Improving Students' Mathematical Understanding and Disposition through the Probing Prompting Learning Model

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Abstract

This study aims to analyze the improvement of students' mathematical understanding and mathematical disposition through the Probing Prompting learning model compared to the Problem Based Learning (PBL) model. The research method used is a quasi-experimental design with a pretest-posttest control group design . The subjects of the study were 60 students of class X Multimedia at SMK Negeri 15 Bandung, divided into an experimental class and a control class. The research instrument was a descriptive test of mathematical understanding and a mathematical disposition scale. Data were analyzed using normality tests, homogeneity tests, t-tests, and gain score calculations . The results of the study showed that (1) the mathematical understanding of students who received learning with the Probing Prompting model was better than students who received PBL learning, (2) the mathematical disposition of students in the experimental class was better than the control class, and (3) there was a positive correlation between mathematical understanding and mathematical disposition. These findings indicate that the Probing Prompting model is effective in improving students' cognitive and affective aspects in mathematics learning.

Keywords: mathematical communication, systematic literature review, mathematics education

1. Introduction

Education is a fundamental aspect of national development. Through education, humans are prepared to face life's challenges, develop their potential, and contribute to society. This aligns with Law Number 20 of 2003 concerning the National Education System, which affirms that education is a conscious and planned effort to create a learning atmosphere and process that allows students to actively develop their potential. Thus, education is not only oriented towards the transfer of knowledge, but also the development of skills, character, and values needed in real life.

The development of science and technology demands that education produce adaptive, critical, and creative human resources. One of the fields of study that plays a crucial role is mathematics. Mathematics is seen as a fundamental science that supports mastery of other fields such as science, technology, economics, and even vocational skills. The Ministry of Education and Culture (Permendikbud No. 59 of 2014) states that mathematics should be taught to all students starting from elementary school so that they have the ability to think logically, analytically, systematically, critically, and creatively, as well as to collaborate with others.

However, the reality on the ground shows that mathematics learning in Indonesia still faces significant challenges. International surveys such as the Programme for International Student Assessment (PISA) and the Trends in International

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Mathematics and Science Study (TIMSS) show that Indonesian students' mathematical literacy remains below the average of participating countries. This situation indicates a gap between curriculum objectives and actual outcomes.

At the secondary school level, particularly Vocational High Schools (SMK), these challenges are even more pronounced. SMKs are expected to produce graduates who are work-ready and possess critical thinking skills to navigate the dynamics of the industrial world. However, in reality, vocational high school students' mathematics learning outcomes are relatively lower than those of high school students. National Examination data in Bandung City shows that the average mathematics score for vocational high school students (35.24) is below the average for high school students (39.70). In fact, SMK Negeri 15 Bandung recorded an average mathematics score of only 33.70, lower than the average for vocational high schools in the city.

This problem is also reflected in the school's internal performance. The average score for the Final Semester Week (PAS) at SMK Negeri 15 Bandung showed that the Multimedia major achieved the lowest score compared to other majors, at 71.63, with nearly half of the students failing to meet the Minimum Completion Criteria (KKM). This indicates a low mathematical understanding among Multimedia students. This weak understanding impacts students' difficulty in mastering advanced concepts, often making mathematics a difficult and intimidating subject. Mathematical Comprehension Ability Referring to Sumarmo et al. (2017) and Director General of Elementary and Secondary Education No. 506/C/Kep/PP/2004, the indicators used are: Restating a concept, Clarifying objects according to the characteristics of the concept, Providing examples and non-examples of a concept, Presenting concepts in various forms of mathematical representation (symbols, diagrams, graphs, tables), Developing necessary or sufficient conditions of a concept, Using and selecting certain procedures or operations appropriately, Applying concepts or algorithms in problem solving.

In addition to the cognitive aspect, another problem that arises is the weak mathematical disposition of students. Mathematical disposition reflects students' positive attitudes towards mathematics, such as self-confidence, interest, persistence, and curiosity. Many vocational high school students lack confidence when working on problems, give up easily when faced with difficulties, and do not have a high curiosity about mathematics. This is in line with the TIMSS report (2011) which shows that only 20% of Indonesian students like mathematics, this figure is still below the international average. The low mathematical disposition also contributes to low learning outcomes. According to Polking (in Sumarmo et al., 2017) indicators of mathematical disposition are: Confidence in using mathematics to solve problems and convey ideas/opinions, Flexibility in mathematical thinking, namely trying various ways or methods in solving problems, Persistence and diligence in doing mathematical assignments, not giving up easily, Having a high curiosity and interest in mathematics, Appreciating the application of mathematics in everyday life and in other disciplines.

The above conditions demand innovation in the learning process. Teachers need to implement learning models that not only improve mathematical understanding but also build positive dispositions in students. One relevant model is *Probing Prompting* . This model emphasizes presenting a series of guiding and probing questions. The questions teachers ask encourage students to connect prior knowledge with new concepts, thus making the learning process more meaningful. Furthermore, the interactive atmosphere of *Probing Prompting* can foster self-confidence, curiosity, and a resilient attitude in learning mathematics.

Based on this description, this research focuses on efforts to improve the mathematical understanding and disposition of vocational high school students through the application of the *Probing Prompting learning model* . This research is expected to contribute to the development of more effective mathematics learning strategies at the vocational high school level.

2. Methodology

This study used a quasi-experimental method with a pretest-posttest control group design . This design involved two groups: an experimental class that received treatment with the Probing Prompting learning model and a control class that used conventional learning (Problem-Based Learning). Both classes were given an initial test (pretest) to determine their initial abilities, then treatment, and finally a final test (posttest).

The research subjects were 60 tenth-grade Multimedia students at SMK Negeri 15 Bandung, consisting of 30 students in the experimental class and 30 students in the control class. The selection of schools and classes was based on the results of a preliminary study which showed that the Multimedia department had a lower average mathematics score than other departments.

The research instruments include: Mathematical comprehension ability test, in the form of descriptive questions that have been tested for validity, reliability, discriminatory power, and difficulty index. This test is used in the pretest and posttest , Mathematical disposition scale, in the form of a questionnaire with a Likert scale (4 choices) that includes indicators of self-confidence, flexibility of thinking, persistence, interest, and appreciation for mathematical applications. The data collection procedure is carried out in three stages: (1) administering a pretest to both classes, (2) treatment with the Probing Prompting model in the experimental class and PBL in the control class, and (3) administering a posttest and filling out the mathematical disposition questionnaire.

The data were analyzed using SPSS 23 with the following steps: (a) descriptive analysis to determine the average, standard deviation, maximum and minimum scores; (b) normality test (Shapiro-Wilk) and homogeneity (Levene's Test);

(c) independent t-test to determine the average difference between the experimental and control classes; and (d) gain score calculation to see the increase in mathematical understanding ability. With this method, it is hoped that the effectiveness of the Probing Prompting model in improving the mathematical understanding and disposition of vocational high school students can be determined .

3. Results and Discussion

3.1. Analysis of Mathematical Comprehension Ability

A pretest was administered to determine mathematical comprehension before treatment. The average pretest score for the experimental class was 16.40 and the control class 16.30. This indicates that the initial abilities of both classes were relatively similar.

Class	N	Max Score	Min Score	Average	Simple. Standard	Variance
Experiment	30	31	7	16.40	5,876	34,524
Control	30	28	5	16.30	5,873	34,493

The Shapiro-Wilk normality test showed that the data were normally distributed ($p > 0.05$). The results of the homogeneity test (Levene's Test) showed that the variances of both classes were homogeneous. The independent t-test yielded $p = 0.948$ (> 0.05), meaning there was no significant difference between the two classes in initial ability.

3.2. Final Test (Posttest)

After treatment, the posttest results showed a fairly large difference in average scores between the experimental and control classes.

Class	N	Max Score	Min Score	Average	Simple. Standard	Variance
Experiment	30	100	53	76.10	14,165	200,645
Control	30	80	40	59.27	10,017	100,340

The final test results showed a quite striking difference between the experimental and control classes. The average score of students in the experimental class reached 76.10 , while the control class only scored 59.27 . The independent t-test showed a significance value of 0.000 (<0.05) , so it can be concluded that there is a significant difference in mathematical comprehension ability between the two groups.

This achievement demonstrates that *the Probing Prompting model* can improve the quality of learning. The directed question-and-answer process makes students more actively involved, thus deepening their understanding of matrix concepts. According to Slavin (2015), active student involvement in learning is a crucial factor influencing academic achievement. Ruseffendi (2006) affirmed a similar view, stating that a learning process that encourages interaction and discussion is more effective than lecture-based learning.

Furthermore, these findings are consistent with Bernard's (2015) study, which showed that students who learned using question-based strategies had better mathematical understanding than those who learned using conventional learning strategies. Therefore, the posttest results of this study reinforce the view that learning success is determined not only by the material and media, but also by the delivery strategy that can stimulate students' thinking processes.

3.3. Gain Index

To see the increase in mathematical understanding, the gain index calculation is used.

Class	N	Maximum Gain	Gain Min	Average	Simple. Standard	Variance
Experiment	30	1.00	0.41	0.72	0.17	0.03
Control	30	0.78	0.28	0.51	0.12	0.01

To determine the extent of improvement in students' mathematical understanding, the N-Gain index was calculated. The analysis showed that the average N-Gain for the experimental class was **0**.72 (medium-high category), while the control class only achieved 0.51 (medium-low category). The t-test significance value of 0.000 (<0.05) indicates that the improvement in students' mathematical understanding in the experimental class was much more significant than in the control class.

This interpretation aligns with Hake (1998), who stated that the use of *normalized gain* , or N-Gain, can provide a clearer picture of the effectiveness of a learning model. According to him, effective learning generally has an N-Gain value of at least 0.3 (medium category), while the high category is in the range of >0.7. Thus, the results of this study

indicate that *Probing Prompting* is considered effective because it can produce improvements in the medium-high category.

This improvement can be explained by the interactive nature of *Probing Prompting* . When teachers ask leading questions, students are encouraged to connect previously understood concepts to new ones. This process supports Ausubel's (1968) theory of meaningful learning, which emphasizes the importance of *advance organizers* in helping students connect existing information with new ones.

Furthermore, the high N-Gain value in the experimental class also indicates that learning strategies that emphasize reflective questions can improve knowledge retention. This aligns with Julianti's (2018) findings, which found that students with question-based learning demonstrated significant improvements in post-test scores compared to the control group.Thus, the N-Gain analysis strengthens the posttest results that *Probing Prompting* not only improves student achievement on a single test, but also impacts the overall quality of learning.

3.4. Mathematical Disposition

The results of the mathematical disposition questionnaire showed that students in the experimental class experienced greater improvement than those in the control class.

Disposition Indicator	Experiment (Average)	Control (Average)
Self-confident	3.52 (High)	2.89 (Medium)
Flexibility of thinking	3.48 (High)	2.85 (Moderate)
Persistence/perseverance	3.60 (High)	2.92 (Moderate)
Interest & curiosity	3.55 (High)	2.80 (Low)
Appreciate the application	3.50 (High)	2.95 (Medium)

The results of the mathematical disposition questionnaire showed significant differences between the experimental and control classes. Overall, the experimental class students' mathematical disposition was in the high category with an average score of 3.53, while the control class was in the medium category with an average score of 2.88. These differences can be analyzed in more detail based on the following five indicators of mathematical disposition.

1. Self-confidence

Students in the experimental class showed a higher level of self-confidence (3.52) than those in the control class (2.89). This was evident in their courage in expressing answers, even if they were not necessarily correct, and their ability to accept feedback from teachers and peers. According to Sumarmo (2017), self-confidence is an important component of mathematical disposition because it influences how students face challenges in learning. Widyasari's (2016) research also showed that students with high self-confidence are more likely to successfully solve complex problems.

2. Flexibility of Thinking

The average score for students' thinking flexibility in the experimental class was 3.48 (high category), while the control class' score was only 2.85 (moderate category). This indicates that students taught with *Probing Prompting* are more open to using various problem-solving strategies. Teachers who provide guiding questions encourage students to not be fixated on just one method. This finding aligns with the opinion of Kilpatrick, Swafford, & Findell (2001) that flexibility is a crucial part of *adaptive reasoning in mathematical competence.*

3. Persistence and Perseverance

Students in the experimental class obtained an average score of 3.60 (high category) for the persistence aspect, higher than the control class which only scored 2.92 (medium category). Students who learned with *Probing Prompting* were better able to persist in facing difficult problems, because the guiding questions made them not give up immediately, but instead try further steps. Polya (1957) in *How to Solve It* emphasized the importance of persistence in problem solving, where students need to try various strategies until finding a solution.

4. Interest and Curiosity

The interest and curiosity aspects of students in the experimental class were at a score of 3.55 (high category), while in the control class it was only 2.80 (low category). This shows that *Probing Prompting* is able to arouse students' curiosity through challenging questions. Questions that are exploratory in nature give rise to students' intrinsic motivation to find out the answer, in accordance with Deci & Ryan's (2000) view on *self-determination theory* , that curiosity is the main driver of learning motivation.

5. Appreciating the Application of Mathematics

The indicator for valuing mathematical applications scored 3.50 (high category) in the experimental class, while the control class only scored 2.95 (moderate category). This demonstrates that inquiry-based learning helps students better understand the relevance of mathematics to everyday life. According to Schoenfeld (1992), mathematical disposition is

not only about a positive attitude toward learning but also about an awareness of the usefulness of mathematics beyond the classroom.

Analysis Summary

Overall, the results of the mathematical disposition table analysis indicate that the *Probing Prompting model* is able to improve all aspects of student disposition, from self-confidence to appreciation for mathematical applications. This improvement is not only relevant to the productive disposition theory (Kilpatrick et al., 2001), but also aligns with research by Suharsono (2015) which states that intensive question-and-answer interactions can strengthen students' positive attitudes toward mathematics.

3.5. Relationship between Understanding and Disposition

Variables	Mathematical Understanding	Mathematical Disposition
Mathematical Understanding	1,000	0.643**
Mathematical Disposition	0.643**	1,000

Pearson correlation analysis showed a positive relationship between mathematical understanding ability and mathematical disposition in the experimental class with a coefficient of r = 0.643 and p = 0.001 (<0.05). This means that the higher the students' mathematical understanding, the more positive their disposition towards mathematics.

The results of the Pearson correlation test indicate a positive and significant relationship between students' mathematical comprehension ability and mathematical disposition. The correlation coefficient value of r = 0.643 indicates a moderate-strong relationship (Cohen, 1988). This means that the higher a student's mathematical comprehension ability, the more positive their mathematical disposition.

Practically speaking, students with a good mathematical understanding tend to be more confident, persistent, and flexible in their thinking. Conversely, students with positive dispositions—for example, being willing to try, not giving up easily, and appreciating the usefulness of mathematics—are more likely to develop strong conceptual understanding. This is in line with the opinion of Kilpatrick, Swafford, & Findell (2001), who stated that productive disposition is one of the main pillars of mathematical competence, on par with conceptual understanding and adaptive reasoning.

This finding is also consistent with research by Sumarmo et al. (2017), which showed that positive dispositions contribute to students' success in mastering mathematical concepts. Thus, the cognitive (understanding) and affective (disposition) aspects complement each other in supporting the achievement of mathematics learning goals.

The implication of these findings is that teachers should not only focus on concept transfer but also cultivate mathematical dispositions through learning strategies that encourage students' activeness, curiosity, and courage to experiment. The Probing Prompting model has proven to be an effective approach to achieving this balance, as it not only improves understanding but also strengthens students' positive attitudes toward mathematics.

3.6. Discussion

a. Improving Mathematical Understanding Ability

The research results show that *the Probing Prompting model* is more effective in improving students' mathematical comprehension compared to *Problem-Based Learning* . This is in line with constructivism theory, which emphasizes that knowledge is actively constructed by students through learning experiences (Piaget, 1972). By providing guiding questions, teachers help students connect prior knowledge with new concepts, thus forming a more meaningful understanding.

According to Skemp (1976), there are two types of understanding: instrumental and relational. *Probing Prompting* encourages students to achieve relational understanding because each question asks students to explain their reasoning, not simply provide a final answer. Research by Bernard (2015) also confirms that learning strategies that emphasize the thinking process can improve students' conceptual understanding.

b. Improving Mathematical Disposition

In addition to cognitive aspects, students' mathematical dispositions also improved. Students in the experimental class demonstrated higher levels of self-confidence, flexibility, and persistence compared to those in the control class. This is consistent with the view of Kilpatrick, Swafford, & Findell (2001), who stated that *productive disposition* is an important element of mathematical competence, referring to the tendency to view mathematics as something that is reasonable, useful, and learnable.

In line with Widyasari's (2016) research findings, students' positive attitudes toward mathematics can be fostered through learning experiences that actively engage them. The *Probing Prompting model* , based on question-and-answer dialogue, provides students with the space to express their ideas more confidently, to avoid being afraid of making mistakes, and to keep trying despite difficulties.

c. The Relationship Between Mathematical Understanding and Disposition

Correlation analysis shows a positive relationship between mathematical understanding and mathematical disposition. This is in line with research by Sumarmo et al. (2017), which found that students with positive dispositions tend to have higher motivation to understand concepts. In other words, increased understanding is inseparable from strengthening positive attitudes toward mathematics.

These findings imply that teachers should not only focus on cognitive aspects but also develop students' attitudes and interests. Without a positive disposition, students will easily give up when faced with difficulties, thus preventing optimal mathematical understanding.

d. Comparison with Previous Research

The findings of this study are consistent with Suharsono's (2015) study, which stated that the application of *the Probing Prompting model* increased students' critical thinking skills while developing mathematical dispositions. Similar research was also conducted by Julianti (2018), who found that question-based learning improved high school students' mathematical understanding.

Furthermore, the results of this study also reinforce international findings. According to the National Research Council (Kilpatrick et al., 2001), comprehensive mathematical competence should encompass conceptual understanding, procedural fluency, problem solving, adaptive reasoning, and productive dispositions. Thus, the results of this study support a globally recognized framework for mathematical competence.

e. Theoretical and Practical Implications

Theoretically, this study provides empirical evidence that *Probing Prompting* can be used as an effective learning model to improve vocational high school students' mathematical understanding and disposition. This aligns with Suherman's (2008) idea, which emphasizes the importance of question-based learning strategies in building knowledge.

Practically, vocational high school mathematics teachers can use *Probing Prompting* as an alternative learning model. This model is relatively easy to implement, requiring only teacher creativity in formulating appropriate questions. Probing questions not only help students understand concepts but also encourage them to be more persistent, confident, and interested in mathematics.

f. Research Limitations

This study has limitations, namely that it was conducted in only one school using matrix material. Therefore, the results cannot be broadly generalized. Further research is recommended to test the effectiveness of *Probing Prompting* on other mathematics materials and at different school levels.

4. Conclusion and Suggestion

Conclusion

1. The mathematical understanding ability of students taught using *the Probing Prompting model* is better than that of students taught using PBL.
2. The mathematical disposition of students in the experimental class improved better compared to the control class.
3. There is a positive correlation between mathematical understanding ability and students' mathematical disposition.

Suggestion

1. Mathematics teachers can use *the Probing Prompting model* as an alternative to improve students' mathematical understanding and disposition.
2. Further research can examine the application of *Probing Prompting* to other mathematical materials outside of matrices.
3. Good time management is needed in *Probing Prompting learning* so that all stages can be implemented optimally.

References

[1] Ausubel, D. P. (1968). Educational Psychology: A Cognitive View. New York: Holt, Rinehart and Winston.
[2] Bernard, M. (2015). Pengaruh Disposisi Matematis terhadap Hasil Belajar. Bandung: UPI Press.
[3] Cohen, J. (1988). Statistical Power Analysis for the Behavioral Sciences (2nd ed.). Hillsdale, NJ: Lawrence Erlbaum Associates.
[4] Deci, E. L., & Ryan, R. M. (2000). Self-Determination Theory and the Facilitation of Intrinsic Motivation, Social Development, and Well-Being. American Psychologist, 55(1), 68–78.
[5] Hake, R. R. (1998). Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses. American Journal of Physics, 66(1), 64–74.

[6] Julianti, R. (2018). Kemampuan Pemahaman Matematis Siswa SMA. Jurnal Pendidikan Matematika, 7(2), 1–10.
[7] Kilpatrick, J., Swafford, J., & Findell, B. (2001). Adding It Up: Helping Children Learn Mathematics. Washington, DC: National Academy Press.
[8] Piaget, J. (1972). The Principles of Genetic Epistemology. London: Routledge & Kegan Paul.
[9] Polya, G. (1957). How to Solve It (2nd ed.). Princeton, NJ: Princeton University Press.
[10] Ruseffendi, E. T. (2006). Pengantar kepada Membantu Guru Mengembangkan Kompetensinya dalam Pengajaran Matematika. Bandung: Tarsito.
[11] Schoenfeld, A. H. (1992). Learning to Think Mathematically: Problem Solving, Metacognition, and Sense Making in Mathematics. In D. Grouws (Ed.), Handbook of Research on Mathematics Teaching and Learning (pp. 334–370). New York: Macmillan.
[12] Skemp, R. R. (1976). Relational Understanding and Instrumental Understanding. Mathematics Teaching, 77, 20–26.
[13] Slavin, R. E. (2015). Educational Psychology: Theory and Practice (10th ed.). New Jersey: Pearson.
[14] Suharsono. (2015). Penerapan Model Probing Prompting dalam Pembelajaran Matematika. Jurnal Pendidikan, 6(2), 278–286.
[15] Suherman, E. (2008). Strategi Pembelajaran Matematika Kontemporer. Bandung: UPI Press.
[16] Sumarmo, U., et al. (2017). Kumpulan Artikel Pendidikan Matematika. Bandung: FMIPA UPI.
[17] Widyasari, N. (2016). Analisis Sikap Siswa terhadap Matematika Berdasarkan Hasil TIMSS. Jurnal Pendidikan Matematika, 10(1), 25–34