

# Improving Students' Ability to Solve HOTS-Based Mathematics Problems with Problem-Solving Theory from Polya

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ARTICLE INFO	ABSTRACT
<p><b><u>Article History</u></b>                      Received : 10 Feb 2023                      Revised : 17 Feb 2023                      Accepted : 14 Aug 2023                      Available Online : 30 Aug 2023</p> <hr/> <p><b>Keywords:</b>                      Problem-Solving Ability;                      HOTS;                      Problem-Solving from Polya.</p> <hr/> <p><b>Please cite this article APA style as:</b>                      Maysaroh, E. &amp; Sutarni, S. (2023).                      Improving Students' Ability to Solve                      HOTS-Based Mathematics Problems with                      Problem-Solving Theory from Polya.  <i>Vygotsky: Jurnal Pendidikan Matematika                      dan Matematika</i>, 5(2), pp. 91-100.</p>	<p>This research aims to describe the improvement of students' ability to solve HOTS-based mathematics problems with the theory of problem-solving from Polya. This research used classroom action research. Data collection techniques use interviews, tests, observations, documentation, and field notes. Data analysis techniques use a flow method consisting of data reduction, data presentation, and data verification. The results showed a classical improvement in students' ability to solve HOTS-based math problems, it can be seen that each indicator reaches a targeted percentage of <math>\geq 60\%</math>, starting from before the action to the second cycle of action. Thus, the conclusions of this research show that Polya's problem-solving theory can improve students' ability to solve HOTS-based math problems.</p>

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## 1. Introduction

Education is a very important provision for every generation because education can make a generation smart, qualified, and characterful. According to Law No. 20 of 2003 article 1 (Kemendikbud, 2003), "Education is a conscious and planned effort to create a learning atmosphere and learning process so that students actively develop their potential to have the spiritual power of religion, self-control, personality, intelligence, noble character, as well as the skills needed for themselves, society, nation, and state." With this, it becomes a demand that quality improvement in the field of education must always be fostered so that it becomes one of the forums to encourage the improvement of student achievement in academic and non-academic fields.

Based on data from the Trends in International Mathematics and Science Study (TIMSS), mathematics learning achievement in Indonesia tends to be low. The International Association for the Evaluation of Educational Achievement (IEA) has organized a Trends in International Mathematics and Science Study (TIMSS), an international comparative study of mathematics and science achievement (Richardson et al., 2020). The results of TIMSS Indonesia's achievements are as follows:

**Table 1.** TIMSS Indonesia Achievement Results

TIMSS Results					
No	Year	Level	Participants	Average Indonesia Score	Average International Score
1.	2003	35	46 Countries	411	467
2.	2007	36	49 Countries	397	500
3.	2011	38	42 Countries	386	500
4.	2015	44	49 Countries	397	500

Based on table 1. That the results of TIMSS Indonesia's achievements in 2003 were ranked 35 out of 46 countries with an average score of 411, while the average international score was 467. Furthermore, in 2007 the achievements of TIMSS Indonesia were ranked 36 out of 49 countries with an average score of 397, in 2011 the achievements of TIMSS Indonesia participants were ranked 38 out of 42 countries with an average score of 386 and in 2015 the achievements of TIMSS Indonesia participants were ranked 44 out of 49 countries with an average score of 397, while the average International score from 2007 to 2015 was 500.

Based on the TIMSS criteria, the achievements of TIMSS participants are categorized into four categories: low 400, intermediate 475, high 550, and advanced 625 from the data shows that Indonesia's position is in a low category (Hadi & Novaliyosi, 2019). The existence of this mathematics event requires that students can think at a high level (HOTS). Based on bloom's revised taxonomy of cognitive realms by Anderson et al. (2001) suggests that Higher Order Thinking Skills consist of three levels, namely analyzing (C4), evaluating (C5), and creating (C6). In this case, the critical thinking aspect includes the level of analyzing and evaluating while the creative thinking aspect is at the level of creating.

Based on the results of interviews and observations conducted on class VIII students at SMPN 1 Kerjo, it can be concluded that students' ability to solve HOTS-based mathematics problems is still low, the low students' ability to solve mathematics problems can be seen from several indicators, namely (1) students can understand and describe what is known, asked and what terms or conditions are given in the questions/problems by 31.25%, (2) students identify appropriate strategies to be used in solving problems/problems by looking at the relationship between what is known and what is asked by 18.75%, (3) students can carry out problem-solving according to the plan that has been prepared and do calculations in sequence of 28.13%, (4) students can re-examine all the steps that have been done, by seeing whether the step is by the provisions of the question/problem by 21.87%.

The following are some of the problems that occur regarding the low ability of class VIII students at SMPN 1 Kerjo in solving HOTS-based mathematics

problems: 1) Lack of teacher variation in mastering various things towards classroom management and learning abilities so that teachers are less optimal in carrying out learning activities, 2) In providing math problems teachers are more likely to give LOTS and MOTS-based questions, 3) Students' interest, motivation and achievement in mathematics learning tend to low, 4) In HOTS questions, students find it difficult to do it, uninteresting and difficult to understand, 5) Students are not able to display the main idea in mathematical language and lack of accuracy when doing the calculation process so that students are less optimal in solving mathematical problems.

The ability to solve mathematical problems is the ability to solve problems by looking at mathematical problems objectively, then students try to solve these problems by involving their knowledge, understanding, and skills and can apply steps in solving problems so that the results obtained are by the objectives of achieving mathematics teaching (Abdiyani et al., 2019; Ariawan & Nufus, 2017; Mardiyana, 2020). The ability to solve mathematical problems can help students develop a deeper understanding of mathematical concepts and other concepts, can foster students' creative nature in mathematical problem-solving strategies, and can gain new knowledge that can later be applied in everyday life or problem-solving that does not have routine procedures (Amam, 2017; Hadi & Radiyatul, 2014; Irawati, 2018).

Based on the description above, with these problems, it is necessary to do or need to cultivate strategies for problem achievement in improving students' ability to solve math problems because mathematics learning achievement is very important to support the achievement of mathematics learning at a higher level. For this reason, one of the strategies that can be used to help students solve math problems is George Polya's problem-solving theory. According to the definition of George Polya (2014), problem-solving is an attempt to solve a difficulty in achieving a goal that is directly not easy to achieve immediately. The problem-solving strategies from George Polya (2014) are (1) Understanding the problem, (2) Devising a plan, (3) Carrying out the plan, and (4) Looking back.

The results of previous research conducted by Widiana et al. (2018) concluded that the use of the Polya-type problem-solving learning model provides better results compared to conventional learning models so the use of the Polya-type problem-solving learning model has a positive influence on problem-solving ability. In addition, research conducted by Sepriyanti et al. (2020) concluded that the ability of students who use Polya steps to solve math problems gives better results than students who do not use Polya steps.

Therefore, the solution to overcome the low ability of students to solve math problems is to use the problem-solving strategy from George Polya. Thus, the purpose of this research is to improve students' ability to solve HOTS-based mathematical problems using George Polya's problem-solving theory.

## 2. Method

The type of research used in this study is Classroom Action Research (CAR). According to Utama (2019) stated that classroom action research is concrete actions taken by teachers and other parties to solve problems faced in the learning process, and to improve processes and results of student learning. Arikunto et al. (2021) stated that the process of class action research in one cycle is carried out in four stages, namely (1) Planning, (2) Acting, (3) Observing, and (4) Reflection.

This research was conducted at SMPN 1 Kerjo located on Jl. Kerjo-Jenawi, Prayan RT 01 RW 06, Karangrejo, Kerjo, Karanganyar in class VIII of the 2022/2023 school year. The researcher chose the place as the research subject because of the following: 1) The low ability of students to solve HOTS-based math problems and 2) George Polya's problem-solving method/model has never been applied at SMPN 01 Kerjo.

The subjects of this research were students and teachers of class VIII SMPN 01 Kerjo for the 2022/2023 school year. The mathematics teacher of class VIII of SMPN 1 Kerjo acts as a subject who will give action assisted by researchers. The students who were the subjects of the action recipients were class VIII F students totaling 32 students consisting of 20 female students and 12 male students, while the object of this research was an effort to improve students' ability to solve HOTS-based math problems using the problem-solving method from George Polya.

The data collection techniques used in this research were interview methods, tests, documentation, observations, and field notes. Data analysis techniques use a flow method consisting of data reduction, data presentation, and data verification. As for the validity of the data, this research uses triangulation sources and methods.

Indicators of achieving students' ability to solve HOTS-based mathematics problems in this research are using problem-solving theory indicators from George Polya, including 1) understanding the problem, 2) devising a plan, 3) carrying out the plan, and 4) looking back. Students' ability to solve HOTS-based math problems is analyzed through test result answers by calculating the scores of each indicator of ability to solve HOTS-based math problems. The criteria for achieving students' ability to solve HOTS-based math problems are presented in the following table:

**Table 2.** Criteria for Achieving Students' Ability to Solve HOTS-Based Math Problems

No.	Percentage (%)	Criteria
1.	$80 \leq \% \leq 100$	Excellent
2.	$60 \leq \% < 80$	Good
3.	$40 \leq \% < 60$	Enough
4.	$20 \leq \% < 40$	Less
5.	$0 \leq \% < 20$	Very Less

(Budiyono, 2015)

Classroom action research is considered successful if students can meet the criteria for the ability to solve HOTS-based math problems, namely achieving a percentage of  $\geq 60\%$  in the good and excellent categories. If the average ability to solve a student's problem reaches  $\geq 60\%$  then corrective action is considered complete. However, if the student's ability to solve HOTS-based math problems reaches a percentage of  $\leq 60\%$  with enough, less and very less categories, the next cycle of action will be carried out until students experience an increase with a percentage of  $\geq 60\%$ .

### 3. Results and Discussion

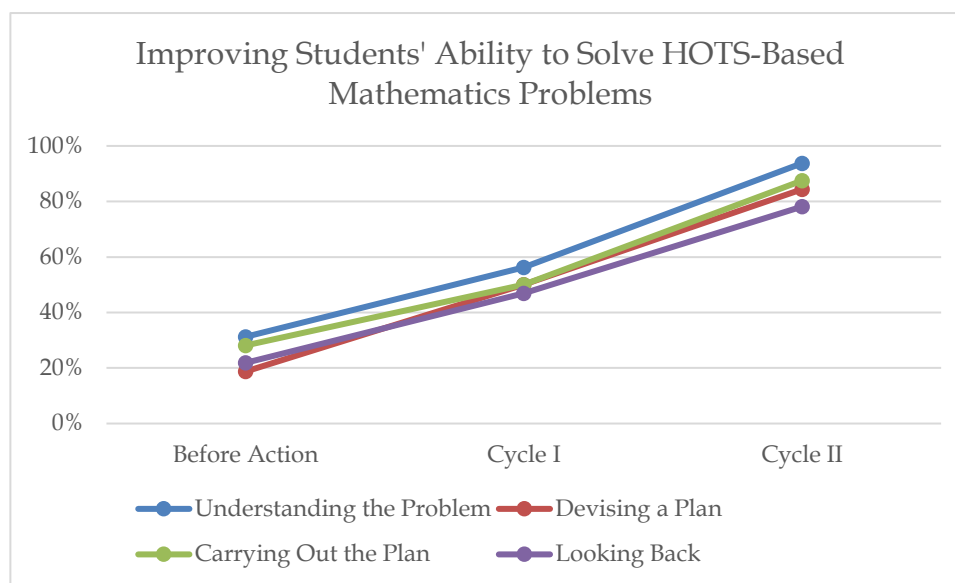
Based on the learning and actions of cycles I and II by applying problem-solving strategies from George Polya, there is an increase in students' ability to solve

HOTS-based math problems. The data obtained by researchers regarding the improvement of students' ability to solve HOTS-based math problems in class VIII F SMPN 01 Kerjo from before the action to the action cycle II can be seen in the following table:

**Table 3.** Data on Improving Students' Ability to Solve HOTS-Based Math Problems

No.	Stage of Solving Math Problems	Before Action	After Action	
			Cycle I	Cycle II
1.	Understanding the Problem	10 Students (31,25%)	18 Students (56,25%)	30 Students (93,75%)
2.	Devising a Plan	6 Students (18,75%)	16 Students (50%)	27 Students (84,38%)
3.	Carrying Out the Plan	9 Students (28,13%)	16 Students (50%)	28 Students (87,50%)
4.	Looking Back	7 Students (21,87%)	15 Students (46,88%)	25 Students (78,13%)

The improvement of the ability to solve HOTS-based math problems starting from before the action to the action cycle II can be seen in the form of the following picture:



**Figure 1.** Graph of Improving Students' Ability to Solve HOTS-Based Math Problems

According to table 3 and figure 1. The ability of grade VIII F students of SMPN 01 kerjo to solve HOTS-based mathematics questions before being given actions is still relatively low, but after the action, there is an increase. It can be seen that every stage of problem-solving from George Polya has an improvement so it can be interpreted that the ability of grade VIII F students of SMPN 01 Kerjo in solving HOTS-based math problems has increased. Thus, problem-solving strategies from George Polya can be applied to improve students' ability to solve HOTS-based math problems.

This research was carried out in 2 cycles by applying the problem-solving strategy from George Polya. Based on observations made in the first cycle, students' ability to solve HOTS-based mathematics problems has increased, which can be seen from the indicators of student's ability to solve math problems including the understanding the problem, devising a plan, carrying out the plan, the looking back, but the improvement that has occurred is still not optimal and has not reached the success indicators that have been implemented in the research. This happens because students and teachers are still not familiar with the learning strategies applied and HOTS-related questions. In line with the research conducted by Rahmawatinigrum et al. (2019) that is based on student learning achievement in solving mathematics problems based on HOTS if student learning achievement is high, they can solve HOTS questions well and with the correct answers. However, if the student's learning achievement is low, they can only understand what is known in the question, so they cannot continue to the next step and cannot find the correct answer. Students can be said to be able to think at a high level if the student meets all three levels of HOTS. Thus, it is necessary to carry out cycle II actions to improve students' ability to solve HOTS questions according to what has been targeted.

The results of the reflection of action I am used as a reference in improving the planning of cycle II actions. In the second cycle of action, there is an increase in students' ability to solve HOTS-based math problems. Students' ability to solve HOTS-based math problems has increased in each research cycle. To find out the improvement of students' ability to solve HOTS-based math problems both before and after the action is carried out, it can be seen from the indicators that can be used as an assessment. The indicators used as research material are as follows.

### **3.1. Understanding the Problems**

Students' ability to understand the problem showed an improvement from before the action to the second cycle of action, namely from the initial condition of 10 students (31.25%) after the action to 30 students (93.75%). This happens because in learning activities students are given worksheets containing HOTS-based problems related to the material that has been delivered. Each student solves a question about a given problem by formulating and writing down information related to the problem so that students can understand and describe what is known, asked, and what terms or conditions are given in the question/problem.

This is to research that has been carried out by Ikhsan et al. (2017) which states that students will be able to solve a problem if the student understands related to the problem that has been given.

### **3.2. Devising a Plan**

The ability to develop plans in solving HOTS-based mathematics problems showed an improvement from before the action to the second cycle of action, namely from the initial condition of 6 students (18.75%) after the action to 27 students (84.38%). This happens because in learning activities students can make plans in solving HOTS-based math problems by illustrating problems regarding the relationship between the information provided and information that is not provided so that each student can identify appropriate strategies to be used in solving the problem/problem and each student can write down important ideas related to the problem in sequence.

This is to research that has been carried out by Hadi & Radiyatul (2014) which states that preparing the plan depends on the experience of the students, the more varied their experience will be, the more creative the student will be in formulating a problem-solving plan.

### **3.3 Carrying Out the Plan**

The ability to carry out plans in solving HOTS-based mathematics problems showed an increase from before the action to the second cycle of action, namely from the initial condition of 9 students (28.13%) after the action to 28 students (87.50%). This happens because, in the learning step, students can carry out problem-solving according to the plan that has been prepared and do calculations in sequence.

This is to the research that has been carried out by Ijirana et al. (2021) which states that implementing the plan depends on what has been planned previously so students need to maintain the plan they have chosen if the plan cannot be implemented then students can choose another plan to solve the problem.

### **3.4 Looking Back**

The ability to look back at solving HOTS-based mathematics problems showed an increase from before the action was carried out to the second cycle of action, namely from the initial condition of 7 students (21.87%) after the action to 25 students (78.13%). This happens because, in the learning step, students can check again all the steps that have been done, by seeing whether the steps are by the provisions of the question/problem.

This is to research that has been carried out by Espinal & Gelvez (2019) which states that looking back at problem-solving is important because by looking back at the completion results students have the opportunity to review their completion results properly and ensure they do not make mistakes in their work.

Increasing indicators of students' ability to solve HOTS-based mathematics problems with George Polya's problem-solving theory can be achieved because, in the mathematics learning process, students are encouraged to think logically, analytically, systematically, critically and creatively and actively seek information to get strategies for solving HOTS-based math problems. In line with previous research conducted by Yapatang & Polyiem (2022) concluded that learning the Polya-type problem-solving model can lead to success in developing mathematical problem-solving skills and student learning achievement. Meanwhile, research conducted by Mustapha et al. (2019) concluded that an online learning environment using a Polya-type problem-solving model can improve HOTS. This is shown by the results of the T-test analysis, namely that there is a statistically significant difference in  $T(31)=-11.58$ ,  $P<0.05$ . This shows that George Polya's problem-solving theory can improve students' ability to solve HOTS-based math problems. Meanwhile, research conducted by Tambunan (2019) concluded that the results obtained through problem solving strategies are more effective than scientific approaches to students' mathematical abilities in problem solving, communication, mathematical reasoning, and creativity. Accordingly, problem-solving strategies are better used than scientific approaches to students' mathematical ability to improve HOTS.

#### 4. Conclusions

Based on the results of research that has been carried out in class VIIIF of SMPN 01 Kerjo, it can be concluded that applying George Polya's problem-solving strategies, can improve students' ability to solve HOTS-based math problems. This can be seen from the achievement of indicators of student's ability to solve math problems, which is indicated by an improvement in the percentage from cycle to cycle.

Therefore, the advice that can be given is the use of problem-solving strategies from George Polya in mathematics learning related to HOTS-based problems should be used as an alternative that can improve students' ability to solve HOTS-based math problems. On the other hand, this strategy also has implications for changes in student attitudes towards the mathematics learning process so that directly this can provide benefits for students in achieving mathematics learning achievement. Thus, researchers recommend that next research is expected to use teaching aids that can support student performance in order to develop their creative thinking skills and be able to solve HOTS-based math problems skillfully.

#### Author Contributions

In writing this article, the first author as a party in carrying out class action research with the process of planning, action, observation and reflection. While the second author as a lecturer who guides and directs the smooth running of classroom action research.

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#### Declaration of Competing Interest

The author states that there is no conflict of interest in this research.

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