# The Effect Size of the Science Teachers' Scientific Method Knowledge on the Planning and Implementing the Scientific Method

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## Abstract

The minimum learning standard in enabling students to be actively involved in building knowledge and skills is the application of the scientific method. The scope of learning activities consists of observing, questioning, experimenting, reasoning, and communicating. The purpose of this study was to discover the effect size of the natural science teachers' scientific method knowledge on the skills of integrating the scientific method in lesson planning and the science teacher's skills in implementing the scientific method in science learning. The study samples were 50 science teachers assigned randomly from 146 junior high school teachers in Kendari City, Indonesia. The scientific method knowledge data collection instrument was a five-step description test of the scientific method whereas data regarding lesson plans were collected using a questionnaire, and learning implementation data used the lesson-plan assessment sheet instrument and the scientific method learning assessment sheet in class. Data were analyzed using a paired samples test statistic in the SPSS version 24 program to determine the effect of knowledge on lesson plans and implementation of the scientific method, while determining the effect size using Cohen's d test. Results showed that the effect size of the scientific method knowledge on learning planning skills was 114 % or large effect, while the effect on the teacher's skills in implementing the scientific method in science learning was 63,2 % or intermediate effect.

Keywords: Scientific Method Knowledge, Planning, Learning Implementation, Science Teacher.

## INTRODUCTION

The minimum standard for science learning in junior high schools is the application of the scientific method. The scientific method is a pedagogical approach through the process of observing, questioning, experimenting, reasoning, and communicating (Setiawan, 2019), a linear process carried out step by step (Cullinane et al., 2019) and become part of learning innovation (Zulfakar, 2020). Pedagogic principles are used by teachers as part of modeled learning to give effect to students' independent learning (Amiruddin et al., 2023). Gaiotto describes that the purpose of applying the scientific method is so that students learn actively, building the students' sense of responsibility and awareness of the learning process (Gaiotto et al., 2020). The learning steps involve students directly in every step of the scientific method through amazing ideas (Haenilah et al., 2021). Learning activities through the scientific method enable the students to gain learning experiences that could be developed personally through the construction of interesting and stimulating contexts. Therefore, improvising science teaching as part of a model-based teaching approach (Botes, 2021).

However, the scientific method is generally associated with learning outcomes such as cognitive learning outcomes (Gaiotto et al., 2020), critical thinking (Lieung, 2020), creative thinking (Masitoh & Prasetyawan, 2019), science process skills (Darmaji et al., 2019), or module development (Hadianto et al., 2018). This study differed from the aforementioned studies in that it reveals the effect size of the science teachers' scientific method knowledge on the skills of integrating the scientific method in lesson planning and the teachers' skills in applying it in learning. Scientific method knowledge is the teacher's cognitive knowledge that includes observing, questioning, experimenting, reasoning, and communicating. Skill in integrating the scientific method into lesson planning is the teacher's ability to design learning activities according to the steps of the scientific method while the skill of applying the scientific method is the teacher's skill in directing student activities according to the steps of the scientific method. Teachers who have good pedagogical knowledge will also demonstrate good lesson-planning skills and be able to apply them effectively in learning.

The ideal expectation for learning science is that science teachers are skilled at directing students to work, study, and process through the scientific method. Teachers with good scientific

method knowledge will display the ability to design good lesson plans as well. In addition, teachers who demonstrate good knowledge of the scientific method will demonstrate a better ability in applying the scientific method. The effect size of knowledge on lesson planning as well as the magnitude of the influence of knowledge on the application of learning will be effective information on the use of the scientific method. Cullinane et al. (2019), the scientific method implemented in the classroom will lead students to reflect on how science learning works. A teacher's job is not only to impart knowledge, but to understand what, when, and how to teach certain materials to students (Zundans-Fraser et al., 2016) and to direct students in building critical and analytical thinking skills based on scientific processes (Setiawan, 2019).

The success of applying the scientific method in learning science depends strongly on the teacher. A teacher must position himself or herself as the students' coach and activate all the students' senses and motor skills (Haenilah et al., 2021). Teacher-designed lesson plans are one of the determining factors for student success (Pratiwi et al., 2020) and consideration of the student learning environment (Sande and Burnett, 2023), as part of global teaching competencies (Van Wervena et al., 2023; Zeeb et al., 2023; Nguyen et al., 2023). Students work through the process of observing, developing questioning skills, working through experimentation or exploration, reasoning by associating facts with concepts, and being skilled at communicating results orally and in writing (Haenilah et al., 2021). This learning process is based on evidence from observable, empirical, and measurable objects with specific principles of reasoning. The application of the scientific method will expose the teacher's way of thinking to develop an effective lesson plan in guiding students in learning to follow the steps of the scientific method. A solid foundation of scientific method knowledge will facilitate science teachers in designing effective scientific method lesson plans. In addition, good scientific method knowledge can improve teacher skills in guiding students in developing experience, knowledge, and skills through observing, questioning, experimenting, reasoning, and communicating activities.

## METHOD

This type of research is comparison of groups with equal size (Cohen, 1988) by involving one independent variable and two dependent variables. The independent variable is knowledge of the scientific method. The

first dependent variable is the skill of integrating the scientific method into lesson planning and the second dependent variable is the implementation of the scientific method in science learning.

The samples were junior high school science teachers in Kendari City who were randomly selected, namely 50 teachers out of the 146 science teachers in Kendari City.

The study instruments consisted of: first, descriptive questions to measure scientific method knowledge (Table 1); second, the questionnaire on integrating the scientific method in lesson planning which was adapted from (Jahidin, 2021). The questionnaire includes seven observing statements, eight questioning statements, fifteen experimenting statements, nine reasoning statements, and six communicating statements; and finally, the rubric for evaluating the application of the scientific method in lesson plans and lesson implementation. The assessment of the steps for implementing the scientific method is presented in Table 2.

Table 1. List of test questions describing knowledge of the scientific method.

| No. | Question items |
|---|---|
| 1 | Describe the activity of observing in the scientific method. |
| 2 | Describe the activity of questioning in the scientific method. |
| 3 | Describe the activity of experimenting in the scientific method. |
| 4 | Describe the activity of reasoning in the scientific method. |
| 5 | Describe the activity of communicating in the scientific method. |

Table 2. Indicators for assessing the scientific method in lesson planning and implementing science learning.

| Steps in the scientific method | Aspects of assessing lesson plans and applying the scientific method |
|---|---|
| Observing | • Observing through sight, hearing, taste, touch, and smell.<br>• Observing science objects.<br>• Observing through controlling nature or information<br>• Identifying changes in science objects.<br>• Describing what is sensed.<br>• Gathering relevant facts.<br>• Observing using tools or kits. |
| Questioning | • Student involvement in asking questions.<br>• Focusing questions. |

| Steps in the scientific method | Aspects of assessing lesson plans and applying the scientific method |
|---|---|
| | • The questions reflect creative ideas.<br>• The waiting time between questions and answers. |
| Experimenting | • Formulation of the objective of the experiment.<br>• Equipment required.<br>• Laboratory experiments or observations outside the classroom.<br>• Manipulation of real objects.<br>• Availability of manuals or practicum instructions.<br>• Evaluation of experiment processes.<br>• Monitoring of the data collection process.<br>• Use of tools and materials.<br>• Accuracy in collecting data or information. |
| Reasoning | • Processing information.<br>• Linking one piece of information with another.<br>• Finding patterns.<br>• Thinking logically and systematically.<br>• Drawing conclusions. |
| Communicating | • Presentation skills.<br>• Presenting data and information using graphs, tables, and diagrams.<br>• Assessment of the presentation process. |

The study data collection was conducted in two stages. First, data collection on knowledge of the scientific method used a description test and data on the integration of the scientific method in lesson planning used a questionnaire. Secondly was data collection on the application of the scientific method. The data on the application of the scientific method came from an assessment of the scientific method in the lesson plans made by science teachers and the implementation of science learning. The lesson plans reviewed were randomly selected from 30 science teachers. Monitoring of the scientific method activities in science learning was carried out on 20 science teachers in 10 junior high schools. Knowledge data, lesson

planning, and learning implementation were in the form of an interval scale of 1 to 4.

The research data were analyzed using a paired samples test statistic in the SPSS version 24 program to determine the effect of knowledge on lesson plans and implementation of the scientific method, while determining the effect size using Cohen's d. Effect size analysis uses formula (1) to determine the combined standard deviation, while determining the effect size uses formula (2) (Cohen, 1988). The interpretation of the effect size value is: 0.00 – 0.10 is no effect; 0.20 – 0.40 is a small effect; 0.50 – 0.70 is an intermediate effect; 0.80 – ≥1.00 is a large effect.

Formula (1) $S = \sqrt{\frac{(n1-1)sd_1{}^2+(n2-1)sd_2{}^2}{n1+n2}}$

Formula (2) $\mathbf{D} = \frac{X1-X2}{S}\ x\ 100\ \%$

The prerequisite data test used the Kolmogorov-Smirnov normality test and the homogeneity test used the Levene test. The results of the scientific method residual knowledge test with lesson planning using the one-sample Kolmogorov-Smirnov Test showed asymp.Sig 200 > α 0.05, and the residual data of scientific method knowledge with the application of the scientific method showed asymp.Sig. 0.090 > α 0.05. It can be concluded that the data were distributed normally. The results of the data homogeneity test using the Levene test resulted in the value of Sig. 0.201 > α 0.05; thus, it is concluded that the data were homogeneous.

**RESULTS AND DISCUSSION**

Knowledge of the scientific method influences the ability of science teachers to integrate the scientific method into lesson plans and also influences the application of the scientific method in learning science. This influence means that science teachers who have good knowledge of the scientific method will demonstrate good skills in integrating the scientific method in lesson plans, and are able to implement the scientific method in learning activities. This is reinforced by the results of the t test in Table 3 which shows a significance value of 0.00 on the effect of knowledge-lesson plan and 0.03 on the effect of knowledge-implementation lower than alpha 0.05.

Table 3 shows that the influence of scientific method knowledge on the teacher's skills in integrating the scientific method in lesson plans is 1.140 or 114%. The influence value is included in the very high category (Cohen, 1988). The ability to integrate the scientific method into lesson plans is greatly influenced by knowledge of the scientific method. The findings of this study have implications that the skills of science teachers in planning lessons by integrating the scientific method really

need to consider the level of knowledge of the scientific method such as the requirements for understanding the meaning of observing, questioning, experimenting, reasoning, and communicating. The focus is on scientific method activities that will be followed by students. For example, in observing activities, lesson plans guide students to carry out real activities by making observations using their vision, observing changes in a particular object, collecting facts, or describing the results of observations. The effect size found by this study was higher than that reported by Smit et al. (2018) who tested the contribution of pedagogical content knowledge (PCK) to the competence to plan learning and obtained results of 0.34 or 34%.

Table 3. Summary of the results of the descriptive analysis, the results of the paired samples test, and the Cohen's d test (n=50).

| | | Paired samples statistics | | | Paired samples test | | Cohen's d | | |
|---|---|---|---|---|---|---|---|---|---|
| | | N | Mean | SD | t | Sig. | SD-combined | Effect Size | Interpre-tation |
| Pair 1 | Knowledge - Lesson Plan | 50 | 2.306 | 0.535 | 5.691 | 0,000 | 0.426 | 1.140 | Large effect |
| | | 50 | 2.792 | 0.335 | | | | | |
| Pair 2 | Knowledge - Implementation | 50 | 2.306 | 0.535 | 3.178 | 0,003 | 0.44 | 0.632 | Interme-diate effect |
| | | 50 | 2.584 | 0.362 | | | | | |

Although the effect size of knowledge of the scientific method with the teacher's skills in compiling lesson plans is very good, the mean value of knowledge is 2.306 and lesson plan is 2.792 in the scale range 1 - 4. Therefore, science teachers still need to increase their knowledge of the scientific method and skills in preparing lesson plans integrated scientific method. Science teachers can choose other approaches such as attending training or workshops as an alternative to increasing scientific method knowledge and skills in integrating scientific methods into lesson plans. Choosing training as an effective source of inspiration in designing lesson plans is also the right choice, as reported by Prihidayanti & Florentinus, (2019) that training affects pedagogical competence but does not affect professional competence. The training will benefit science teachers in acquiring the skills to plan scientific method lessons if the training is conducted correctly (Rohmah et al., 2021; Postholm, 2018; Widayatia et al., 2021). However, it is important to analyze the scientific method required by teachers before they attend training so that training objectives can be achieved. For more effective scientific method training, Gopang (2016) recommends teacher development be

conceptualized as an ongoing process of learning the required practical skills and included in teacher education (Sjoen, 2023).

Likewise in the implementation of scientific method learning, the effect size of scientific method knowledge on the implementation of scientific methods in learning as shown in Table 3 is in the intermediate effect category, namely 0.632 or 63.2%. The findings of this study indicate that the teacher's skills in applying the scientific method are influenced by knowledge of the scientific method, but there is an influence of other factors of 36.8%. Therefore, the implementation of the scientific method by science teachers in teaching science material to students is not only because of their knowledge of the scientific method but also because of other factors such as training and workshops on integrating and applying the scientific method in science learning as reported by Mufidah et al. (2021) that training has a significant effect on teachers' teaching skills. Another factor that causes the skills of science teachers to apply the scientific method is in the intermediate effect category reported by Nkanyani & Mudau (2019) due to lack of mastery of the material, inappropriate knowledge, and poor knowledge of context.

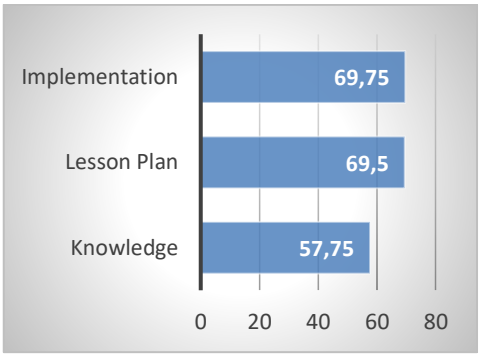


Figure 1. Percentage of the scientific method knowledge, integration of the scientific method in lesson planning, and implementation of the scientific method in science learning activities (n=50).

Although the effect size of the teacher's scientific method knowledge on the skills of integrating the scientific method into lesson plans and the application of the scientific method in science learning has a large effect and an intermediate effect, the average percentage of scientific method knowledge reaches 57.75%, the average percentage of skills science teachers in planning scientific method learning is 69.50%, and the average percentage of teachers' skills in implementing the scientific method is 69.75% (Figure 1). The data shows that the average knowledge of the scientific method is lower than the skills to plan lessons and apply the scientific method. In the aspect of implementing the scientific method, the findings of this study are higher than those reported by Setiawan (2019) at

66.73% and Setiawan and Sugiyanto (2020) at 51.49%.

In the knowledge of the scientific method aspect (Figure 2), knowledge of observing and communicating were the two steps of the scientific method with the highest achievements, while the lowest was experimenting or conducting experiments and exploration. Therefore, science teachers to increase their knowledge of conducting experiments and explorations. Knowledge of experiment or exploration design is a major requirement for science teachers in developing cognitive competence in the scientific method. Experiments and exploration are important aspects of science learning activities because science learning is oriented towards proving concepts. So that science teachers can strengthen their knowledge of experiments and exploration, Jahidin, (2021) emphasized that science teachers must have knowledge of preparation, implementation, and follow-up of experimental or exploratory activities. Teachers need to develop and apply special techniques and procedures suitable for the various stages of problem-solving in natural science (Da Silva, 2022).

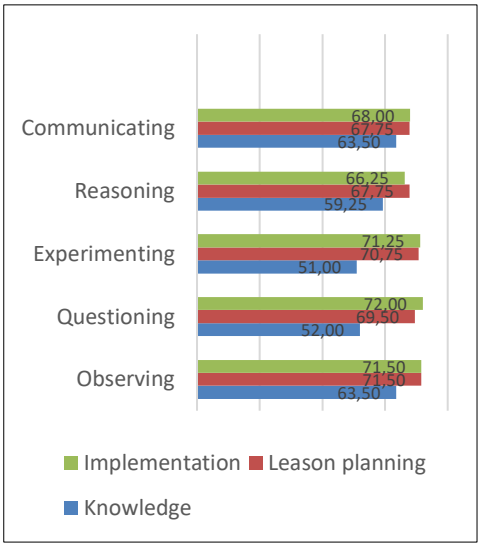


Figure 2. Percentage of teacher achievement in each scientific method indicator based on knowledge, lesson planning, and learning implementation (n=50).

The average science teacher's skill in integrating the five steps of the scientific method was in the range of 67.75 – 71.50%. The skills of integrating the steps of observing were 71.50%, questioning 69.50%, experimenting 70.75%, and reasoning and communicating each 67.75%. This average achievement illustrates that the lesson plan had functioned as a scientific method learning guide, such as becoming a student learning guide (scaffolding) in supporting reasoning (Minken et al., 2021), creating challenges for teachers in scientific modeling (Stammen et al., 2018), improving the quality of learning (Rachmawati et al., 2019), making teaching more meaningful (Masitoh &

Prasetyawan, 2019), and giving experience in the scientific method (Nur & Yalçin, 2015). Even though of the effect size of knowledge on lesson planning was very low, science teachers need to have and develop pedagogical knowledge so that they become skilled at planning scientific methods in teaching science both inside and outside the classroom. It is highly expected that science teachers be skilled at developing valid scientific method learning tools (Rachmawati et al., 2019).

In the aspect of implementing the scientific method in science learning, the percentage of achievement ranged from 66.25 to 72.00%. Viewed from every aspect, the steps of reasoning and communicating were the two steps with the lowest achievements; reasoning at 66.25% and communicating at 68.00%. Both were still below 70% while observing, questioning, and experimenting all exceeded 70%. In the reasoning step, science teachers were still weak in guiding students in processing information, linking one piece of information to another, finding patterns, thinking logically and systematically, and drawing conclusions. Whereas in the communication step, the teachers still need to improve their role in guiding students to improve presentation their skills, encouraging students to present data and information using graphs, tables, and diagrams, and applying assessment of the presentation process. The expectation is that the implementation of the scientific method will become a meaningful teaching experience if conducted realistically with various learning activities. However, it has not been implemented perfectly. Naturaal science teachers must develop skills in applying the scientific method so they may guide students in learning through scientific method steps.

Given the teachers' important role as professional educators in planning and implementing the scientific method in science learning, teachers are expected to be not only competent but also professional. For this reason, science teachers must have adequate knowledge and skills related to the practice of teaching scientific methods to meet the demands and quality standards of the scientific method which have not been realized, 42.25% in the knowledge aspect, 30.50% in the lesson planning aspect, and 30.25% in the implementation aspect of learning. To realize minimum learning standards using scientific methods, teacher training is currently seen as a central mechanism for increasing teacher knowledge and teaching skills to meet high learning standards (Hammond &

Mclaughlin, 1995) and increasing teachers' critical awareness of designing learning activities (Botes & Barnett 2022). To ensure the effectiveness of the training, Richards and Farrell (2005) suggest direct training to focus on teacher responsibilities for short-term goals, designing different training programs that can help in improving skills (Al-Ramamna and Jreisat, 2023), and forming partnerships with universities (Muhsin et al., 2021). The training program helps teachers hone their teaching skills, deepening and increasing their knowledge (Boudersa, 2016; Camp, 2017). The findings of this study also support the opinion of Minken et al., (2021) that implementing the scientific method is not a simple pedagogic process for teachers because there are difficulties that science teachers will face such as experiencing obstacles in teaching science. This obstacle can be seen in the teacher's lesson-planning skills achievement at 69.5% and the implementation of the scientific method achievement at 69.75%.

## CONCLUSION

The effect size of the scientific method knowledge on the skills of science teachers in integrating the scientific method into lesson plans is very high, while the effect size of of the scientific method knowledge on the skills of science teachers in applying the scientific method in teaching science in class is intermediate. Science teachers need to improve their skills in implementing the scientific method in teaching science. Increasing skills in applying the scientific method is achieved through training.

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