the average that occurred in the two models in Table 4 shows that by using the PjBL model, both game and non-game based, there is an increase in the average value. Both have a level of influence on scores before and after treatment. However, it turns out that using the PjBL model combined with games has a more significant influence on students' critical thinking abilities. This is based on the average results between learning models using game-based PjBL which are higher compared to non-game PjBL learning models. The significance of the two models is 0.006, indicating that there is a significant influence between the two classes.

Simultaneously using both bases in the PjBL model there is a significant difference in mean. However, independent tests need to be carried out. The independent test is a parametric test used to determine whether there is a difference in the mean between the two groups in the experimental class and the control class. Differences will appear in Tabel 5.

Tabel 5. Independent Samples Test

Independent Sampel Test	Means	N	Sig. (2-tailed)
Experiment Class	81.19	16	-
Control Class	72.19	16	-
Equal Variances assumed			0.000
Total	9.00		0.000

Based on Tabel 5 the sample test shows that the post-test results of both bases on the PjBL learning model show that the use of game-based learning in the PjBL learning model is proven to be better because it has an average post-test score of 81.19 compared to using the non-game-based PjBL learning model. The non-game based PjBL learning model only has an average score of 72.19 which is smaller than the average of the game based PjBL learning model. This is in accordance with the hypothesis that the use of the game-based PjBL learning model is suitable for students to use in class 5 mathematics lesson building material. Compared to using a non-game-based learning model, adding a game base to lessons is something teachers

can do to make learning more meaningful. Even so, the use of the non-game based PjBL learning model also has a positive influence on students' critical thinking abilities, students did experience an increase in scores, but the increase was not as high as using the game-based PjBL learning model.

The next test was to determine the difference in the mean results of the combination of PjBL with games and PjBL without games using the ANOVA test with the results show in Table 6.

Tabel 6. ANOVA Test

Model	Sum of Square	df	Mean Square	F	Sig.
Regression	591.035	1	591.035	12.557	0.003
Residual	658.965	14	47.069		
Total	**1250.000**	**15**			

Based on the Anova output in Table 6, the sig value is known. of 0.003 is smaller than the alpha value of 0.05, so it can be concluded that the average of the two models, namely the game-based PjBL model and the non-game PjBL model, is significantly different.

Discussion

Project-based learning has attracted and received increasing scholarly attention and enthusiasm in recent years, with applications ranging from elementary to university level for professional training (Kholid et al., 2022; Son & Penry, 2022; Vindergor, 2022). Several studies show that using the PjBL approach leads to significant improvements in all areas of achievement. Previous study noted this evidence to support the development of research, problem solving, and critical thinking skills (Gultekin & Bilimleri, 2005). Other study stated that learning through the PjBL model also increases students' interest in critical thinking processes, student presence and communication as well as developing their skills and abilities to work effectively in teams (Yanti et al., 2012). The concept of a high-quality PjBL learning model implies that teachers incorporate projects into learning activities without consistent quality outcomes. Although further study would help to validate this implication, the course design matrix we propose below recognizes that course attributes such as student voice and collaboration exist in various variations, and the matrix encourages teachers to design projects that best suit the discipline being studied (Son & Penry, 2022).

Learning with projects certainly increases students' critical abilities to complete learning or get to know concepts in real terms because students form their own knowledge based on what students do. Meaningful learning can be obtained from various activities and models, one of which is the use of the Project Based Learning (PjBL) learning model (Faridah et al., 2022; Setyowati & Mawardi, 2018). Apart from the meaningfulness of learning mathematics using the PjBL model, understanding concepts is also very important for improving critical thinking skills. Understanding concepts becomes a skill seen by the extent to which students explain the relationship between concepts and apply concepts or algorithms in a flexible, accurate, efficient and precise manner in solving problems (Munawwarah et al., 2020; Winarsih, 2020).

In accordance with research results, the use of PjBL in learning has a significant increase in thinking abilities before and after use. Based on the research results shows there is increase between pretest and posttest of 17.19 points. This shows that the use of the PjBL model is very dominant in improving critical thinking skills. In accordance with previous research, it shows that the use of the PjBL model increases student responses in creating cognitive results and student behavioral results during the learning process (Khafalah et al., 2023; Yoicu & Hasan, 2023). This can be seen from data on students' PjBL experiences collected through surveys. Apart from increasing activity in the classroom, the use of the PjBL model can encourage students to seek knowledge on their own which makes it possible to increase knowledge from practice and improve the skills needed for students. A supportive environment for students to work together critically can improve students' ability to work in teams well, thereby allowing for discussions within groups to solve the projects they will work on (Kongkhen & Chatwattana, 2023; Son & Penry, 2022).

Based on the research results, the application of the PjBL learning model combined with games has a higher increase than just using the PjBL model. The increase in score on the combination of the PjBL model and the game is increased by 20.56 points. This increase in points is due to the use of games being considered appropriate for elementary school age children who are still at the stage of enjoying playing so that using games results in higher point gains compared to without a combination of games. The use of games in learning can also improve understanding of concepts, increase critical thinking skills, improve learning outcomes, and increase learning achievement (Kholid et al., 2022; Pratama et al., 2019; Puspita et al., 2023; Winarsih, 2020). It can be concluded that modifying the PjBL model with games does have an influence on the intended results. Maximizing the results is the research objective so that the project based learning model can be implemented optimally.

The use of the PjBL model without a combination of games and the PjBL model with a combination of games has a mean difference as evidenced by the SPSS output results in the ANOVA test. The significance that appears in the SPSS output shows results that are smaller than the alpha value of 0.05, this proves that there is no similarity in the average between the two. Thus, the use of PjBL combined with games is proven to be more significant in improving students' critical thinking skills compared to using only PjBL without the combination, although the use of PjBL without the combination also has an increase in points between before and after implementing the model.

Research has been carried out on pure project based learning models and modified project based learning models. However, it is a little difficult to find a comparison that examines the two parts of the project based learning model. The benefit of this research is to find out what model is suitable for improving critical thinking skills by adding activities to each student's activities in mathematics subjects. The use of both pure and modified models influences the impact of research results. Based on the results of research and theoretical studies that have been carried out, it can be seen that the use of the PjBL model which is modified with the addition of games maximizes the results of students' critical thinking abilities. This research can be a recommendation for teachers in determining the appropriate PjBL model with a combination of games to overcome similar problems. Teachers can combine games periodically so that students are more interested in mathematics lessons. With the habit of combining games in the PjBL model, students will be challenged in each lesson to always maximize their learning process,

Although this research has been able to compare the use of the two bases in the PjBL model, there are research limitations. Limitations of the research include that the time used in this research was only a month, although there was an increase in critical thinking skills, it would be better if this research was carried out periodically and long term to get maximum benefits for students. Another limitation is the scope, this research was only carried out in the sub-district at the elementary school level. It would be optimal if the research was carried out in all districts in Yogyakarta Province to see a more heterogeneous impact between levels of scope and level of education. Thus, the researcher suggests that future researchers develop the research time to be longer, have a wider scope, and have a higher level of education so that they can see the similarities and differences in the benefits of using the PjBL model combined with games.

4. CONCLUSION

The use of the PjBL learning model combined with games significantly increases students' critical thinking skills compared to the use of the PjBL learning model without a combination of games. The PjBL model without a combination and the PjBL model with a combination of games have significantly different means. There is a difference in scores in the form of an increase in scores between before and after using the PjBL learning model without a combination of games. However, this score is not as high as the average score between before and after using the PjBL model which has been modified with the game. The use of the PjBL model combined with games is superior in improving students' critical thinking skills than the PjBL model in general without a combination of games for elementary school students in mathematics lessons.

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