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Scientific Method Skills of Prospective Teacher Students Based on Their Major Background Science and Non-Science

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Abstract: The systematic method of acquiring knowledge based on physical evidence is known as the scientific method. It is also one of the main goals of science education, aiming to evaluate one's ability to solve problems and generate new knowledge systematically. This study aims to analyze differences in scientific method skills between prospective teacher students from science and non-science backgrounds, and to explore the correlations between scientific thinking components. Of the 102 potential teachers from Hamzanwadi University who participated in the study, 58 had a background in science and 44 did not. In order to represent the variety of educational streams enrolling in teacher education programs, participants were chosen based on their high school academic performance. Pearson correlation analysis and an independent samples t-test were used to analysis data. The results showed that science students performed better in the question and procedure components. However, there were no significant differences in problem identification, hypothesis, prediction, and conclusion components. Correlation analysis revealed that science-background students displayed more systematic and logical thinking patterns, with strong correlations among scientific thinking stages. Conversely, non-science students exhibited weaker and inconsistent relationships among components, especially in the initial stages of the scientific process. Systematic and contextual science learning must be strengthened using differentiated approaches based on students' educational backgrounds. These results have significant implications for developing curricula that enhance scientific thinking skills across disciplines.

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Introduction

Science is a method for obtaining knowledge about the world and the universe through observation, experimentation, and analysis. One of the primary goals of science education is to train students in scientific thinking through scientific processes. According to Zeidan & Jayosi (2015), the goal of science education is to develop scientific ideas. Tyas et al. (2021) state that in developing science-based learning, the essential aspects involved include observing, formulating hypotheses, and conducting experiments. Studying science provides students with the ability to comprehend concepts and facts comprehensively. Sumirat (2017) emphasized the development of logical thinking and conceptual understanding through more complex scientific approaches. Science is a process of solving testable problems (Wazni & Fatmawati, 2022).

The scientific method in learning science trains students to think rationally and based on evidence, which helps them better understand scientific concepts through activities such as observing, testing hypotheses, analyzing data, and drawing conclusions. Hestiana & Rosana (2020) advocate for involving students in evidence-based inquiry to develop rational thinking. Madondo (2021) suggests that learning scientific concepts should be done contextually. This method is crucial in helping students understand fundamental concepts in math and science (Murzabaev et al., 2022). Ramadhan & Mardin (2023) affirm that scientific approaches can improve students' critical thinking and scientific literacy.

In practice, students still struggle with the scientific method. They have difficulties understanding experimental concepts, identifying variables, and drawing conclusions. Suwono et al. (2017) emphasize the need for developing students' scientific literacy and critical thinking through case-based learning. Maryani et al. (2018) identified that the lack of interest in science learning stems from inappropriate teaching methods. Many students still struggle to grasp abstract concepts (Utemov, 2019). Subali et al. (2019) state that the use of scientific methods in science learning needs enhancement. Santhalia & Yuliati (2021) found that students often are not engaged in investigative activities, hampering their scientific literacy and critical thinking development. Even after graduating, students may still lack understanding of scientific inquiry (Lederman et al., 2021). Students in South Africa, for example, lack basic knowledge of scientific inquiry (Penn & Ramnarain, 2021). Rahmatika et al. (2022) report that students still struggle with formulating problems, developing hypotheses, collecting and analyzing data, hence limiting the development of scientific skills. Lim & Kim (2023) highlight the difficulty middle school students face in interpreting data and drawing conclusions from investigations. The ability to solve scientific problems and conduct analysis is affected by limited understanding of the scientific method.

The low level of competence is attributed to the lack of mastery and skills in the scientific method among teachers when instructing their students, which may stem from their non-science educational backgrounds. The limited understanding and capabilities of teachers regarding the scientific method hinder students' engagement with scientific knowledge (Aalderen-Smeets & Molen, 2015). Non-science teachers often fail to assist students in comprehending and applying the scientific method (Zamora-Polo et al., 2019). According to Agustiani et al. (2020) and Etobro & Fabinu (2017), it is not easy for teachers without a science education background to implement the scientific method in the classroom and to teach complex scientific concepts. Erman et al. (2018) state that essential scientific thinking skills are still lacking among novice teachers, which is critical for implementing inquiry-based learning. Zhou & Xiao (2018) found that prospective science teachers often cannot anticipate students' learning difficulties in mechanics. Many teachers struggle to apply the scientific method, which affects their ability to guide students toward scientific inquiry (Leonard & Wibawa, 2020). Teachers' scientific and methodological competencies must be developed as they impact teaching effectiveness and progress in science education (Kulishov et al., 2021).

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To enhance teachers' abilities in utilizing the scientific method, teaching materials based on scientific literacy should be developed (Dewi et al., 2022). Due to pedagogical limitations, teachers find it challenging to integrate socio-scientific issues into the scientific method (Zhang & Du, 2022). If science lessons are taught by non-science teachers, it affects students' understanding of essential scientific concepts (Deforzh & Kalinichenko, 2022). Teachers with non-science backgrounds struggle to implement the science curriculum (Paz & Locatelli, 2023). Educators still require substantial additional training to effectively apply this method in teaching (Haenilah et al., 2023). Many prospective teachers lack sufficient experience in teaching science using experiential-based approaches (Gui & Akuba, 2023). To teach science effectively, it is crucial for teachers to receive training in scientific writing in order to improve their professionalism and mastery of scientific skills (Samsilayurni et al., 2024).

In addition, Non-Science students often choose education majors when they enter university. These students are generally not accustomed to scientific and investigative ways of thinking, resulting in prospective teachers having significantly different scientific method skills. There is a lack of knowledge and expertise in scientific methods among future teachers (Krämer et al., 2015). Many prospective teachers still face difficulties in developing their scientific thinking (Kaçan & Şahin, 2018). According to Fatmawati & Nuryani (2020), prospective teachers require training and guidance to foster scientific thinking. There is also a notable lack of scientific and methodological competence among vocational education teachers (Kulishov et al., 2021). Fatmawati & Khotimah (2023) emphasize that not all students possess sufficient scientific literacy skills to enter higher education. Sometimes, students preparing to become teachers are unaware of the importance of scientific method skills (Molefe & Aubin, 2023), highlighting the need for further research into the relationship between scientific method abilities and academic performance in both secondary schools and universities (Dolapcioglu & Subası, 2022).

Therefore, strategic actions are needed to train prospective teachers—both from Science and Non-Science backgrounds—in mastering the scientific method through its integration into the learning process. With this instructional design, it is expected that students will acquire adequate scientific skills, enabling them to teach science in a more practical and experiential manner. Furthermore, integrating the scientific method into science education encourages students to think critically, conduct research, and attempt to solve real-world problems within their environment. The objectives of this study are to analyze the differences in scientific method mastery between Science and Non-Science students. Given that many aspiring Indonesian teachers have a variety of academic backgrounds, many of which include non-science fields, this comparison study is crucial. Due to their limited exposure to structured scientific thought, students from non-science backgrounds often struggle to teach scientific topics, even while they are enrolled in education faculties. The efficiency of scientific instruction in Indonesian schools is impacted by this disparity. Given the national curriculum revisions' emphasis on scientific literacy and inquiry-based learning, it is imperative that this issue be addressed. As a result, this study offers important and relevant insights to guide teacher preparation programs that take into account the academic backgrounds of pupils.

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Research Method

Design

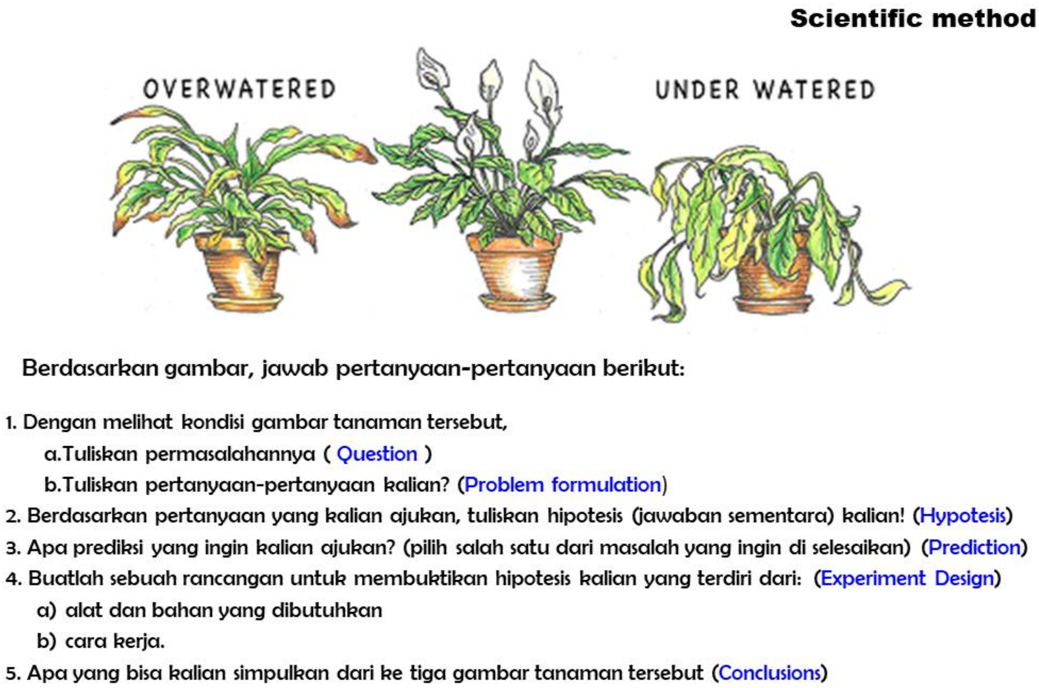
This study employed a non-experimental quantitative approach with comparative and correlational designs (Creswell & Creswell, 2018). The comparative method was used to describe and compare students' initial abilities in the scientific method based on their academic backgrounds in high school (Science and Non-Science), while the correlational design aimed to examine the relationships among elements of scientific thinking. The comparative design identified differences in scientific method abilities between groups, and the correlational analysis explored the relationships among problem formulation, scientific questioning, hypothesis, prediction, procedures, and conclusions.

Subjects

The participants in this study were 102 prospective education students from Hamzanwadi University, comprising 58 students from science backgrounds and 44 from non-science backgrounds.

Instrument

The instrument used was a scientific method skill test in the form of open-ended questions covering components such as asking questions, problem formulation, hypothesis development, prediction, experiment design, and conclusions (Reece et al., 2011). Each component was scored on a scale of 1 to 3, The instrument form is presented in Figure 1.


Scientific method

OVERWATERED

UNDER WATERED

Berdasarkan gambar, jawab pertanyaan-pertanyaan berikut:

1. Dengan melihat kondisi gambar tanaman tersebut,
   a.Tuliskan permasalahannya (Question)
   b.Tuliskan pertanyaan-pertanyaan kalian? (Problem formulation)
2. Berdasarkan pertanyaan yang kalian ajukan, tuliskan hipotesis (jawaban sementara) kalian! (Hypotesis)
3. Apa prediksi yang ingin kalian ajukan? (pilih salah satu dari masalah yang ingin di selesaikan) (Prediction)
4. Buatlah sebuah rancangan untuk membuktikan hipotesis kalian yang terdiri dari: (Experiment Design)
   a) alat dan bahan yang dibutuhkan
   b) cara kerja.
5. Apa yang bisa kalian simpulkan dari ke tiga gambar tanaman tersebut (Conclusions)

Figure 1. Test scientific method

Data analysis

Comparative Test (Independent Samples t-Test); To determine the differences in scientific method abilities between Science and Non-Science students, a two-sample independent t-test is used with the formula:

$$t = \frac{\bar{X}1 - \bar{X}2}{\sqrt{[\left(\frac{s1^2}{n^1}\right) + \left(\frac{s2^2}{n^2}\right)}}$$

(Gravetter & Wallnau, 2016)

Description:
- - $\bar{X}_1$, $\bar{X}_2$ = average of group 1 and group 2
- - s_1^2, s_2^2 = variance of each group
- - n_1, n_2 = number of samples in each group
- - t = value of test statistics

This test is performed assuming that the data is normally distributed and has homogeneous variance. Levene's test is used to test the homogeneity of variance

Correlation Analysis (Pearson Product Moment); To determine the relationship between the components of the scientific method, the Pearson correlation formula is used as follows:
$r = [n\Sigma XY - (\Sigma X)(\Sigma Y)] / \sqrt{\{[n\Sigma X^2 - (\Sigma X)^2][n\Sigma Y^2 - (\Sigma Y)^2]\}}$

$$r = \frac{[n\Sigma XY - (\Sigma X)(\Sigma Y)]}{\sqrt{\{[n\Sigma X^2 - (\Sigma X)^2][n\Sigma Y^2 - (\Sigma Y)^2]\}}}$$

(Sugiyono, 2021).

Description:
- r = Pearson correlation coefficient
- X and Y = two correlated variables
- n = number of data pairs

The r value ranges from -1 to +1, indicating the direction and strength of the relationship between two variables.

Result and Discussion

Comparative Test (Independent Samples t-Test)

The results of the Independent Samples t-Test showed that there were significant differences in the Question components ($p < 0.001$) and Procedure ($p = 0.0007$) between the Science and Non-Science groups. Students from a Science background showed better abilities in formulating scientific questions and designing experimental procedures. Pearson correlation coefficients from the examined data matrix were mapped using Microsoft Excel's conditional formatting function to create the heatmap visualizations. The degree of the association between the elements of the scientific method is represented by each color intensity, making it easier to

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see thought processes. The full results are presented in Table 1. Students from non-science backgrounds face difficulties in understanding basic science concepts (Zamora-Polo et al., 2019). Haw et al., (2022) The absence of significant differences between the two groups of students indicates that more efforts are needed to encourage students' interest and desire for basic science disciplines. in cycle I students had difficulty finding research problems, determining research titles, and determining problem-solving techniques (Marpaung et al., 2023). Students' abilities are still lacking in interpreting data, designing and evaluating scientific research, and explaining phenomena (Siswanto et al., 2023). Most prospective science teachers are unable to provide examples of the operationalization of scientific method procedures (Supeno et al., 2020).

Table 1. Results of the Independent Samples t-Test)

Component	T-Statistik	P-Value	Signifikan (α = 0,05)
A problem	-1.35	0.1805	Not Significant
Question	-6.80	<0.001	Significant
Hipotesis	-0.29	0.7737	Not Significant
Prediction	-1.20	0.2345	Not Significant
Procedure	-3.52	0.0007	Significant
Conclusion	-1.64	0.1041	Not Significant

Correlation Analysis (Pearson Product Moment)

The main purpose of correlation analysis (Pearson Product Moment) is to measure the closeness and direction of the linear relationship between two quantitative variables. In addition, this analysis is used to determine whether there is a positive or negative relationship between the two variables, as well as the strength of the relationship. Pearson correlation analysis is used to further explore the relationship between elements in students' scientific thinking processes. For each group, this analysis is carried out separately. The following are the results of the correlation analysis presented in table 2.

Table 2. Results of correlation analysis of scientific method abilities in science and non-science groups.

Component Pairs	r (Science)	r (Non-Science)
A problem ↔ Question	0,66	-
Procedure ↔ Conclusion	0,49	0,45
Prediction ↔ Procedure	0,47	-
Prediction ↔ Conclusion	0,43	0,4
Hypothesis ↔ Conclusion	0,29	-
Hypothesis ↔ Prediction	-	0,52

Science Group

Students with a science background have a structured ability to develop scientific problems and questions, as shown by a strong correlation between: A problem ↔ Question (r

= 0.66). In addition, moderate to quite strong correlations were found between prediction ↔ procedure (r = 0.47), procedure ↔ conclusion (r = 0.49), and prediction ↔ conclusion (r = 0.43). In addition, a negative correlation was found between problem ↔ prediction (r = -0.29) and problem ↔ conclusion (r = -0.25). This suggests that some science students are unable to link the initial problem discovery to the final conclusion. This is because they are likely thinking technically without thinking deeply about the problem. This shows that Science students have an integrated and logical scientific thinking structure, the full results are presented in Figure 2.

These results are in line with research conducted by Sheng-Lin (2014), which found that students who study in science majors have better critical thinking and argumentation skills compared to students who study in non-science majors. Farillon (2022) supports this finding, critical thinking skills and scientific reasoning in science students have a high correlation.

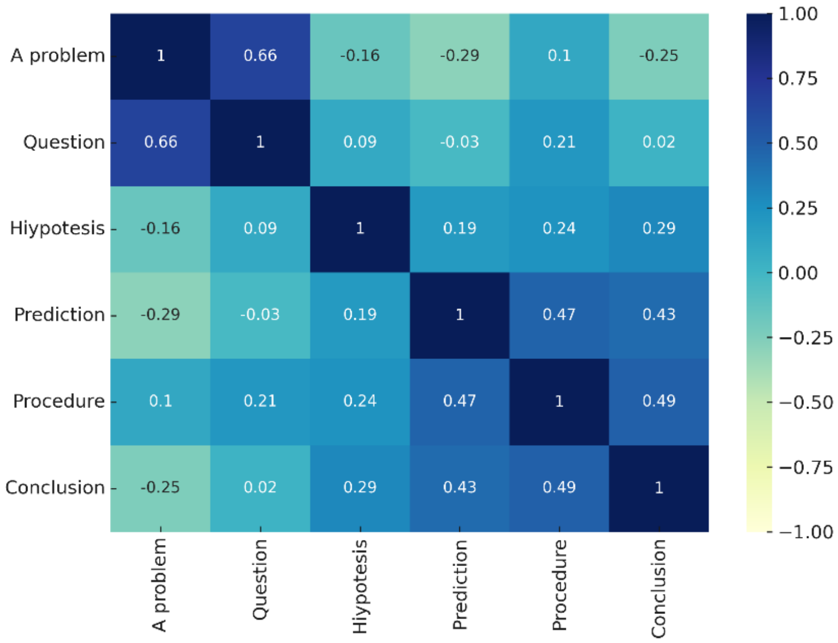

Figure 2. Heatmap of Correlation Between Components of the Science Group

Science students show a connection between sequential and logical scientific thinking processes. The strength of this connection indicates that their scientific thinking structure has been sufficiently formed and consistent.

Non-Science Group

The Non-Science group showed a more limited correlation between scientific thinking components. The highest correlation was found between Hypothesis ↔ Prediction (r = 0.52), but the relationship between initial components such as A problem and Question was not significant. This suggests that Non-Science students may have difficulty in developing an initial understanding of scientific problems, the full results are presented in Figure 3. Moore & Rubbo (2012) found that the scientific reasoning ability of non-science students was lower than that of science students, especially in terms of proportional and hypothetico-deductive

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reasoning. Agustiani et al., (2020) Elementary school teachers, especially those without prior science education, face difficulties in teaching complex scientific concepts. Yarkova et al., (2024) Science teachers, especially those from non-science backgrounds, need to be strengthened so that they can develop practical skills in teaching scientific methods to improve student education in schools. Due to their educational experiences and processes, science and non-science teachers have different perspectives on NOS (Azninda, 2021). Non-science undergraduate students are not yet accustomed to using scientific methods in the science process (Deta et al., 2020).

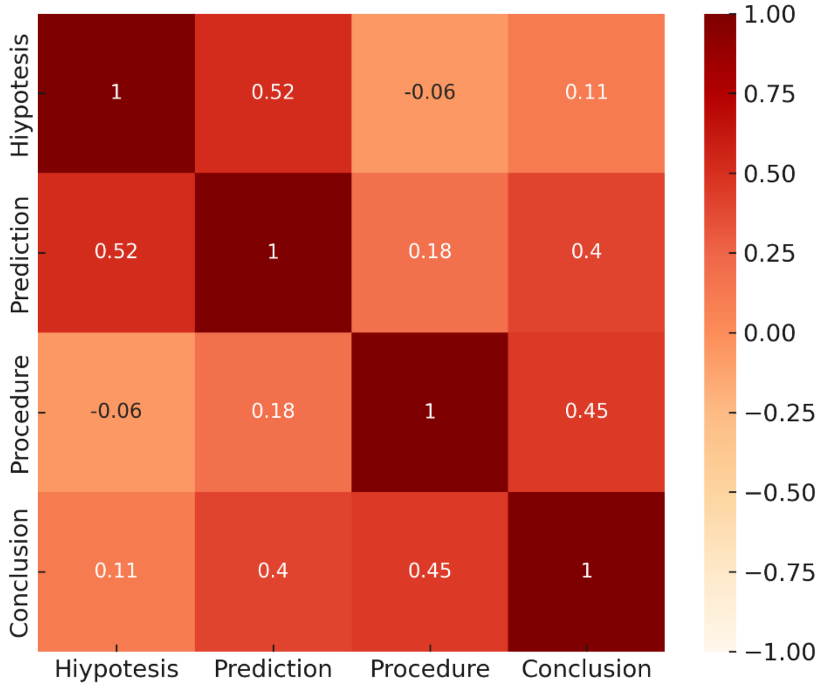

Figure 3. Heatmap of Correlation Between Non-science Components

These findings imply that, perhaps as a result of earlier exposure, science students have more sophisticated scientific reasoning processes. These results point to the need for specialized training programs designed for aspiring educators with backgrounds outside of science. In order to improve the practical application of the scientific method, training should emphasize on basic scientific literacy, integrating inquiry-based teaching simulations, and strengthening organized reasoning in the formulation of issues and questions. This study emphasizes the necessity of diversified teaching strategies, particularly when it comes to helping non-science students develop fundamental scientific thinking. It also emphasizes how crucial it is for teacher preparation programs to expose students to inquiry-based scientific education at a young age.

The results of this study have a significant impact on the way curriculum and teaching methods in higher education institutions are created. Clear education on basic scientific thinking, such as finding problems and building questions, is essential for non-science students. However, science students should be directed to strengthen the connection between initial findings and final results so that their scientific thinking process is more reflective and comprehensive. Science students have a more systematic and comprehensive thinking pattern from the beginning to the end of the scientific process, while non-science students show potential in the early stages, such as questions and planning, but are weak in the early stages. Asmoro et al., (2021), This learning model significantly improves students' scientific thinking skills compared to the expository learning model. Teaching that involves debate can help students understand concepts in the context of science (Hung & Ko, 2017). Analysis of the relationship between teacher learning styles and students' scientific reasoning abilities to improve students' scientific reasoning abilities (Saad et al., 2019).

Scientific method skills are needed for future teachers because of the rapid development of science and technology. As prospective teachers, especially those who teach science in schools, they should understand the concept and master these skills because they will train their students to think scientifically. Aydogdu et al.,l (2014); Yamtinah et al., (2016) Teachers play an important role in building science process skills as a provision for applying scientific methods in formal education. Science learning in elementary schools must be actualized with scientific methods (Subali et al., 2019). Scientific education and research methods, and their value in the learning process and development of students' skills in engineering and science (Sharma, 2022). Scientific approaches such as observation, asking, arguing, trying or creating, presenting or communicating including scientific learning are sources of ideas in scientific learning (Nur'ariyani et al., 2023). Scientific methods improve teachers' attitudes in the classroom, solve students' inappropriate attitudes, and encourage students to learn as well (Chheun & Kong, 2023). Scientific methods can be used in learning supervision to improve the quality of education (Nisa' et al., 2023). By asking scientifically oriented questions, responding to questions, making explanations, connecting explanations with scientific knowledge, and communicating them, science teaching can be planned strategically (Lee & Shea, 2016). development of educational approaches based on scientific research and application of research findings into educational practices to improve the effectiveness of education at the university level (Liu & Sun, 2018). In addition, Lumbantoruan et al., (2019) emphasized the importance of student practicums to identify science process skills, which are key to understanding basic concepts of physics and science as a whole. Science process skills can improve students' academic achievement, indicating that such training can benefit all students, regardless of their academic discipline background (Utami et al., 2017). Effective learning management will produce learning outcomes that are in accordance with the objectives (Motlan et al., 2019). Science ability is influenced by scientific learning models such as project-based learning, problem-based learning, and discovery learning (Imtihana & Restiana, 2023). To teach their students about scientific literacy, teachers must use a constructivist learning approach (Adnan et al., 2021).

The sample size of this study is restricted to one university, which may have an impact on how broadly the results may be applied. Furthermore, the information was based on written exam instruments and self-report, which would not accurately reflect students' use of scientific reasoning in the classroom. To confirm and build on these findings, future research should include observational or performance-based evaluations and various universities with a wider range of disciplines. The effects of diverse educational interventions over time might potentially be investigated through longitudinal research.

Conclusion

The scientific method is a systematic approach used to develop or revise existing knowledge through a structured series of steps, including observation, problem formulation, hypothesis generation, experimentation, and conclusion drawing. Students with Science and Non-Science educational backgrounds demonstrated significant differences in their scientific thinking abilities, especially in the *question* and *procedure* components. Science-background students outperformed in formulating scientific questions and designing experimental procedures, suggesting that prior exposure to scientific content and practices positively influences their abilities. The Science group displayed a more organized and logical structure of scientific thinking, with strong interconnections among components like problem identification, question formulation, and conclusion. Conversely, the Non-Science group showed weaker and fewer correlations, particularly in the early stages of scientific thinking. This indicates a need for guided instruction to develop their conceptual understanding. Overall, these results underscore the necessity of adopting holistic and differentiated teaching approaches to enhance scientific thinking skills. Science students should be guided to more reflectively integrate each stage of the scientific process, while Non-Science students need targeted support in building foundational scientific reasoning. This study emphasizes how essential it is for teacher education programs to use diverse teaching strategies. In particular, it highlights how crucial it is for aspiring educators with backgrounds outside of science to develop fundamental scientific reasoning abilities. In order to gradually develop scientific method abilities, educational institutions should provide organized interventions like inquiry-based teaching practicums, focused workshops, and scaffolded modules. In terms of academia, the results support curriculum improvement that matches teaching methods to students' existing knowledge areas, guaranteeing that scientific literacy is developed fairly across all subject areas. The results suggest that organized help in problem-solving and experiment design for non-science students should be a part of diversified teaching techniques. Scaffolded laboratory simulations, guided inquiry activities, and problem-based learning modules that prioritize scientific inquiry and hypothesis testing are some examples of these. Instruction for students with a scientific background should emphasize on reflective thinking skills and using metacognitive exercises to connect preliminary findings to thorough conclusions.

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