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Research Article

# Improving Teacher Competence Through Open Inquiry-Based Scientific Investigation Development Training

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**Abstract**

This research aims to improve science teachers' competence in formulating problems, determining investigation variables, drawing conclusions, interpreting tables, and interpreting graphs through training in developing open inquiry-based scientific investigations. The research design uses a quasi-experimental approach with pre-test and post-test to measure changes in competencies by Ten (10) teachers before and after participating in the training. The study showed a significant improvement in teachers' skills after participating in the training. Teachers can better formulate investigation problems, determine relevant variables, draw the correct conclusions, and interpret data in tables and graphs. Despite the challenges in implementing the training, such as time and resource management, this training has proven to be effective in improving science teachers' competence in designing and implementing open inquiry-based learning. This research contributes to developing teacher competencies in the future and scientific inquiry-based learning in Indonesia, which is expected to improve the quality of education and students' critical thinking skills.

***Keywords***: teacher competence, open inquiry, scientific investigation, teacher training

## Introduction

Education is the main foundation in the development of every State. Good quality education will produce more qualified human resources and, in turn, will contribute to a nation's social, economic, and cultural progress (Brown & Lauder, 1996; Indrawati & Kuncoro, 2021). One factor that significantly affects the quality of education is the competence of teachers (Fauth et al., 2019; Glaesser, 2019). Teachers with better competence can create a more effective, engaging, and able to stimulate students' creativity and critical thinking skills (Calavia et al., 2021; Varenina et al., 2021). Therefore, strengthening teacher competence through training that focuses on the development of open inquiry-based scientific investigation is very important (Cigdemoglu & Köseoğlu, 2019), especially in facing the increasingly complex challenges of education in the 21st century (González-pérez & Ramírez-montoya, 2022).

Open inquiry is a learning approach emphasizing scientifically investigative activities oriented to science process skills (Acar & Tuncdogan, 2019; Rodríguez et al., 2019). This approach helps students be more actively involved in the learning process by formulating problems, conducting experiments, and analyzing the results of investigations. The teacher is a facilitator who accompanies and guides students during the investigation process. Open inquiry-based learning focuses on knowledge transfer and developing critical thinking skills, creativity, and problem-solving skills, which are important skills in the 21st century (Costes-Onishi et al., 2020; Sam, 2024). However, although this approach has proven to be more effective in improving the quality of learning, many teachers still face difficulties in implementing it optimally (Chew & Cerbin, 2021). The results of a study by Chew and Cerbin (2021) have identified that there are nine cognitive challenges that can affect the effectiveness of open inquiry learning by teachers, including students' mental mindset, metacognition and self-regulation, and misconceptions. Therefore, training for teachers to develop open inquiry-based scientific inquiry is essential.

The importance of this research can be seen in its contribution to improving teacher competence through activities to develop scientific investigations based on open inquiry. Theoretically, this study aims to expand and increase teachers' understanding of the open inquiry approach and how this approach can be adapted in the context of learning. In addition, this study also aims to provide empirical evidence on training that focuses on developing scientific inquiry activities to improve teachers' competence in designing and implementing learning based on open inquiry. In practical terms, this research can contribute to creating a more enjoyable, interactive learning environment and supporting the development of students' scientific skills and critical thinking.

## Objectives

The primary purpose of this study is to train science teachers in developing open inquiry-based scientific inquiry activities to be implemented to students in the classroom. This research aims to provide teachers with a deeper understanding of the concepts of open inquiry and practical skills in designing and implementing inquiry-based learning activities. Teachers are trained to formulate relevant inquiry questions, determine research variables, design experiments or investigations appropriate to the learning topic, and guide students in data collection and analysis (Mutlu, 2020). In addition, this study also aims to assess the


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impact of the training on improving teachers' competence in managing learning through open inquiry-based scientific investigation.

The main problem solved in this study is the need for more understanding and skills of science teachers in developing open inquiry-based scientific inquiry activities. Many teachers need to become more familiar with this approach, even though they know the importance of a learning approach involving science process skills and critical thinking. One obstacle to implementing open inquiry is the need for more appropriate training and practical experience in designing and implementing inquiry-based learning (Baroudi & Rodjan Helder, 2021; Fitzgerald et al., 2019). Therefore, this research aims to improve science teachers' competence in formulating problems, determining investigation variables, drawing conclusions, interpreting tables, and interpreting graphs through training in developing open inquiry-based scientific investigations.

This research is expected to positively contribute to the world of education, especially in improving teacher competence using an open inquiry approach. Through open inquiry-based scientific inquiry development training, teachers gain new skills and can enrich the learning experience offered to students. Thus, the quality of learning can be improved through open inquiry-based learning and can improve students' critical and creative thinking skills in facing future challenges.

## Methodology

### Design

This study uses a quasi-experimental design with a pre-test-post-test approach (Chusni et al., 2022; Taufik et al., 2021) to assess the improvement of the competence of science teachers in formulating problems, determining investigation variables, drawing conclusions, and interpreting tables and graphs after participating in training on the development of open inquiry-based scientific investigation. In this design, researchers collected data at two different times: pre-test and post-test. This approach was chosen because it can provide a clear picture of changes in science teachers' competence after participating in training with a relatively short time interval between pre-test and post-test of approximately a maximum of 10 hours (Kirk, 2009; Tho et al., 2015).

### Research Subject

The subjects in this study are science teachers who are members of the science teacher community in several junior high schools and have scientific backgrounds in physics, biology, and chemistry. The research subjects were selected by purposive sampling technique based on criteria (Ames et al., 2019): science teachers who teach at the junior high school level, teachers who are interested in participating in open inquiry-based scientific inquiry development training, and teachers who are willing to participate in research actively. A total of 10 science teachers were involved as research subjects in the hope of providing in-depth insights into changes in their competencies after attending the training. All subjects participating in this study were voluntary, and filling out the questionnaire was considered a form of participant consent. The data collected is kept confidential and used only for the purposes of this research in accordance with the applicable data protection policy.

### Research Instruments

The main instruments in this study are pre-test and post-test tests, which aim to measure teachers' abilities in several aspects related to open inquiry-based scientific investigation. This instrument is compiled to assess five main aspects of competencies that are to be developed through training, namely (Afandi et al., 2019; Elfeky et al., 2020): Ability to Formulate Problems, Ability to Determine Investigation Variables, Ability to Draw Conclusions, Ability to Interpret Tables, and Ability to Interpret Graphs. These pre-test and post-test use multiple-choice questions designed to assess teachers' understanding and skills in managing open-ended inquiry-based scientific inquiry (Fan, 2024). Each question is prepared by referring to the competency indicators to be achieved through training. In addition to the test, the questionnaire with a 5-point Likert scale was also used to assess how satisfied teachers are with the abilities they have acquired from training in inquiry-based learning practices. All instruments in this study have been validated by peers with reliability greater than .82 using Cronbach's Alpha.

### Analysis

The data collected from the pre-test and post-test were analyzed using comparative analysis techniques to see changes in science teachers' competence before and after the training. Comparison between pre-test and post-test scores will be made using statistical tests such as the average N-Gain score (Wardani et al., 2020) to find out if there is a significant difference in the teacher's ability to formulate problems, determine investigation variables, draw conclusions, and interpret tables and graphs. N-gain was chosen because it can compare two data sets obtained from the same subject at two different times (Saputra & Chaeruman, 2022). In addition, the collected data will be analyzed in a descriptive qualitative manner for the questionnaire analysis. Researchers identify patterns or themes that arise from teacher satisfaction during training and the implementation of inquiry-based learning. The findings from the questionnaire were used to provide more convincing support regarding the application of skills acquired by teachers during training.

## Results

This research aims to improve science teachers' competence in formulating problems, determining investigation variables, drawing conclusions, and interpreting tables and graphs through training in developing open inquiry-based scientific investigations. The arrangement of the results obtained from the observation of the training session, as shown in Table 1, corresponds to the five main variables. The first variable concerns the ability to formulate an investigation problem. It concerns how teachers can formulate research problems appropriate to the relevant science learning topics. The second variable focuses on determining the investigation variable. It examines the extent to which teachers can identify relevant and significant variables in scientific inquiry.

The third variable is the activity of summarizing. This is related to the teacher's competence in drawing conclusions based on the investigation's data analysis results. The fourth variable is related to the competence of interpreting tables, which focuses on the teacher's competence to read and interpret the data presented in tables and correlate it with the conclusion of the investigation. The last competency variable is graph interpretation. This variable shows the extent to which the teacher's competence can understand, interpret, and project the data presented as graphs. By examining these five variables, we can obtain clear and structured research results on the observed open inquiry-based training approach and its relative effectiveness.

Based on Table 1 above, information was obtained that teacher E showed significant progress in all aspects, with a prominent transformation in preleasing test results before and after training. Before the training, Teacher E starts with a score of one, only demonstrating knowledge of the proper formulation of the problem. However, after participating in the training in this study, Teacher E achieved an impressive score of 5 out of 5, indicating that he or she had effectively followed and adopted the training competencies taught. This progress underscores the positive impact of training on improving teacher competence through training in developing open inquiry-based scientific inquiry (Khaokhajorn & Srisawasdi, 2024). The open inquiry approach has proven effective in improving teacher competence, especially professionalism competence, in terms of facilitating students through the learning tools they develop (Rachmadtullah et al., 2024; Sun et al., 2023). This makes education more effective in training students to think critically to face problems in the future. Teacher E's progress will significantly impact the development of students' science process skills if applied in the classroom.

**Table 1**
*Results Obtained from Pre-Training and Post-Training Tests*

| Variable | Teacher | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | A | | B | | C | | D | | E | | F | | G | | H | | I | | J | |
| | BF | AF | BF | AF | BF | AF | BF | AF | BF | AF | BF | AF | BF | AF | BF | AF | BF | AF | BF | AF |
| Formulating the research problem | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 0 |
| Determining the variables of the investigation | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 |
| Drawing conclusion | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 |
| Interpreting tables | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| Interpreting graphic | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| Total | 3 | 3 | 2 | 4 | 3 | 5 | 2 | 3 | 1 | 5 | 1 | 3 | 4 | 5 | 2 | 3 | 1 | 2 | 2 | 3 |

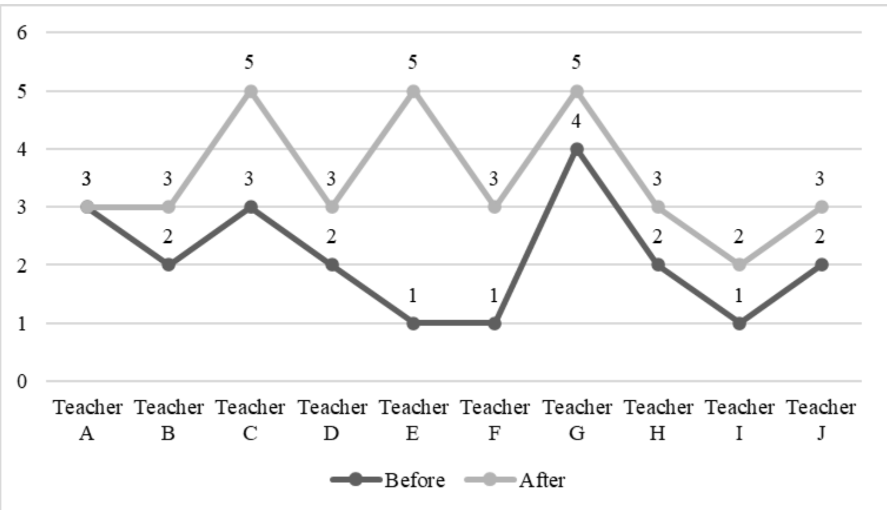
*Note*. BF = Before, AF = After.

Teachers B, C, and F showed a significant increase in competence. Teacher B experienced an increase in competence in the variables of interpreting tables and graphs before and after participating in the training. Teachers C and F experienced increased competence in interpreting charts and determining the variables of inquiry. Interpretation of tables and graphs is an important science process skill to be developed in teachers and students (Cairns & Areepattamannil, 2019; Mulyeni et al., 2019). Every data presented in tables or graphs always contains beneficial information, both past, present, and future. Students are trained to take meaningful information through the relationships between data presented in tables or graphs (Börner et al., 2019). Students are also trained to project the future based on data presented in tables or graphs.

Teachers D, G, H, I, and J showed a significant but insignificant improvement in teacher competence before and after participating in the training. The improvement experienced by Teachers D, G, H, I, and J generally lies in their ability to interpret charts. Finally, teacher A has yet to show the significance of increasing competence. Especially in terms of determining the variables of the investigation and interpreting the graph, teacher A did not experience any inability. This is because teacher A has a background in biology education so there are still obstacles, lack of motivation, and lack of involvement in understanding physics materials. The insignificance of teacher A's ability in several variables related to competence does not reduce the accuracy of the significance of teacher competency improvement in this study because the significance of teacher competency improvement is determined by calculating the gain index (Zahra et al., 2025): average gross gains (AGG) dan average relative gains (ARG). AGG represents the difference between the average after training and the average before training, thus reflecting what is obtained. In contrast, ARG measures the difference between what is and can be obtained. ARG is calculated using (1).

$$\frac{(\text{average post-training} - \text{average pre-training})}{(\text{average maximum} - \text{average pre-training})} x100 \quad (1)$$

**Figure 1**
*Comparison of Teacher Competencies Before and After Training*




We have presented the results in Figures 2 and 3 to facilitate our research. From Figure 2, we can see that the two teachers E made the most significant progress with AGG "4" followed by teachers B, C, and F (AGG = 2), teachers D, G, H, I, and J (AGG = 1), and teacher A (AGG = 0). AGG is positive, which indicates that there has been an increase in the average competency of teachers after participating in the training.

The training effect is considered positive when the ARG exceeds 30% (Zahra et al., 2025). By analyzing the results shown in Figure 3, we can conclude that the training has varied results in improving teacher competence. There is a gradual progression from 25% to 100%. This means that the teachers experience a significant increase in competence after the training.

**Figure 2**
*Comparison of Teachers' Average Gross Gains*

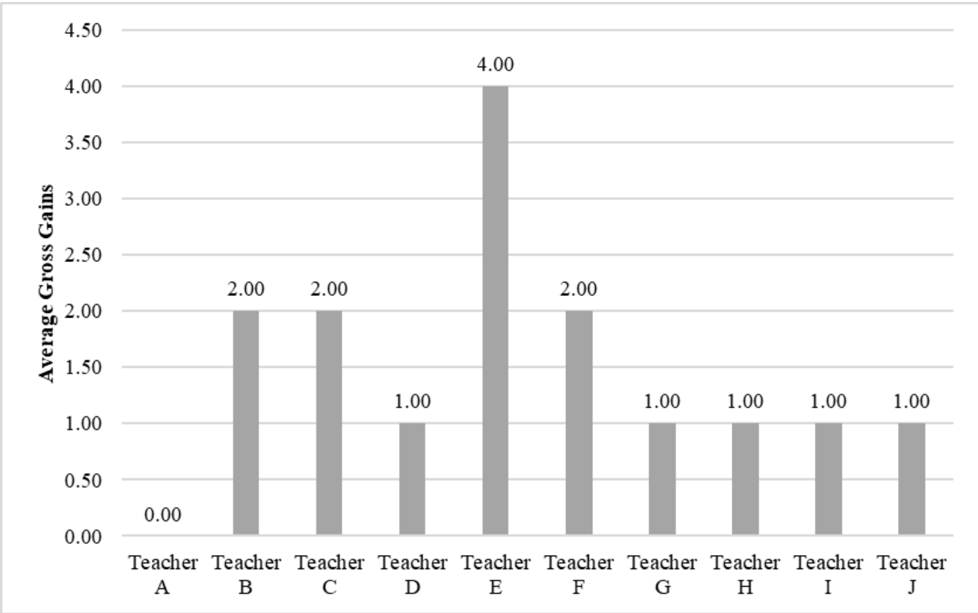
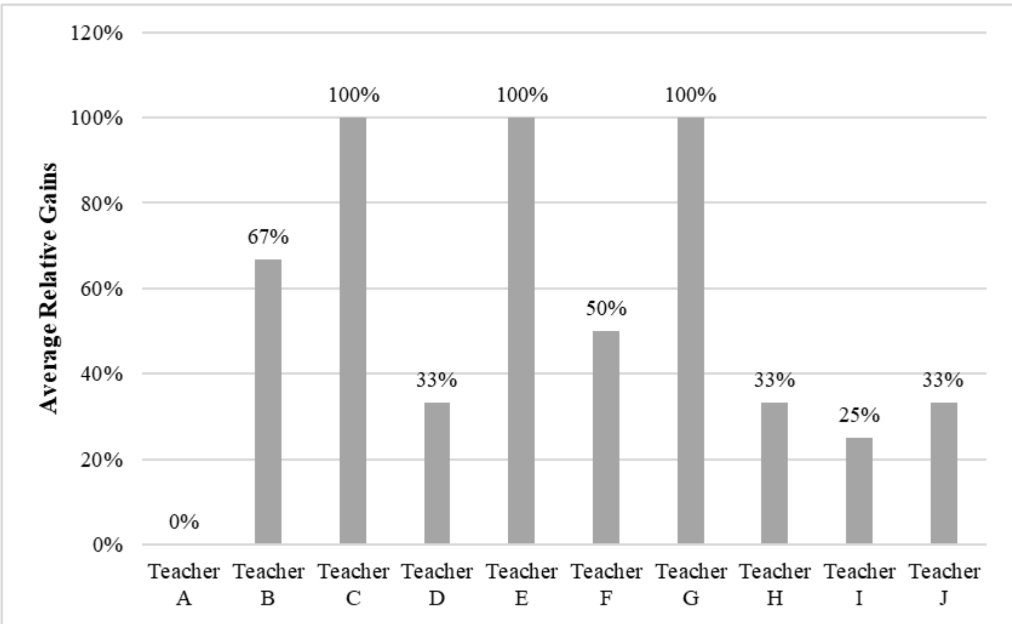



**Figure 3**
*Comparison of TEACHERS' AVRAGE RELATIVE GAINS*




The data obtained from the pre-test and post-test showed a significant increase in science teachers' competence in formulating problems, determining investigation variables, drawing conclusions, and interpreting tables and graphs after participating in the training. In the pre-test, most teachers needed a more fundamental understanding of the steps in open inquiry-based scientific inquiry. Most teachers still need help formulating an apparent research problem and determining relevant variables. Likewise, in terms of interpreting data, many teachers need help drawing conclusions based on table and graph data.

However, after the training, the post-test results showed significant changes. The average teacher's post-test score increased significantly compared to the pre-test score, especially in formulating the investigation problem and determining the research variables. This shows that open inquiry-based inquiry development training for teachers has succeeded in helping teachers better understand the process of scientific inquiry. Teachers become more skilled in identifying research problems that can be explored further and in formulating hypotheses that are in accordance with the topic being taught.

Teachers' ability to draw conclusions based on the data has also improved. After participating in the training, teachers become more confident in analyzing data and making conclusions supported by concrete evidence. Likewise, regarding table and graph interpretation, the post-test results show that teachers can better understand and relate data in tables and graphs with conclusions relevant to the studied material.

## Discussion

Strengthening the science teachers' competence in this study aligns with the training objectives that want to introduce and develop teachers' abilities in designing and implementing scientific investigations based on open inquiry. This training focuses on providing a theoretical and practical understanding of the correct steps of scientific investigation. This training contributed to a change in teachers' perspectives on open inquiry-based learning approaches. Teachers are not only given knowledge about the concept of inquiry but are also trained to develop scientific inquiry activities to apply them directly in their learning activities.

### Teachers' Ability to Formulate Problems

One of the most striking results is improving teachers' ability to formulate research problems (Kwangmuang et al., 2021). Before the training, many teachers found it difficult to design research problems that were appropriate to the context of science learning. However, after participating in the training, they can better formulate apparent problems and use them as a basis for investigation activities. This training provides them with a better understanding of how to choose topics that students can investigate further and formulate questionable inquiry questions through experiments or observations (Eckerd et al., 2021).

### The Teacher's Ability to Determine the Variables of the Inquiry

In addition, this training also succeeded in improving teachers' ability to determine investigation variables (Podolsky et al., 2019). Many teachers needed help understanding how to choose the correct variables in a scientific study at the beginning of the study. After the training, teachers can be more precise in determining independent, dependent, and control variables in scientific investigation activities (Cairns, 2019). This is important because a good understanding of the variables of investigation is the basis for the preparation of valid and reliable experiments.

### Teacher's Ability to Draw Conclusions

In conclusion, the training has improved teachers' skills in analyzing the results of investigations and drawing conclusions based on the evidence (Sumarni & Kadarwati, 2020). Teachers who previously felt less confident in conclusions can now better analyze data and make conclusions supported by existing information in the form of numbers, tables, and graphs (Parkhouse et al., 2019). This shows that the training in this study focuses on theory and practical skills that can be directly applied by teachers in classroom learning.

### Teachers' Ability to Interpret Tables

Teachers' ability to interpret tables has also improved significantly. Previously, many teachers had difficulty reading data in the form of tables. After training, teachers can better relate the investigation table's data to the correct conclusions. This shows that open-inquiry training helps teachers to be more sensitive to how data is presented and how it can be used to support arguments in scientific research (Adler et al., 2019; Wang et al., 2022).

### The Teacher's Ability to Interpret the Graph

Teachers' ability to interpret graphs has also improved significantly. Previously, many teachers had difficulty reading data in graphs (Mazibe et al., 2020). After training, teachers can better project data according to the correct conclusions. This shows that open inquiry training helps teachers be more sensitive to how data is presented and how the data can be used to project the following data and support arguments in scientific research (Sergis et al., 2019).

In addition to the results obtained through the test, the observation results during the training also show that teachers are starting to apply the skills learned in designing an open-ended, inquiry-based learning plan. Teachers can design activities that allow students to actively investigate scientific phenomena, from formulating problems to concluding (Sari et al., 2021). Teachers also begin to introduce the concept of scientific inquiry to students in a more interactive and experimental-based way (Alsufyani, 2023; Soudani, 2024).

However, despite the significant improvements, some challenges still arise, especially in implementing open inquiry-based learning in the classroom. Some teachers reported difficulties managing time during investigation activities and providing the necessary experiment resources. In addition, some teachers still feel anxious about giving students greater freedom to design and conduct their investigations. However, the results of this study show that with the proper training, teachers can improve their competence in designing and implementing open inquiry-based scientific investigations. One of the limitations of this study is that it is carried out with a duration of 10 hours of training, which is very short of the duration of long-term competency improvement that should be.

## Conclusion

Based on the research results obtained, the training on the development of open inquiry-based scientific inquiry has succeeded in improving science teachers' competence in several important aspects. The teacher who is the subject of this study shows an increased ability to formulate problems, determine investigation variables, draw conclusions, and interpret data in tables and graphs. The pre-test and post-test analysis results showed a significant increase in scores. This significance in implementing learning is interpreted as the effectiveness of this training to develop teacher skills through an inquiry-based learning approach. However, implementing the open inquiry approach still faces challenges for some students. These obstacles include limited time, difficulty directing students to conduct inquiries independently, and limited resources in several schools. For this reason, this training is an innovative solution to help teachers overcome these obstacles. This research can contribute significantly to the professional development of science teachers, especially in preparing teachers to develop students' science process skills. However, the conclusion of this study only applies to the subjects in the study. Further research is needed to measure its achievement in the post-training classroom. Taking into account the challenges teachers face in the field, more adaptive and sustainable training programs can be further designed by teachers with a focus on table and graph interpretation training. This will allow teachers to apply the open inquiry approach more effectively and ultimately improve the quality of science learning and encourage the development of students' scientific thinking skills.

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