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Is the Problem Based Learning Using Media Puzzle Effective on Students' Mathematical Connection Ability?

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Abstract

Effective mathematics learning not only teaches concepts, but also encourages students to connect the various concepts in real life. This study aims to determine the effectiveness of Problem-Based Learning (PBL) using puzzle media in improving students' mathematical connection skills in elementary school. To contribute to this problem we used two classes to test how the effect of PBL using puzzle media helps students to connect their ability to understand comparison material in grade V elementary school. This research is quasi-experimental quantitative research with posttest-only with nonequivalent groups design. The sample in the study amounted to 54 students who were divided into a control class and an experimental class. The statistical analysis of the independent t-test results indicates a significant difference in the mathematical connection skills between students in the control and experimental classes. The implication of this study is that the use of puzzle-assisted PBL is effective in improving students' mathematical connection skills on connect mathematical concepts more practically and contextually.

Keywords: *Effectiveness, PBL, puzzle media, mathematical connection.*

Abstrak

Pembelajaran matematika yang efektif tidak hanya mengajarkan konsep, tetapi juga mendorong siswa untuk menghubungkan berbagai konsep tersebut dalam kehidupan nyata. Penelitian ini bertujuan untuk mengetahui efektivitas Problem-Based Learning (PBL) dengan menggunakan media puzzle dalam meningkatkan kemampuan koneksi matematis siswa di sekolah dasar. Untuk berkontribusi terhadap masalah ini kami menggunakan dua kelas untuk menguji bagaimana pengaruh PBL menggunakan media puzzle membantu siswa untuk menghubungkan kemampuan mereka dalam memahami materi perbandingan di kelas V sekolah dasar. Penelitian ini merupakan penelitian kuantitatif kuasi-eksperimental dengan posttest-only with nonequivalent groups desain. Sampel pada penelitian ini berjumlah 54 siswa yang terbagi menjadi kelas kontrol dan kelas eksperimen. Dari hasil analisis statistik uji independen t-test menyatakan bahwa terdapat perbedaan yang signifikan kemampuan koneksi matematis siswa di kelas kotrol dan eksperimen. Implikasi dari penelitian ini adalah penggunaan PBL berbantuan puzzle efektif dalam meningkatkan kemampuan koneksi matematis siswa dalam menghubungkan konsep matematika secara lebih praktis dan kontekstual.

Kata kunci: *Efektivitas, PBL, media puzzle, koneksi matematis.*

INTRODUCTION

Learning mathematics is hard work for most students in the world (Téglási, 2022). Learning mathematics is not just about acquiring andmastering computational and problem-solving techniques or solely about understanding definitions, arguments and proofs. In addition, it also involves the reconstruction of the thoughts or works of other mathematicians (Heather, 2003; Lavasani et al., 2011) . Also Kahn (2001); John (1998) asserts that learning mathematics requires you to develop ways of thinking mathematically. John emphasized that there is a perception that mathematics is an effective tool for analyzing, checking and verifying the truth. Empirically human life remains incomplete without mathematics and mathematics plays an important role in one's daily life (John, 1998; Lumbre et al., 2023; Sasmita et al., 2019; Pa'indu et al., 2020).

The ability to connect mathematics (*mathematical connection*) is one of several basic mathematical competencies that must be developed in secondary schools, which connect ideas, principles, content, concepts, mathematical theorems and relationships between mathematical content and other scientific fields or everyday problems (Nurlaily & Sholihah, 2021). Based on critical thinking skills, the ability to make mathematical connections is very important for every student to have (Rahayu et al., 2021; Sari, 2023). In Switzerland, a study on the relevance of mathematical connection skills to student learning outcomes states that there is a consistent positive relationship. This lies in the operational nature of mathematical performance whether arithmetic calculations or solving more complex problems, one needs to mentally store, manipulate and update information, to select and switch between solving strategies, and to inhibit inappropriate strategies (Berkowitz et al., 2022).

Teachers need to know how to promote their students to excel, and identify what conditions are most likely to facilitate their mathematics learning (Huang & Chin, 2022). It takes learning methods that are relevant to material studies, one of which is Problem Based Learning (PBL). The results of a study in Ghana revealed that PBL interventions were effective in teaching mathematics concepts (Boye & Agyei, 2023). One of the external factors

that determine the success of meaningful and comprehensive mathematics learning is the learning media used. The use of interesting learning media can help students build an abstract understanding of mathematics independently. Apart from media, meaningful learning is learning that is adapted to students' cognitive development (Widodo & Wahyudin, 2018; Sudarto & Sasongko, 2020; Baharudin et al., 2022; Buana, 2018). Reviewing Piaget's theory, it is said that children aged 6-12 years are logically based on the physical manipulation of concrete objects. During this period, children need physical manipulation of concrete objects and direct experience so that the material presented is easily understood by children (Nurdyansyah et al., 2020). Up to now, instructional media has become the right solution for conveying messages and transferring knowledge in supporting motivation and achievement in student learning outcomes (Anggrasari & Dayu, 2022).

Learning mathematics globally has incorporated the effectiveness of numerous games into its process. As in Turkey and Hungary, game-based learning has helped students improve problem-solving skills and enabled them to interpret society, nature and the world around them through experience. Through games, it will also provide information in a relevant context or setting for students (Ucus, 2015; Téglási, 2022; Vidergor, 2021). Using games in the learning process encourages reflection and understanding of learning (Yunita & Supriatna, 2021; Sunarti et al., 2022). In addition, in Iran, cooperative-based learning has been carried out through more innovative learning variations. Students will gain direct experience by interacting with discussions and exchanging views (Lavasani et al., 2011). Whereas in Indonesia, the benefits of using puzzle media on student learning outcomes are an increase in understanding while increasing visual spatial abilities and mathematical connection abilities (Abidin & Kurniawati, 2020; Alika & Radia, 2021; Anggraeni & Sole, 2020). Students respond more enthusiastically and positively to using learning media with puzzle games because it can help them to learn independently (Abdullah et al., 2020; Ritonga et al., 2021; Abidin & Kurniawati, 2020). Learning with puzzle media has its own charm, which was previously only a game of assembling pairs, after being modified it changes its function to become an interesting, effective, and fun learning media (Sudarto & Sasongko, 2020; Gilli, Yatri, & Dalle, 2019; Nurdyansyah et al., 2020; Hidayah & Nurtjahyani, 2017). However, compared to previous studies that have mostly focused on general learning outcomes, this study specifically investigates how puzzle-assisted problem-based learning (PBL) successfully improves students' ability in relationship math. It also aims to gain a better understanding of how puzzle media works together with PBL to improve relationship math.

This study mainly aims to determine whether there is effectiveness in the learning outcomes of elementary school students using the puzzle-assisted PBL method by looking at the analysis of different sample tests in the experimental class and the control class. It is hoped that this research can contribute to the intervention knowledge base that motivates teachers at the elementary school level.

METHODS

This research is a quasi-experimental study with a posttest-only design with a nonequivalent group design (Creswell, 2012). The design only includes post-treatment measurements for two different samples.. In this study, a test was carried out to determine whether there was a significant difference between the treatment group and the control group

in the variables studied after the treatment was given. The variable being measured in this case is the dependent or outcome variable. The study used experience-based criteria in PBL-supported learning to determine the study groups. The treatment lasted for 4 weeks and was divided into 4 units based on the Grade 5 Mathematics curriculum using puzzle media.

Posttest data were collected from both the experimental and control classes after the learning process. The experimental class received treatment in the form of using puzzle media to enhance mathematical abilities, particularly in comparative material, while the control class followed conventional learning without treatment. The research design is shown in the following figure:

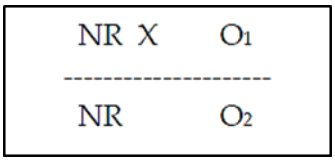

Figure 1. *Posttest-only design with nonequivalent groups*

The sample selection employed a purposive sampling technique, where 54 students were divided into an experimental class of 26 students and a control class of 28 students based on the research objective (Fraenkel & Wallen, 2006). This study used several data collection tools, including test questions and media practicality questionnaires. The mathematical connection abilities were assessed using a 15-item test designed to measure students' abilities to make connections between mathematical concepts, both within mathematics itself and with real-world contexts. These indicators included the ability to relate mathematical ideas, recognize patterns, and apply concepts to solve problems. The interest questionnaire was based on a 5-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree), to gauge students' engagement with the learning process.

The necessary permits were obtained from the school where the research was carried out following the guidelines and ethical principles set by the Indonesian Ministry of Education, Culture, Research and Technology. Furthermore, The researcher also told participants the data would be used for research only.. Two expert judges, including material and media experts, carried out the validation of the instrument and media. Experts highlighted several issues, and their feedback was received and combined and refined according to the suggestions provided. For the internal consistency scale, the reliability coefficient was obtained for this study and was found to be 0.00592.

Table 1. Instrument reliability results

Scale Reliability Statistics

	Mean	SD	Cronbach's α
scale	73.2	3.68	0.00592

The data were analyzed to test the assumptions determined by the normality test using Shapiro Wilk, then to test the hypothesis using *independent sample t-test analysis* with Jamovi software. In order to determine potential mean differences between the experimental

and control groups, this study used descriptive statistics like the mean and standard deviation, as well as other statistical tests like the independent sample t-test. Primary criteria for assessing the effectiveness of the PBL-assisted puzzle media was a large effect size, along with a statistically significant difference in posttest scores between the experimental and control groups. The improvements in the mathematical connection skills of the students were measured using a predefined threshold of statistical significance ($p < 0.05$).

RESULTS AND DISCUSSION

Data on post-test learning outcomes in both the control and experimental classes were tested for assumptions first in the form of homogeneity tests and normality tests before entering further analysis. The results obtained are as follows:

Table 2. Result analysis for homogenity data

Homogenity of variances test (Levene's)				
	F	Df	df2	p
Learning outcomes	0.111	1	52	0.740

Note, A low p-value suggests a violation of the assumption of equal varaices

From the results of data analysis on the learning outcomes of the control class and experimental class using levene's test, it was stated that the data had a homogeneous distribution as seen from the p value > 0.05, namely 0.740. This result indicates that the variance of learning outcomes between the experimental and control groups is not significantly different. Therefore, subsequent statistical analysis can be conducted without worrying about the effect of variance variation on the results. With the assumption of homogeneity fulfilled, we can conclude that the treatment (PBL method with puzzle media) caused a difference in learning outcomes rather than uncontrolled variation in the data.

Table 3. Result analysis for normality data

Normality test (Shapiro-Wilk)		
	W	p
Learning outcomes	0.974	0.289

Note, A low p-value suggests a violation of the assumption of normality

In this context, with a p-value = 0.289, the assumption of normality is met. This means that the distribution of student learning outcome scores in your study can be considered normal, so further statistical analysis, such as the independent sample t-test, can be conducted with confidence that the results will be valid and unbiased due to violations of the normality assumption. the calculation results are as follows:

Table 4. Descriptive analisis for control and experiment

Group Descriptives						
	Group	N	Mean	Median	SD	SE
Learning outcomes	Control	28	58,5	58,0	6,62	1,25
	Experiment	26	83,2	84,5	5,78	1,13

These descriptive results clearly show that the puzzle-assisted problem-based learning (PBL) method had significantly higher learning outcomes on average (83.2) compared to the control group that used the conventional learning method (58.5). This indicates a significant difference in learning outcomes between the two groups. In addition, there was a consistent median difference that supported this mean difference. The mean of the experimental group (84.5) was higher than the control group (58.0), and the standard deviation of the experimental group was lower (5.78) than the control group (6.62). In the experimental group, scores were closer to the mean or more consistent than in the control group.

Problem-based and interactive learning (PBL), according to constructivist learning theories such as Vygotsky and Piaget, allows students to actively participate in the learning process. Ultimately, this method allows students to improve their understanding and skills. In this situation, the use of puzzle media helps students strengthen their understanding of abstract concepts by helping them develop mathematical connections. Active learning theory states that interactive learning methods such as puzzle-assisted PBL can significantly improve student learning outcomes compared to traditional or passive learning methods.

The plot produced by the output shows that the mean and median of the experimental group are higher than the control class. The learning model applied to the experimental class encourages students to be more active and creative in solving problems and is able to improve students' mathematical connection skills. Students must identify and comprehend problems, then design and determine strategies to solve them. One of the learning models that can be used is PBL (Sari, 2023; Lavasani et al., 2011). The problem-based learning model is learning that emphasizes the full involvement of students in finding the material being studied and relating it to everyday life. Problem-based learning also encourages students to be able to construct their own knowledge, cultivate higher skills, train student independence, and can increase student self-confidence (Boye & Agyei, 2023).

The PBL-based experimental research with the help of marble machine puzzles is carried out scientifically. This puzzle media is called Puzzle Marbles Machine "Gayatri" which is a product designed by a research team from lecturers at Wahid Hasyim University Indonesia, and has been launched through a community service program in 2021. Then in 2022 researchers will try to apply puzzle media in classroom learning . In the marble machine puzzle game, students are asked to assemble the available components, and if they are assembled students can see the movement of the marbles from the lowest to the highest position by turning the existing knob. To facilitate assembly, each component in the marble puzzle machine is connected by magnets located at each end of the component. The educational mechanical puzzle marble machine game is a game specifically designed to stimulate children's curiosity through the media of colours, shapes and mechanisms. This game is composed of a combination of puzzle and Lego game concepts.

Researchers prepared learning tools in the form of lesson plans and worksheets to be applied in learning activities in class for 2 weeks. Learning tools follow basic competence and core competence in the syllabus and follow the needs of math material in grade V. Puzzles have been designed to help students connect understanding of comparative material. The puzzle components are as follows:

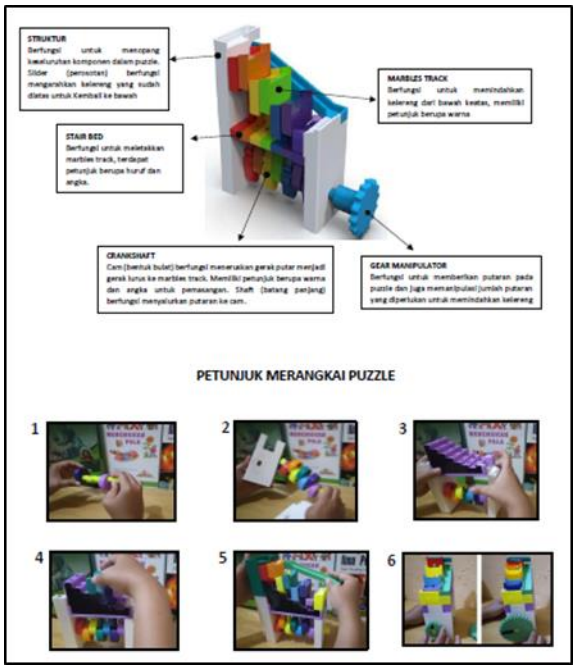

Figure 3. Marbles machine puzzle components

Based on the results of research that has been done in the experimental class and control class, the results of the final test (*post test*) are obtained in both classes. As for the results of the data that the researchers obtained, they were analyzed using the Jamovi application and displayed in table form accompanied by their interpretation. The final result of the processed data aims to prove whether there is a significant difference between the control class and the experimental class after the learning activities.

The population that was used as the object of this study were fifth grade students at Islamic Elementary School (MI) Nurul Islam Semarang City. There are 3 study groups, namely classes Va, Vb, and Vc with a total population of 82 students. Selection of the sample using the purposive sampling technique. We use a purposive sampling technique because it selects two homogeneous classes from the three available classes, which can accurately represent the characteristics of the population..

Figure 4. Puzzle-assisted PBL process in grade V

Problem-based learning models during learning activities make students think more than memorize, understand lessons better through discussion and can accept learning models can also improve student learning outcomes in chemistry, encourage democracy in learning

effectiveness and can develop creativity. This makes students think by maximizing their ability to produce creative ideas which are then discussed in group discussions in choosing and determining possible strategies to apply. Because mathematical problem solving abilities can develop if there is interaction or exchange of opinions in solving problem solving questions (Rostika & Junita, 2017).

Students who have a lower interest in learning tend to find it more difficult to understand a given mathematical problem. This greatly affects the mistakes made both in modelling the problem and determining the solution strategy. However, in the experimental class students were formed in several groups and presented with problems starting from the simplest and supplemented by providing video as initial knowledge so that students at least have an idea of the material to be studied and have a basic foundation for thinking about strategies to be applied to find solutions to the given problem. In addition, the teacher requires students who already understand the material to guide and explain parts that are not yet understood. This is because at the end of the meeting, one of the group representatives will be randomly assigned, ensuring that every member understands the material. Even though the maximum has not been achieved, the ability to solve mathematical problems of students who have a lower interest in learning in the experimental class is better than the control class.

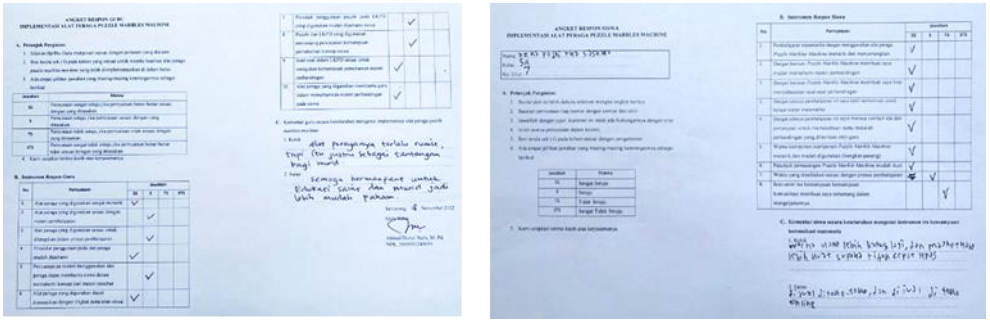

Figure 4. Puzzle-assisted PBL process in grade V

From the calculation of the average student response questionnaire filling in the experimental class by implementing PBL assisted by puzzle props expressed a high interest of 80.56. The majority of students felt enthusiastic and interested in learning comparative material with puzzle props. The activity of assembling and comparing large and small gear rotations will help students develop an independent understanding. Many students commented that the puzzles' magnets were weak and came off easily when operated.

Based on the results of observations of learning activities carried out in the experimental class, it was found that the learning process carried out was conducive and students enthusiastically participated in the learning process. Students were seen actively asking questions and expressing their opinions during discussions. During the process of solving the problem, many have been able to independently model the given problem, although there are some who still have difficulty designing a solution strategy. In general, the problem solving activities carried out at each meeting went well.

According to the student response survey in the experimental class, the problem-based learning (PBL) process with puzzle media showed that it was effective to increase students' desire to learn more. This process also shows that students can create problem-solving strategies in the student worksheet and maximize their abilities. The available puzzle props

are considered very interesting and fun, which makes the learning process more interactive and enjoyable. In addition, group discussions improved students' abilities as students could ask their peers about unclear ideas rather than relying solely on the teacher

After verifying the qualitative data collected, it was concluded that the problem-based learning model assisted by puzzle props applied to the experimental class can make students become more enthusiastic and enthusiastic in participating in the learning process; easier to understand the material and solve problems because it has prior knowledge; students' mathematical connection abilities are further improved and honed able to maximize creative thinking through discussion; more independent in learning and preparing to solve the problems that will be given. In general, it can be said that the learning that is applied to the experimental class contributes positively to students' ability to solve mathematical problems.

CONCLUSION

The results showed that problem-based learning assisted by puzzle media was effective in improving students' mathematical connection skills. Students in the experimental group who used PBL assisted by puzzle media showed much better learning outcomes compared to students in the control group who used conventional learning methods. By using puzzle media in PBL, students not only improve their understanding and application of mathematical concepts, but they also become more creative, actively participate, and better at problem solving. It is suggested that, based on the positive results of this study, educators in primary schools consider incorporating PBL as a puzzle media aid into their math teaching strategies. Future research could investigate the impact of this method on different math concepts and age groups. To improve students' critical thinking and conceptual understanding in mathematics, the development of more interactive and engaging learning media should remain a top priority.

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