JIML JOURNAL OF INNOVATIVE MATHEMATICS LEARNING

(JIML) JOURNAL OF INNOVATIVE MATHEMATICS LEARNING
Volume 8, No. 3, September 2025

P-ISSN 2621-4733
E-ISSN 2621-4741

https://dx.doi.org/10.22460/jiml.v8i3.p28161

THE EFFECTIVENESS OF HEURISTIC VEE MODEL TO IMPROVE STUDENTS' MATHEMATICAL PROBLEM SOLVING SKILLS

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ARTICLE INFO

Article history:

Received Jun 23, 2025
Revised Jul 02, 2025
Accepted Jul 03, 2025

Keywords:

Mathematical Problem Solving Skills
Heuristic Vee Model
Junior High School

ABSTRACT

Mathematical problem solving ability is a key component of students' cognitive development, enabling them to understand, analyze, and apply mathematical concepts in various real-life situations. Despite its importance, many students struggle with problem-solving due to teacher-centered approaches and the lack of interactive, concept-oriented instructional models. This study aims to examine the effectiveness of the Heuristic Vee learning model in improving students' mathematical problem-solving skills, particularly in the topic of two-dimensional shapes. The research employed a quasi-experimental method using a Non-Equivalent Posttest-Only Control Group Design. The participants were two seventh-grade classes at MTs Negeri 1 Kota Gorontalo, selected through purposive sampling based on class equivalence and teacher recommendations. The experimental group received instruction using the Heuristic Vee model, which involved problem exploration, concept mapping, and guided reflection, while the control group was taught through the direct instruction method. Data were collected through a post-test consisting of essay questions based on Polya's four problem-solving stages. All instruments were validated by experts and tested for reliability. Data analysis included descriptive statistics, normality and homogeneity tests, independent t-tests, and effect size measurement. The results showed that the experimental group achieved a higher mean post-test score (49.83) than the control group (31.70), with a significant t-value of 3.458 > 2.002 at the 5% significance level. The effect size (Cohen's d = 0.89) was categorized as high. These findings indicate that the Heuristic Vee model significantly enhances students' mathematical problem-solving skills and serves as an effective strategy for promoting student-centered and meaningful mathematics learning.

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How to Cite:

Djafar, K., Pomalato, S.W., & Takaendengan, B.R. (2025). The Effectiveness of Heuristic Vee Model to Improve Students' Mathematical Problem Solving Skills. *JIML*, 8(3), 573-582.

INTRODUCTION

Mathematics is a subject that plays an important role in shaping students' logical, critical, and systematic thinking skills. At every level of education, mathematics is not only taught as a set of procedural knowledge, but also as a means of training higher-order thinking skills, particularly the ability to solve problems. Problem-solving ability is an essential skill that supports students' success in understanding mathematical concepts and applying them in various contexts of life. Problem-solving is an individual skill in independently resolving issues encountered during the learning process (Suleman et al., 2023).

Wirevenska et al. (2022) emphasize the importance of analytical skills as part of the process of deep mathematical thinking. However, the results of a study by Fikri et al. (2022) show that many students still have difficulty solving word problems, particularly in understanding the context of the problem and choosing the appropriate solution strategy. This weakness not only hinders mastery of the material but also impacts overall learning outcomes. One cause of low student learning outcomes, particularly at the junior high school level, is their weak problem-solving ability, influenced by the suboptimal application of learning strategies or methods in the teaching-learning process, which limits the development of students' problem-solving skills (Unonongo et al., 2021).

According to the results of the 2018 Programme for International Student Assessment (PISA) international study, Indonesia ranked 64th out of 65 countries in the aspect of problem-solving for mathematics, with an average score of 375, far below the OECD average (Rumapea, 2017). This is also the case in Gorontalo, where problem-solving skills remain low because the mathematics learning process tends to focus on listening, writing, and solving problems using pre-existing formulas, making it difficult for students to understand abstract concepts (Suleman et al., 2023). This ability remains at a low level, as reflected in the results showing that students at SMP Negeri 10 Gorontalo only achieved a problem-solving level of 60.89%, which is categorized as low (Zakiyah et al., 2021).

One of the causes of students' low ability in solving mathematical problems is the use of ineffective learning models and minimal active student participation (Szabo et al., 2020). In the classroom, mathematics learning is still dominated by teacher-centered lecture methods, so students tend to be passive and only memorize procedures without understanding the concepts in depth (Adji & Meilawati, 2020).

A similar condition was found at MTs Negeri 1 Kota Gorontalo, where the results of daily mathematics tests showed that out of 36 seventh-grade students, only 3 students (8.33%) achieved scores above the minimum passing standard. Based on interviews with teachers, it was found that many students experienced confusion when faced with problem-based questions and showed low learning participation. This indicates that students' mathematical problem-solving abilities are still relatively low, and the teaching approach used has not been able to stimulate optimal cognitive engagement.

The gaps identified from various studies and field findings indicate that efforts are still needed to develop innovative learning that enables students to understand concepts comprehensively and apply them in problem-solving. To make mathematics learning more effective, teachers need to design creative and interactive plans to actively engage students (Bito & Lokiman, 2020). One relevant model is the Heuristic Vee learning model, which emphasizes the integration of conceptual and methodological aspects in the learning process.

Heuristic Vee is a model based on the analysis of messages and the processing of data or information collected by students to obtain the necessary knowledge, skills, and values (Rineka et al., 2018). According to Pratama et al. (2020), this model encourages students to actively build understanding through observation, reflection, and interconnections between concepts, enabling them to develop critical and independent thinking in solving problems. Ajayi (2020) also adds that the Heuristic Vee model provides visual guidance and a systematic thinking structure that helps students understand how knowledge is formed and connected. The Heuristic Vee learning model is a learning model for problem solving that utilizes mathematical procedures. The "V" shaped model, Heuristic Vee, is referred to as an effort to solve problems using procedural discovery steps which are then translated into a "V" diagram (Safitri & Wahyuningsih, 2019).

This study aims to analyze the effect of the Heuristic Vee learning model on the mathematical problem-solving abilities of seventh-grade students at MTs Negeri 1 Kota Gorontalo. This study is expected to contribute to the development of effective, relevant, and contextual learning models to improve the quality of mathematics education at the junior high school level.

METHOD

This study is a quantitative study with a quasi-experimental design. The purpose of this study is to determine the effect of the Heuristic Vee learning model on students' mathematical problem-solving abilities.

This study uses a quasi-experimental design. The design applied is the Nonequivalent Control Group Design, which is an experimental design involving two different classes, namely the experimental class, which will be given the Heuristic Vee learning model, and the control class, which will be given the direct instruction learning model. After the entire learning process was completed, the next step was to determine the effect of the learning model by administering a post-test on mathematical problem-solving skills in flat shapes to both classes and testing the comparison of the average scores of each class using a T-test.

The subjects in this study were seventh-grade students at MTs Negeri 1 Kota Gorontalo, with a purposive sampling method that considered the similarity of the initial characteristics of the students in both classes and their readiness to follow the established learning model. The selection of classes was also made based on recommendations from the school and mathematics teachers. The subjects were divided into two classes: an experimental class and a control class. The experimental class was class VII-1, which used the heuristic Vee model, while the control class was class VII-7, which used the direct instruction model.

The indicators used to measure mathematical problem-solving ability are those developed by Polya: first, understanding the mathematical problem, second planning a solution strategy, third implementing the formulated strategy and finally, evaluating and verifying the accuracy of the results. The research instruments used were teaching modules, Student Worksheets (LKPD), and essay tests to measure mathematical problem-solving ability, which had been validated through expert validation and empirical validation using the Product Moment correlation formula and Cronbach's Alpha formula.

The steps for applying the model and LKPD for the experimental class with the heuristic Vee model are as follows: first, the orientation phase is the stage where the teacher begins by sparking students' interest by linking the lesson material to everyday experiences to encourage students to learn more deeply; the idea disclosure phase is when students conduct research and present their results using worksheets and concept maps to deepen their understanding; the problem-solving phase requires students to discuss and critically evaluate problems in groups to find solutions; the new knowledge construction phase encourages students to organize and synthesize material using Vee diagrams that connect abstract concepts with practical applications; the final evaluation phase is a process where the teacher guides a question-and-answer session to assess students' understanding while sharpening their thinking skills through discussion and clarification (Khafifah, 2022). The steps for implementation in the control class using the direct instruction learning model are as follows: the first phase is orientation or communication of objectives, where the educator clearly communicates the learning objectives, provides relevant background information, and motivates students to learn. The second phase is presentation or demonstration, when educators present new material or skills gradually and systematically so that they are easy for students to understand; the third phase is guided practice, which gives students the opportunity to try to apply the material with guidance through instructions, examples, or simple tasks; the fourth phase is checking understanding and providing feedback, where educators evaluate the extent of students' understanding and provide immediate feedback to correct mistakes and reinforce correct concepts; and the fifth phase is providing opportunities for further practice and application, which allows students to practice independently and apply the knowledge or skills they have acquired in more complex or real-life situations (Sitompul & Hayati, 2019).

RESULTS AND DISCUSSION

Results

This study aims to determine the effect of the Heuristic Vee learning model on the mathematical problem-solving abilities of seventh-grade students at MTs Negeri 1 Kota Gorontalo. The study used a quasi-experimental design with a non-equivalent posttest-only control group design. The experimental class was taught using the Heuristic Vee model, while the control class used Direct Instruction. Based on the results of the descriptive analysis, it was found that the average post-test score of students in the experimental group reached 49.83, which was higher than that of the control group, which had an average of 31.70. In addition, the maximum and minimum scores in the experimental group, namely 98 and 20, were also higher than those of the control group, which recorded scores of 80 and 6, respectively.

Tabel 1. Descriptive Analysis of Research Results Data

Class	Data	n	Skor Min	Skor Maks	Mean $\bar{x}$	Median (Me)	Modus (Mo)
Experiment	Post-Test	30	20	98	49.83	47	54
Control			6	80	31.7	32	45

The normality test as a prerequisite for data analysis was conducted using the Shapiro-Wilk method. This test produced a statistical value W, which was then compared with the critical value from the table at a significance level of $\alpha = 0.05$. The results showed that the calculated W value was greater than the table W value, indicating that the data was normally distributed.

Table 2. Normality Test

Class	Test	W-value	W-table	Decision
Experiment	Post-Tes	0.92718475	0.927	Normally distributed
Control		0.9278420		Normally distributed

The next prerequisite test, the homogeneity of variance test, was conducted to determine whether the variance between data groups was uniform or not. This test used the Levene method, which produced an F statistic value and compared it with the critical value of the F table at a significance level of α = 0.05. The results show that the calculated F value is smaller than the table F value, so the data is considered to have homogeneous variances. The results of the homogeneity test for the post-test data on mathematical problem-solving ability for the experimental and control groups are presented in the following table:

Table 3. Results of the Homogeneity Test for Mathematical Problem-Solving Ability

Data	Class	n	dk	F-value	F-table	Decision
Post-Test	Experiment	30	29	1.122832	1.860811	Homogen
	Control	30	29			

The post-test results indicate that there is a significant difference in mathematical problem-solving ability between the two classes. The average post-test score for the experimental class is 49.83, while the control class obtained an average score of 31.70. These results suggest that learning using the Heuristic Vee model yields better outcomes compared to direct instruction.

Table 4. Average Post-test Results for Mathematical Problem-Solving Ability

Class	Average Post-test Score
Experiment	49.83
Control	31.7

This difference is rei Table 5. Results of the t-Test on Mathematical Problem-Solving Ability nforced by an independent t-test, which yielded a calculated t-value of 3.458 and a table t-value of 2.002 at a degree of freedom of 58 and a significance level of 0.05. Since the calculated t-value is greater than the table t-value, H0 is rejected and H1 is accepted. Thus, there is a statistically significant difference between the two groups.

Table 5. Results of t-tests on mathematical problem-solving abilities

Class	Avarage	Degrees of Freedom **(df)**	t_value	t_table	Decision
Experiment	49.83	58	3.458508	2.001717	H_1 accepted
Control	31.7				

Based on table 5, the calculated t-value is greater than the t-table, which is 2.002 at 58 degrees of freedom and a significance level of 0.05. This indicates that there is a statistically significant difference in mathematical problem-solving ability between the experimental group taught using the Heuristic Vee model and the control group using the Direct Instruction approach.

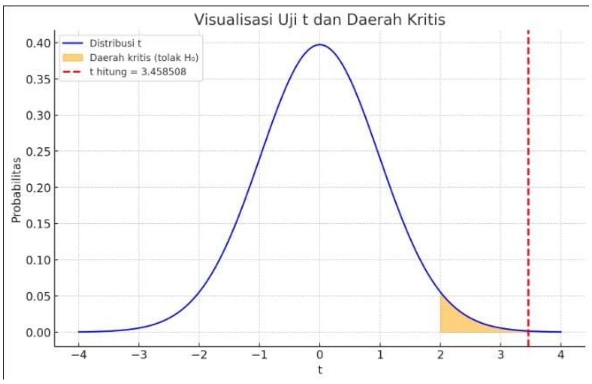

Figure 1. Hypothesis acceptance curve for mathematical problem solving

The t-distribution curve shown depicts the test output for the post-test mean value difference between the experimental and control classes. The blue line indicates the t-probability distribution curve with 58 degrees of freedom, while the orange area on the right is the critical region, i.e., the area where the t-value exceeds the t-table limit value = 2.001717. The red dotted line indicates the position of the calculated t-value = 3.458508, which is well within the critical region. This indicates that the difference between the two groups is statistically significant, so the alternative hypothesis H_1 is accepted. In other words, the Heuristic Vee learning model has a more positive effect on mathematical problem-solving ability compared to the Direct Instruction model.

Additionally, the effect size (Cohen's d) was 0.893, which falls into the large category. This indicates that the application of the Heuristic Vee model has a strong impact on improving students' mathematical problem-solving abilities.

Tabel 6. *Effect Size* (Cohen's d)

Data	Avarage	n	SD	$\overline{x_1} - \overline{x_2}$	S_{Pooled}	*effect size*	Category
Experiment	49.83	30	20.8857	18.13333	20.30647	0.892983	High
Control	31.7	30	19.71023				

The findings of this study provide evidence supporting the effectiveness of the Heuristic Vee learning model in enhancing students' mathematical problem-solving skills. This is reflected in the descriptive statistics, where the experimental group, taught using the Heuristic Vee model, achieved a higher mean post-test score of 49.83, compared to 31.70 in the control group that received direct instruction. The statistical analysis using an independent t-test revealed a t-value of 3.458, which exceeds the critical value of 2.002 at a 5% significance level, indicating a significant difference between the two groups. Additionally, the effect size value (Cohen's d = 0.89) suggests a strong practical impact of the model in supporting students' problem-solving performance.

Discussions

These results suggest that the Heuristic Vee learning model contributes meaningfully to students' ability to understand mathematical problems, formulate appropriate strategies, carry out solutions, and evaluate the results, as outlined in Polya's problem-solving framework. The structured phases of learning, combined with visual aids such as the Vee diagram, appear to facilitate deeper conceptual and procedural understanding, while encouraging active participation, discussion, and reflection. Such outcomes align with the constructivist view of learning and reinforce the relevance of heuristic-based approaches in promoting student-centered, conceptually rich mathematics instruction. Theoretically, this approach is consistent with constructivism, in which students are considered active subjects in constructing knowledge based on their experiences and interactions with the learning environment. These findings demonstrate that the Heuristic Vee learning model has a significant and positive impact on students' mathematical problem-solving abilities, supporting its role as an effective strategy for fostering meaningful and student-centered mathematics instruction. This is consistent with the study conducted by Setiani et al. (2024), which found that learning facilitated through heuristic-based modules effectively trained students in understanding problems, planning solution strategies, executing those strategies, and reviewing the completed solutions. The alignment of these findings reinforces the effectiveness of heuristic approaches in developing students' comprehensive problem-solving skills in mathematics.

The higher and significant average difference with the use of the Heuristic Vee model is due to differences in learning models, where the Heuristic Vee model emphasizes active student involvement in constructing knowledge through Vee diagrams and group discussions, while direct learning focuses more on the provision of information by the teacher without much interaction or deep reflection from students. In the process of implementing the model in the experimental class, the teacher created an interactive atmosphere and actively involved the students. During the orientation phase, the teacher explained the connection between flat shapes and everyday examples, such as gardens and roof shapes, so that students could demonstrate and utilize mathematical thinking patterns to solve real-world problems. Students responded enthusiastically by asking questions and providing other relevant examples. When the Vee diagram was introduced as a problem-solving tool, students appeared curious and motivated to explore the material further. The interactions were two-way and encouraged active discussion between students and teachers.

The Heuristic Vee learning model has been shown to effectively improve students' mathematical problem-solving abilities while also guiding them in articulating the concepts and reasoning involved in solving problems. This aligns with the findings of Kaitera & Harmoinen (2022), who reported that a teaching approach emphasizing the exploration of multiple strategies for solving mathematical problems characteristic of heuristic-based instruction has the potential to enhance students' performance in problem-solving tests as well as their ability to explain their thinking. Their study suggests that teachers can foster the development of students' problem solving strategies through classroom discussions and the use of visual heuristic tools, which support the core principles of heuristic learning by encouraging systematic and reflective thinking.

In the learning process using this model, students are encouraged to connect previously understood concepts with new information visually and systematically through the Vee diagram. Such a strategy aligns with the principles developed by Novak and Gowin, who state that the Vee diagram is a tool for organizing knowledge and reflecting on the relationship between conceptual and procedural aspects (Gowin & Alvarez, 2005). The Vee diagram functions as a visual aid for solving mathematical problems. The use of visual heuristic tools has been shown to play an important role in supporting students' mathematical thinking. Similarly, Ling et al. (2019) found that the application of the Vee diagram as a problem-solving strategy significantly improved students' conceptual and procedural knowledge. This indicates that heuristic based visual aids can help bridge students' understanding with the problem-solving process in a structured way. In line with this, the present study also found that the implementation of the Heuristic Vee learning model had a positive impact on students' mathematical problem-solving abilities. The model helped students not only understand the problems more clearly but also apply systematic reasoning when developing solutions. Through conceptual and procedural aspects, the construction of the Vee diagram has explained to students why they use certain mathematical approaches to solve problems. This model is consistent with constructivist theory, which states that students build knowledge through experience and active engagement. In learning with the Heuristic Vee model, students are asked to fill in the conceptual and methodological sections of the Vee diagram, which encourages active engagement, discussion, and deep reflection on the material.

During the heuristic Vee model learning stage, group discussions were active and productive, with the teacher providing guidance without giving direct answers, thereby encouraging students to think critically and independently. Students organized their findings and reflections from the learning stage using Vee diagrams and worksheets. They presented their discussion results in front of the class, while other groups provided feedback and questions. This activity creates a collaborative atmosphere that supports evaluation and communication among students. Positive attitude changes are also evident during the learning phase. Students who initially found the material difficult begin to show higher interest because they feel actively involved and have a role in the learning process. Some students who were previously passive begin to take the initiative to share ideas and help their group members.

Putra et al. (2018) found that the use of peer tutoring combined with the Heuristic Vee strategy led to improvements in students' problem-solving abilities, with the experimental group achieving higher gain scores than the control group. These results support the findings of the present study, which also showed a positive impact of the Heuristic Vee model on students mathematical problem-solving skills. Both studies highlight the model's effectiveness in enhancing students' structured thinking and performance in solving mathematical problems.

In the control class using the Direct Instruction model, learning took place systematically with structured material delivery and exercises. Students followed the learning process well according to the applied method, although their involvement was more focused on listening and completing tasks individually. Question-and-answer interactions occurred according to the learning pattern, and students participated according to their respective capacities.

The main difference between the two learning models lies in the approach and role of students during the learning stages. The Heuristic Vee model emphasizes active student involvement in building knowledge through systematic thinking stages that integrate concepts and problem-solving methods visually using Vee diagrams. During the learning stages, the teacher acts as a facilitator who encourages students to explore information, discuss, and reflect on their learning independently or collaboratively. This approach helps students practice their skills in identifying problems, developing solution strategies, and strengthening their understanding of mathematical problem solving in a more comprehensive manner.

The present study demonstrated that the Heuristic Vee model significantly enhances students' mathematical problem-solving abilities by reinforcing the integration between conceptual understanding and procedural skills. This finding suggests that the model facilitates not only students' comprehension of mathematical concepts but also their systematic application during problem-solving processes. Consistent with these results, Riantini et al. (2018) reported a substantial increase in students' mastery of mathematical concepts across learning cycles from 25% to 85% improvement was attributed to active student engagement in exploration, experimentation, and collaborative discussions, as well as positive student perceptions of the Heuristic Vee model. Collectively, these findings underscore the efficacy of the Heuristic Vee instructional approach in fostering deeper conceptual understanding and improving students' problem-solving performance, thereby providing strong empirical support for its implementation in mathematics education. This resulted in a significant difference in problem solving ability scores between the experimental and control classes. In contrast, the Direct Instruction model emphasizes the direct delivery of material by the teacher through one-way communication, where students mostly listen and do exercises, so that their active participation and exploration tend to be lower.

The theoretical implications of this study suggest that the Heuristic Vee learning model can be used as an alternative in the development of meaningful mathematics learning models. Practically, these results can serve as a basis for teachers in selecting effective learning strategies to enhance students' higher-order thinking skills. Therefore, the implementation of the Heuristic Vee learning model is recommended as a viable strategy to adopt in the mathematics learning process to significantly and meaningfully improve students' problem-solving abilities.

CONCLUSION

The results of this study indicate that the application of the Heuristic Vee learning model contributes significantly to improving students' mathematical problem-solving abilities. This is reflected in the significant difference in posttest results between the group of students taught using the Heuristic Vee model and the group that received direct instruction, with an average of 49.83 for the experimental class and 31.70 for the control class, and a t-test result showing $t_{count} = 3.458$ greater than $t_{table} = 2.002$ at a significance level of 5%. Additionally, the effect size value of 0.89 falls into the high category. Thus, the Heuristic Vee learning model has a positive and significant effect on students' mathematical problem-solving abilities. The experimental group achieved higher average scores, supported by statistical analysis results indicating a significant difference between the two groups. Additionally, the large effect size reinforces the finding that this model is not only statistically effective but also has a strong practical impact in supporting the mastery of problem-solving skills. Based on these findings, the Heuristic Vee model is worthy of consideration as a model that supports more meaningful mathematics learning and is oriented toward the development of mathematical problem-solving skills.

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