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The Impact of Polyya's Problem-Solving Technique on Mathematical Problem-Solving Ability

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Abstract

Penelitian pengembangan ini secara umum bertujuan untuk mengembangkan perangkat pembelajaran berbasis masalah yang valid, praktis dan efektif, secara khusus tujuannya untuk: 1) Menghasilkan produk pengembangan perangkat pembelajaran berbasis masalah yang valid, praktis dan efektif dalam meningkatkan kemampuan pemecahan masalah matematik dan kemandirian siswa. 2) Menganalisis peningkatan kemampuan pemecahan masalah matematik siswa dalam penerapan perangkat pembelajaran berbasis masalah. 3) Menganalisis tingkat kemandirian belajar siswa dalam penerapan perangkat pembelajaran. Peneliti memberikan soal pretest kepada siswa untuk melihat kemampuan awal siswa sebelum diberikan perangkat pembalajaran yang telah dikembangkan. Data yang diperoleh dari hasil pretest dan posttest dianalisis untuk mengetahui seberapa besar peningkatan kemampuan kemandirian belajar siswa yang terjadi. Uji coba instrument penilaian dilakukan di awal (pretest) dan diakhir (posttest) pertemuan. Perangkat pembelajaran ini dikembangkan menggunakan model pengembangan mengacu pada teori Plomp, yang terdiri dari lima fase yaitu fase penelitian investigasi awal, fase desain, perancangan, fase penilaian dan fase implementasi (uji coba).LKPD merupakan perangkat lain yang dikembangkan dengan model pembelajaran berbasis masalah untuk kemampuan pemecahan masalah dan kemampuan kemandirian belajar peserta ini dapat dikatakan efektif, valid dan praktis.
Kata Kunci : Pengembangan perangkat pembelajaran berbasis masalah, pemecahan masalah matematik dan kemandiri belajar.

Abstract (English-Indonesian)

This development research generally aims to develop valid, practical and effective problem-based learning devices, specifically the objectives are to: 1) Produce valid, practical and effective problem-based learning device development products in improving students' mathematical problem-solving abilities and independence. 2) Analyze the improvement of students' mathematical problem-solving abilities in the application of problem-based learning devices. 3) Analyze the level of student learning independence in the application of learning devices. The researcher gave pretest questions to students to see the students' initial abilities before being given the developed learning devices. Data obtained from the pretest and posttest results were analyzed to determine how much increase in students' independent learning abilities occurred. The assessment instrument trial was conducted at the beginning (pretest) and at the end (posttest) of the meeting. This learning device was developed using a development model referring to Plomp's theory, which consists of five phases, namely the initial investigation research phase, design phase, design, assessment phase and implementation phase (trial). LKPD is another device developed with a problem-based learning model for the problem-solving abilities and independent learning abilities of participants. This can be said to be effective, valid and practical.
Keywords: Development of problem-based learning tools, mathematical problem solving and learning independence.

Introduction

In everyday life, consciously or unconsciously, every day we are faced with various problems that require problem solving skills (Abdiyani et al., 2019). According to Aljaberi (Anugraheni, 2019) problem solving is one of the most important cognitive aspects used in everyday life, and problem solving is also the most important part in the field of mathematics. This means that students are required to master problem solving skills with the aim that students are more thorough in solving mathematical problems related to everyday life, so problem solving skills are very important for students in learning mathematics (Aini & Mukhlis, 2020).

Problem solving is defined as an effort to find a way out of a difficulty. When someone solves a problem, he does not just learn to apply various knowledge and rules he already has, but also finds the right combination of various concepts and rules and controls his thinking process (Aini & Mukhlis, 2020). However, the reality that occurs is that students' cognitive learning outcomes do not always reach the point of success and have not met the learning objectives. This is like what happens in learning mathematics in class VIII at MTs Aljamiyatul washliyah Tembung. Based on observations made by researchers at the school, namely the lack of problem-solving skills for story problems on the material of linear equations of two variables (Rahma & Sutami, 2023) (Rara et al., 2022). This is indicated by the answers of students who lack variety, students rarely get the opportunity to ask questions or exchange ideas with other students in the classroom, students also have not been able to answer fluently the questions asked and the attitude of dependence of students on the teacher makes most students ask the teacher to give examples first so that they can work on the problem (Hartanto & Dani, 2020).

In addition to factors from students themselves, learning factors carried out by teachers are also one of the factors that cause students to experience difficulties in solving mathematics problems. Based on the results of observations made on May 3-7, 2023, it can be seen that teachers rarely give non-routine problems, so that when students are faced with non-routine problems, students have difficulty solving them. In addition, the teacher's role in the classroom is more dominant so that students tend to act more as passive recipients of information. As a result, the concepts that have been taught are easily forgotten by students (Nuraini et al., 2020).

One of the efforts that can be made to improve problem solving skills is to choose a learning approach that emphasizes student activeness. One approach that supports this is the Polya model problem solving learning approach (Anugraheni, 2019) (Ariani Sari, 2001). The Polya model problem solving approach stimulates the development of students' thinking skills creatively, thoroughly, and familiarizes students to dare to think out of the box (thinking other than others) because in the learning process students do a lot mentally by highlighting problems from various aspects in order to find solutions to problems (Yusmarni, 2017) (Hidayat & Sariningsih, 2018). The advantages of the Polya model problem solving approach are: (1) makes students more careful in recognizing the appropriate stages in the problem-solving process, (2) can provide a neatly arranged framework for solving complex and long problems that can help students to organize their efforts in solving problems, (3) stimulates the development of students' thinking progress to solve the problems faced appropriately (Nst et al., 2023)(Sinurat et al., 2021).

Based on the description of the problem above, the research objective is to analyze the effect of the Popsot Learning Model (Polya's Problem solving Technique) on students' mathematical problem-solving ability in terms of students' initial abilities.

Method

Research Design

This type of research is Quasy Experiment with the design used is Posttest-only Control Design (Meke & Wondo, 2020)(Setyosari, 2014). This design has one experimental group with a treatment and given a posttest but without a pretest and a control group that is only given a posttest but without a pretest and without treatment. In this design, the treatment between the experimental group and the control group is not the same and the subjects are not randomly selected. The design of this research design can be seen in Table 1:

Table 1. Research Design

Class	Pretest	Treatment	Posttest
Eksperiment	√	X	√
Control	√	O	√

The population in this study were VIII grade students who were located at JL. Besar Tembung No 78 Percut Sei Tuan District. Researchers took samples of class VIII 1 as an experimental class and class VIII 2 as a control class with 30 students each. Sampling was taken by purposive sampling technique. The data collection techniques used in this study were observation, interviews, tests and documentation. Analysis of research data using the t-test.

Results and Discussion (70%)

The results of the research on the ability to solve math problems were assessed from the pretest and posttest. The test given was in the form of a test question on the ability to solve math problems as many as 5 questions. The test was used in two groups as research subjects, namely the experimental group and the control group. The following are the average results of pretest and posttest scores in the control group and experimental group. The following are the results of the validity, reliability, level of difficulty and differentiation tests.

Table 2. Results of Validity, Reliability, Level of Difficulty and Distinguishing Power

Item	r_{xy}	Interpretasion	TK	Criteria	DP	Criteria
1	0,87	Very High	0,66	Medium	0,25	Simply
2	0,95	Very High	0,59	Medium	0,28	Simply
3	0,83	Very High	0,59	Medium	0,25	Simply
4	0,87	Very High	0,55	Medium	0,23	Simply
5	0,83	Very High	0,56	Medium	0,28	Simply

Based on the table above, the problem solving ability questions can be used by students. this can be done at school for 7 days. In this study, a number of data will be obtained which include the results of the test of students' mathematical problem solving skills according to Polya experimental class and control class.

The math problem solving ability test was carried out at the end of learning with the same type of problem in 2 class groups. The final test (posttest) was attended by 60 students who were divided into 2 classes, namely, the experimental class totaling 30 students and the control class totaling 30 students. Based on data from the post test results, the lowest score (x_{min}), the highest score (x_{max}), the average score (x), and the standard deviation (SD) for the experimental group and the control group as shown in Table 3 below:

Table 3. Data from the Mathematics Problem Solving Ability Post Test Results

Kelas	Skor Total	Data Postest			
		x_{min}	x_{max}	$\bar{x}$	SD
Eksperiment	100	78	96	88.56	5.80
Control		76	92	85.25	5.04

The table above shows that the minimum posttest score of students' mathematical problem solving ability in the experimental group is higher (78) than the control group (76), at the maximum score of students' mathematical problem solving ability the experimental group is also higher (96) than the control class (92). Likewise, the average posttest score of students' mathematical problem solving ability for the experimental group (88.56) was higher than the average posttest score for the control group (85.25).

The description of the posttest

results of mathematical problem solving ability based on initial math ability can be seen in the figure below:

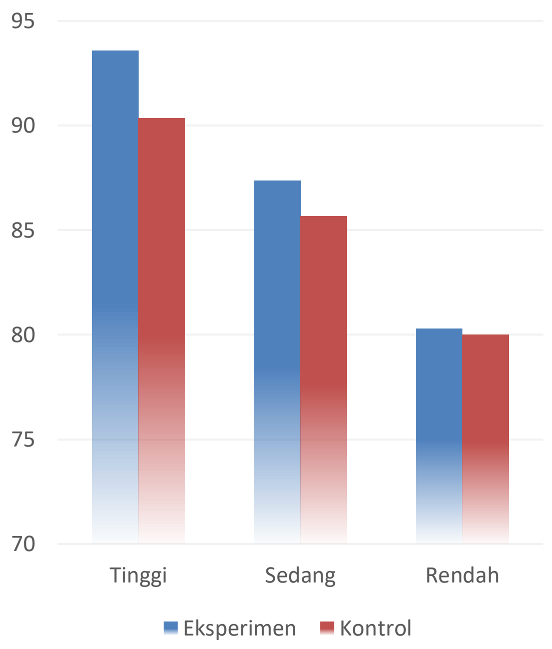

Figure 1. Description of Post Test Based on KAM

The following is the Normality and Homogeneity Test before hypothesis testing. The following are the summary results of the normality calculation of the math problem solving ability test using SPSS 26 presented in Table 4 below:

Table 4. Normality Results of Mathematics Problem Solving Ability

	Class	Kolmogorov-Smirnov[a]		
		Statistic	**Df**	**Sig.**
Post Test of Problem Solving Ability	Experiment	.150	31	.074
	Control	.138	31	.140

Based on the results of the Kolmogorov Smirnov normality test in Table 4 above, it is obtained that the experimental class has a significance value of 0.74 and the control class has a significance value of 0.140. This shows that the significance value for the experimental class is greater than the significance level of 0.74 > 0.05, as well as the control class significance value is also greater than the significance level of 0.140 > 0.05 so it can be concluded that the data of the two sample classes come from a population that has normally distributed data.

The following are the results of the calculation of the homogeneity of students' problem solving ability with the variance test of two variables using SPSS 26 can be seen in Table 5 below:

Table 5. Homogeneity Test of Mathematics Problem Solving Ability

Test of Homogeneity of Variance					
		Levene Statistic	**df 1**	**df2**	**Sig.**
Post Test of Problem Solving Ability	Based on Mean	1.558	1	60	.217
	Based on Median	1.308	1	60	.257
	Based on Median and with adjusted df	1.308	1	59.318	.257
	Based on trimmed Mean	1.565	1	60	.216

Based on Table 5 above, it is obtained that the significance value for the experimental class and control class is 0.271. This means that the value of *sign* > 0.05. Thus the variance of data from the post test results of students' mathematical problem solving ability in the experimental class and control class has a homogeneous data variance. After the normality and homogeneity tests were carried out, the next step was the hypothesis test. Statistical hypothesis testing is carried out using two-way ANOVA.

Table 5. Two-way ANOVA Calculation Results

Tests of Between-Subjects Effects
Dependent Variable: Kemampuan Pemecahan Masalah

Source	Type III Sumof Squares	df	Mean Square	F	Sig.
Corrected Model	1085.841[a]	5	217.168	66.223	.000
Intercept	383639.402	1	383639.402	116986.889	.000
Model Pembelajaran	62.999	1	62.999	19.211	.000
Kemampuan Awal Matematika	998.451	2	499.226	152.234	.000
Model Pembelajaran *Kemampuan Awal Matematika	3.571	2	1.785	.544	.583
Error	183.643	56	3.279		
Total	464996.000	62			
Corrected Total	1269.484	61			

a. R Squared = .855 (Adjusted R Squared = .842)

From Table 5 above, the significance value for the learning model is 0.000 ($sig.$ < 0.05). Thus $H0$ in statistical hypothesis 1 is rejected and Ha is accepted. This means that the problem solving ability of students in the Problem-Based Learning (PBM) class is higher than the Direct Learning class. In other words, there is a significant difference between the problem-based learning model and the direct learning model on students' mathematical problem solving ability. Furthermore, for the learning model * KAM shows a significance value of 0.583, so for hypothesis test 2, $H0$ is accepted, which means that there is no interaction between initial math ability and learning model on students' mathematical problem solving ability.

The application of the ICON model has a significant impact on students in solving mathematical proof construction problems. This aligns with Bond (2020) and Alon et al (2019). Starting with presenting real-world problems about transformation geometry, students try to understand and visualize concepts from the real world as mathematical concepts. The next step is for students to carry out the process of mathematization in constructing proofs by generating mathematical models. Constructing mathematical proofs produced by students is interpreted and validated through real-world conditions. The challenges faced by teachers in implementing the ICON-Model in mathematics education include the teacher's role in guiding students in constructing proofs, the strategies used to overcome students' learning obstacles, and the positive impact of using the ICON model on students' abilities, especially in mathematical proof construction.

Strategies to overcome the challenges in implementing the ICON-Model in mathematics learning can involve periodic teacher training and mentoring, collaboration among teachers to share experiences and practical strategies, and support from the school and government in providing the necessary resources. In addition, regular evaluations of the implementation of the ICON-Model are also necessary to assess its success and identify areas that still need improvement. With these efforts, implementing the ICON-Model in mathematics education can significantly positively impact the advancement of mathematics education in Indonesia.

The research results obtained six indicators in constructing proofs: initial steps, proof flow, related concepts, arguments, interpretation, and proof language. The initial step in constructing a mathematical proof is crucial, as it determines the subsequent steps (Harel & Larry, 2007). The findings show that most students fail to determine the initial step, which impacts their ability to construct proof. The proof path is related to the students' logical reasoning (Ball & Bass, 2003). The accuracy of the proof outline indicates the appropriateness of the strategies used by students in constructing the proof. The related concept is associated with students' understanding of mathematical concepts that support the construction of mathematical proofs. Arguments in proof construction play a role in determining the quality of mathematical proof construction (Hanna, 2020; Lin et al., 2004)—interpretation of proof construction as a form of mathematical communication language linked to the real world. Moreover, the language of proof uses logical and communicative mathematical language, so it does not have the potential to cause multiple interpretations for the reader (Rohid et al., 2019). Mathematical modelling is a complex process compared to arithmetic skills. It does not rely solely on conception, as argued by (Zulkarnaen, 2018) (Zulkarnaen, 2020) students must understand (1) what mathematical structures are available; (2) aspects and elements that are relevant to the characteristics of the problem situation being modelled; and (3) how to justify the use of specific mathematical structures to represent aspects or elements identified from real-world situations (Zulkarnaen, 2018). Therefore, mathematical concept schemes are not enough to make students skilled in mathematization, and students do not know enough mathematical concepts and procedures (e.g., systems of linear equations and statistics). Mathematical modelling requires selecting and using appropriate mathematical concepts or procedures in representing real-world problems in mathematical form or constructing mathematical models (Slamet Kusumawardana & Diantarini, 2021) (Indriawati et al., 2017). Thus, students should not be accustomed to memorizing mathematical facts, rules, and procedures. However, students should also be able to explain how or why mathematical concepts and procedures are used in solving problems. In addition, the use of real-world problem situation contexts should be familiar, which can make students imagine themselves in the problem situation presented.

The interpretation-construction design model is implemented to develop mathematical modelling skills, including the principles of observations in authentic activities, interpretation construction, contextualization, cognitive apprenticeship, collaboration, multiple interpretations, and multiple manifestations (Indriawati et al., 2017). Mathematics learning using the interpretation-construction design model (hereinafter abbreviated as ICON-model) emphasizes the importance of students constructing interpretations from real-world problem situations, discussion activities in building interpretations, reflecting, analyzing, and concluding interpretations that students build as the primary focus of learning activities, teachers act as facilitators in providing a learning environment, and students are actively involved in building student knowledge independently (Indriawati et al., 2017; Kusumawati et al., 2024).

Conclusion (5%)

In this study, in the group of students who had moderate initial mathematical abilities, the average value of mathematical problem-solving ability of students who received learning using the Popsot model (Polya's Problem Solving Technique) was higher than students who received learning using the conventional learning model (Abdiyani et al., 2019).

In addition, students have difficulty in working on the questions given. The results of this study indicate that students with high KAM groups have better mathematical problem-solving abilities at the stage of understanding problems, developing strategies and completing problem-solving strategies than students in the medium KAM group and students in the low KAM group (Anugraheni, 2019). However, both students in high KAM, medium KAM and low KAM, students do not master the 4th indicator, namely checking the correctness of the answers.

So, the Popsot (Polya's Problem Solving Technique) learning model is able to improve the mathematical problem-solving abilities of MTs Aljamiyatul Washliyah Tembung students. Students are able to understand the problems given, students are also able to carry out solutions, students are able to solve problems and students are able to recheck the results of their solutions (Talantu et al., 2023).

This is relevant to the research conducted by Utami & Puspitasari, (2022) entitled Problem-solving abilities of junior high school students in solving story problems on quadratic equation material. From the results of the study, it can be concluded that junior high school students have not been able to solve story problems on the Quadratic Equation material because students have not been able to apply all indicators of problem solving. This is because students are not careful in arithmetic operations which result in many errors (Lutfiya et al., 2021). In addition, because students do not understand the concept of the problem, they have not been able to solve the problem completely and most importantly, students are not used to non-routine questions (Yustiara et al., 2021).

Based on the discussion above, the ability of grade VIII students in solving problem solving problems on quadratic equations meets the sufficient category. Indicators of understanding problems for students with high abilities, they do not have much difficulty in finding information contained in the problem, but for students with low abilities it is still difficult to find complete information contained in the problem (Editorial, 2015). At the stage of planning problem solving, some students have been able to write down the formulas and steps to solve the problem that will be used to solve the problem, but some students are still less than optimal in making a solution plan (Sianturi, 2016). At the problem-solving stage, not all problems can be solved properly. Some students do the correct stages but are still less than optimal both in arithmetic operations and when getting the final answer (Hidayatullah et al., 2019). In this study, the stage that many students missed was re-checking. Some students were able to make conclusions but there were still many students who were wrong in making conclusions (Rahma & Sutami, 2023).

This is in line with the results of interviews conducted by researchers with junior high school students, where in solving problems, many students still do not recheck their answers and write conclusions (Purbaningrum, 2017). Some students can understand the problem and work according to the steps, but do not recheck, so the results are less accurate (Deo et al., 2022). Students' ability to recheck and make conclusions is still categorized as lacking, also supported by the results of previous research conducted by Novitasari & Wilujeng (2018) low-ability students who can solve problems, but not completely solved, only partially, so they do not have results (Septianingtyas & Jusra, 2020). In addition, the errors that occur are caused by a lack of care in solving problems and errors in the calculation process carried out, resulting in students' final answers being wrong and resulting in the conclusions made by students (Rara et al., 2022). Therefore, students still need more guidance from teachers to train in rechecking answers and making conclusions.

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