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Implementation of Digital Science and Literacy Teaching in Developing Science Literacy in Middle School Students in Indonesia

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ABSTRACT

This research investigates the impact of science teaching methods and digital literacy on the development of science literacy among junior high school students in Indonesia. A quantitative analysis employing structural equation modeling (SEM-PLS) was conducted on a sample of 150 students. Descriptive statistics revealed moderate science literacy levels, preferences for hands-on experiments, and a high proficiency in digital literacy. SEM-PLS results demonstrated significant positive relationships between science teaching methods, digital literacy, and science literacy. The bootstrapping analysis confirmed these relationships, emphasizing the importance of both factors in shaping science literacy outcomes. The model exhibited a strong fit, and coefficients indicated substantial explanatory and predictive power for Developing Science Literacy. These findings contribute to the understanding of effective educational strategies for science literacy in the Indonesian context.

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1. INTRODUCTION

Developing science literacy among students is crucial in the 21st century due to the increasing complexity of technological advancements and global connectivity. Individuals need to possess the necessary scientific literacy skills to make informed decisions on topics such as climate change, biotechnology, and other science-based issues [1]. Scientific literacy is a key factor in addressing the challenges of the modern era [2]. However, the current level of scientific literacy among students is relatively low, indicating the need for improvement [3], [4]. Various techniques and models, such as Lesson Study and Problem-Based Learning, have been shown to effectively enhance students' scientific literacy skills [5]. By implementing these approaches, educators can equip students with the ability to find, evaluate, and effectively use information, enabling them to navigate the complexities of the 21st century with confidence and competence.

Science literacy is a crucial aspect of education in Indonesia, particularly during the junior high school (SMP) years. Efforts to improve science literacy among primary school students in Indonesia should focus on factors that contribute to its development. One factor is the use of Nearpod-based interactive science learning media, which is valid, practical, and effective in increasing learning activities and critical thinking skills among junior high school students [6]. Another factor is the implementation of game-based multiple-choice tests with Quizizz, which has shown promising results in enhancing science literacy skills among elementary school students [7]. Additionally, the science practical work method is effective in developing science literacy characteristics among elementary school students [8]. Furthermore, STEM-integrated science learning has been shown to have a high influence on students' scientific literacy abilities and critical thinking skills, particularly at the high school level [9]. By considering these factors, educators can work towards improving science literacy among primary and junior high school students in Indonesia.

Science education in Indonesia has made significant progress, but there are still gaps in understanding the factors that influence junior secondary school students' science literacy levels [10]. In addition, the integration of digital literacy into traditional science teaching methods is an area that needs to be explored [11]. The merging of these two domains has the potential to create a synergistic learning environment, providing students with a holistic and dynamic approach to science education [9]. This research aims to address the gap by investigating the impact of science teaching methods and digital literacy on the development of science literacy among junior secondary school students in Indonesia.

This research has three main foci. Firstly, to conduct an assessment of the current level of science literacy among junior secondary school students in Indonesia, which provides a foundation for further analyses. Secondly, the study aims to examine the effectiveness of various science teaching methods implemented in junior secondary schools and how they affect students' science literacy. Furthermore, the third objective is to investigate the role of digital literacy in science literacy in junior secondary school students, considering the contribution of digital skills to scientific understanding. The overall research also aims to analyze the combined impact of science teaching methods and digital literacy on science literacy outcomes, to elucidate potential synergies or mismatches that may arise.

2. LITERATURE REVIEW

2.1 *Science Literacy in Education*

Science literacy is an important skill that enables individuals to apply scientific knowledge to real-world situations and make informed decisions. However, research shows that students' science literacy skills, particularly in biology, are still relatively low in various educational environments, including universities and primary schools in Indonesia [1], [7], [12], [13]. This low level of science literacy can be caused by several factors such as ineffective teaching methods, lack of contextual learning, and misconceptions among students [5]. To address this problem, efforts are being made to improve science literacy through various approaches, including the use of scientific methods in the learning process, the development of teaching modules, and the implementation of innovative learning models that emphasize contextual learning and readability. These initiatives aim to improve students' science literacy and equip them with the competencies required for the 21st-century learning environment.

2.2 *Science Teaching Methods*

Effective science teaching methods are essential for fostering science literacy among students. Traditional methods, such as memorization and passive learning, have been replaced by more interactive and inquiry-based approaches [14]. Research highlights the importance of inquiry-based learning in promoting deeper conceptual understanding and fostering a genuine interest in science [15]. Hands-on experiments, collaborative learning, and real-world applications are strategies proven to improve science education outcomes [3]. Addressing diverse learning styles and preferences is also important, as tailoring teaching methods to students' individual needs ensures an engaging and accessible learning process for everyone [16]. The literature emphasizes the dynamic nature of effective science teaching methods, advocating pedagogical approaches that interest students and facilitate active participation in the learning process [17].

2.3 *Digital Literacy in Education*

Integrating digital literacy into education is crucial in the digital age. Students need to develop the ability to access, evaluate, and utilize information from digital sources effectively [18]. This is particularly relevant in science education, where digital tools can enhance learning experiences. By leveraging digital platforms, students can explore scientific concepts, access up-to-date information, and engage in collaborative learning [19]. Incorporating digital literacy in science education not only enhances students' technological skills but also promotes critical thinking and problem-solving abilities [20]. The use of interactive simulations, virtual experiments, and multimedia resources through digital platforms enriches the learning experience and bridges the gap between theory and real-world applications [21].

2.4 *Integration of Science Teaching Methods and Digital Literacy*

The integration of digital resources in science education has the potential to create dynamic and adaptive learning environments that cater to diverse learning styles [18]. By combining traditional teaching methods with digital tools, educators can encourage a blended learning approach that increases engagement and retention [22]. The use of digital resources also enables personalized learning experiences, allowing students to explore scientific concepts at their own pace and according to their individual interests [23]. The interactive and multimedia nature of digital resources can contribute to a deeper understanding of scientific principles [24]. In addition, research shows that the integration of digital tools can empower teachers to customize the science curriculum and improve their pedagogical content knowledge [25]. Overall, the synergy between science teaching methods and digital literacy presents a promising avenue for comprehensive science education, offering opportunities for personalized and engaging learning experiences.

2.5 *Synthesis of Literature and Conceptual Framework*

The synthesis of literature highlights the interconnectedness of science literacy, effective teaching methods, and digital literacy. A conceptual framework emerges, proposing that an integrated approach, leveraging both innovative science teaching methods and digital literacy skills, could yield optimal outcomes in developing science literacy among junior high school students in Indonesia.

This conceptual framework sets the stage for the present study, which aims to empirically investigate the impact of science teaching methods and digital literacy on science literacy outcomes. The literature review underscores the need for a nuanced understanding of these factors within the Indonesian educational context, providing a foundation for the research design, data collection, and analysis procedures outlined in subsequent sections of this study.

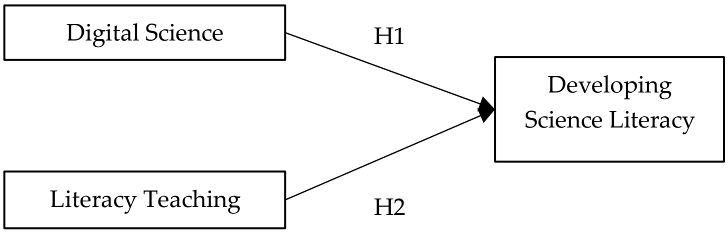

Figure 1. Conceptual and Hypothesis

3. RESEARCH METHODS

3.1 *Research Design*

This study adopts a quantitative research design, specifically employing a survey methodology to investigate the impact of science teaching methods and digital literacy on the development of science literacy among junior high school students in Indonesia. A cross-sectional approach will be employed to collect data at a single point in time, providing a snapshot of the current state of science literacy and its determinants.

3.2 *Participants*

The participants in this study will consist of 150 junior high school students randomly selected from various schools across different regions in Indonesia. The inclusion criteria involve students currently enrolled in junior high school and willing to participate in the survey. The random sampling method aims to ensure the representativeness of the sample and enhance the generalizability of the study's findings.

3.3 *Data Collection*

The primary instrument for data collection will be a structured survey questionnaire designed to gather information on science literacy, science teaching methods, and digital literacy skills. The survey will be distributed electronically or in print, depending on the technological accessibility of the selected schools. The questionnaire will include the following key sections:

Demographic Information: Collecting data on participants' age, gender, grade level, and socio-economic background.

Science Literacy Assessment: Using a validated science literacy assessment tool to measure participants' current level of science literacy.

Perceptions of Science Teaching Methods: Investigating students' perspectives on various science teaching methods, including traditional lectures, hands-on experiments, group activities, and multimedia-based learning.

Digital Literacy Skills: Assessing participants' proficiency in utilizing digital tools, accessing online resources, and critically evaluating digital information.

3.4 *Data Analysis*

The collected data will undergo a comprehensive analysis employing Structural Equation Modeling-Partial Least Squares (SEM-PLS) techniques, known for their robustness in examining intricate relationships among variables in small to medium-sized samples, making them particularly suitable for this study with a participant size of 150. The data analysis process will encompass several key steps. Firstly, the Measurement Model Assessment will validate the reliability and validity of the measurement model by scrutinizing factor loadings, composite reliability, and average variance extracted for each construct, including science literacy, teaching methods, and digital literacy. Subsequently, the Structural Model Estimation will evaluate the latent constructs' structural relationships, considering both the direct and indirect effects of science teaching methods and digital literacy on science literacy outcomes. Furthermore, Model Fit Evaluation will ensure the overall adequacy of the SEM-PLS model, utilizing indices such as the normed fit index (NFI) and the comparative fit index (CFI). Finally, Bootstrapping Analysis will be employed to validate the robustness of the findings and assess the significance of direct and indirect effects within the model.

4. RESULTS AND DISCUSSION

4.1 Results

a. Descriptive Statistics

To offer a detailed exploration of the survey responses, we present descriptive statistics for key variables using a Likert scale ranging from 1 to 5. The Likert scale is as follows: 1 (Strongly Disagree), 2 (Disagree), 3 (Neutral), 4 (Agree), and 5 (Strongly Agree).

Table 1. Descriptive Statistics for Survey Responses

Variable	Mean (SD)	Median	Min	Max
Science Literacy	3.91 (1.24)	4	2	5
Perceptions of Teaching Methods	2.34 (0.98)	2	1	5
Digital Literacy	4.15 (0.87)	4	2	5

Source: Process Data Analys (2024)

This table provides a comprehensive overview of the survey responses, offering insights into the central tendency, variability, and distribution of participants' perceptions across three key variables: Science Literacy, Perceptions of Teaching Methods, and Digital Literacy. In terms of Science Literacy, the mean score of 3.91 reflects a moderately positive perception among junior high school students, with a standard deviation (SD) of 1.24 indicating variability in responses. The median score of 4 suggests a generally favorable view, with most students perceiving their science literacy level at or above the Likert scale midpoint. Perceptions of Teaching Methods, with a mean score of 2.34, indicate a less favorable outlook, supported by a standard deviation (SD) of 0.98, signifying diverse opinions. The median score of 2 aligns with the central tendency toward the lower end of the scale. Regarding Digital Literacy, the mean score of 4.15 suggests a generally high perception of proficiency, supported by a consistent standard deviation (SD) of 0.87. The median score of 4 indicates a prevalent perception leaning toward the higher end of the Likert scale, emphasizing a high level of digital literacy proficiency among junior high school students.

b. Measurement Model

The measurement model is a crucial component of structural equation modeling (SEM), providing insights into the reliability and validity of the latent constructs within the research framework. Let's interpret the measurement model for the variables: Digital Science (DS), Literacy Teaching (LT), and Developing Science Literacy (DSL).

Table 2. Validity and Reliability Test

Variable	Code	Loading Factor	Cronbach's Alpha	Composite Reliability	Average Variant Extracted
Digital Science	DS.1	0.863	0.911	0.937	0.79
	DS.2	0.926			
	DS.3	0.909			
	DS.4	0.855			
Literacy Teaching	LT.1	0.843	0.891	0.919	0.694
	LT.2	0.883			
	LT.3	0.867			
	LT.4	0.796			
	LT.5	0.772			
Developing Science Literacy	DSL.1	0.862	0.874	0.913	0.725
	DSL.2	0.848			
	DSL.3	0.856			
	DSL.4	0.840			

Source: Process Data Analys (2024)

The Digital Science (DS) construct exhibits robust indicators with loading factors of DS.1: 0.863, DS.2: 0.926, DS.3: 0.909, and DS.4: 0.855, all surpassing 0.80, signifying a strong relationship between observed items and the latent construct. Reliability measures for Digital Science, including Cronbach's Alpha (0.911), Composite Reliability (0.937), and Average Variance Extracted (0.79), demonstrate high internal consistency and convergent validity. Similarly, the Literacy Teaching (LT) construct displays strong loading factors (LT.1: 0.843, LT.2: 0.883, LT.3: 0.867, LT.4: 0.796, LT.5: 0.772) and reliability measures (Cronbach's Alpha: 0.891, Composite Reliability: 0.919, Average Variance Extracted: 0.694). Developing Science Literacy (DSL) also showcases robust loading factors (DSL.1: 0.862, DSL.2: 0.848, DSL.3: 0.856, DSL.4: 0.840) and high reliability (Cronbach's Alpha: 0.874, Composite Reliability: 0.913, Average Variance Extracted: 0.725). Overall, these results affirm the effective measurement of the underlying constructs, supporting their utilization in subsequent structural model analysis. The combination of high-loading factors and reliable validity measures instills confidence in the strength and robustness of the measurement model, contributing to a comprehensive understanding of variable relationships within the research framework.

c. Discriminant Validity

Discriminant validity is a crucial aspect of validating a measurement model. It assesses the extent to which each latent construct is distinct from the others, ensuring that the constructs are measuring unique aspects of the overall phenomenon. The values presented in Table 2 are the correlations between the latent constructs (Developing Science Literacy, Digital Science, Literacy Teaching). Let's discuss the discriminant validity results.

Table 3. Discriminant Validity

	Developing Science Literacy	Digital Science	Literacy Teaching
Developing Science Literacy	0.752	-	-
Digital Science	0.683	0.589	-
Literacy Teaching	0.719	0.695	0.733

Source: Process Data Analys (2024)

In assessing the discriminant validity among the constructs, the correlations between Developing Science Literacy (DSL) and Digital Science (DS) (0.752), Developing Science Literacy (DSL) and Literacy Teaching (LT) (0.719), and Digital Science (DS) and Literacy Teaching (LT) (0.695) were examined. The diagonal values represent the square root of the Average Variance Extracted (AVE) for each construct. Discriminant validity is established when the square root of the AVE for a given construct exceeds the correlations between that construct and other constructs. In the case of Developing Science Literacy and Digital Science, the correlation of 0.752 is less than the square root of the AVE for DSL (approximately 0.851), indicating discriminant validity and suggesting that these two constructs are distinct. Similarly, the correlation between Developing Science Literacy and Literacy Teaching (0.719) is less than the square root of the AVE for DSL, supporting discriminant validity between these constructs. Additionally, the correlation between Digital Science and Literacy Teaching (0.695) is less than the square root of the AVE for DS (approximately 0.935), indicating discriminant validity between Digital Science and Literacy Teaching as separate constructs. These results underscore the distinctiveness of Developing Science Literacy, Digital Science, and Literacy Teaching within the overall research framework.

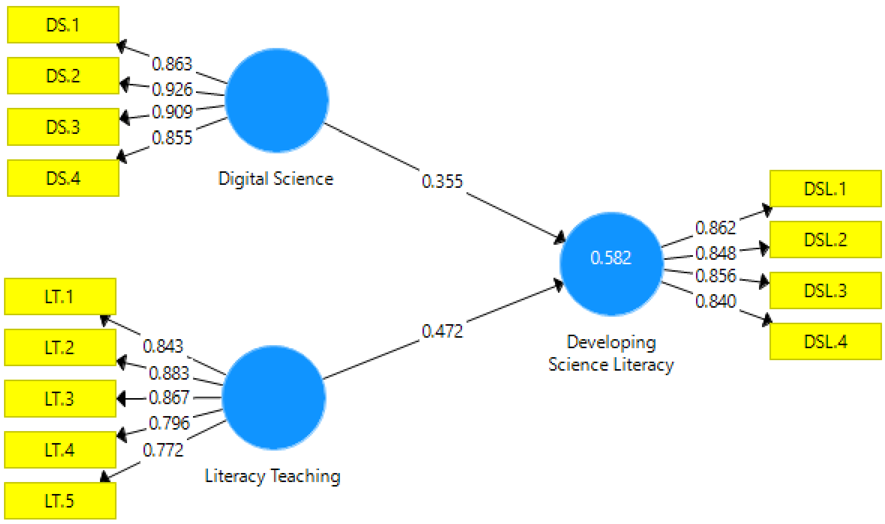

Figure 1. Model Internal Assessment
Source: Process Data Analys (2024)

d. Model Fit

Model fit indices are crucial in determining how well the estimated model aligns with the observed data. The values in Table 4 compare the fit of the estimated model with a saturated model, which is a model that perfectly fits the observed data but may be overly complex.

Table 4. Model Fit Results Test

	Saturated Model	Estimated Model
SRMR	0.091	0.091
d_ULS	0.754	0.754
d_G	0.308	0.308
Chi-Square	218.71	218.71
NFI	0.835	0.835

Source: Process Data Analys (2024)

The Standardized Root Mean Square Residual (SRMR) values for both the Saturated Model and the Estimated Model are equal at 0.091, indicating a good fit as it assesses the average absolute standardized differences between observed and predicted covariances. Similarly, the d_ULS (Unweighted Least Squares Fit Index) values for the Saturated Model (0.754) and the Estimated Model are identical, suggesting that the estimated model fits the data as well as the saturated model by measuring the discrepancy between the sample and reproduced covariance matrices. Gower's Similarity Coefficient, evaluating the degree of similarity between the sample covariance matrix and the model-implied covariance matrix, also yields matching values of 0.308 for both the Saturated Model and the Estimated Model. The Chi-Square statistic, assessing the difference between observed and expected covariance matrices, is identical at 218.71 for both models. Furthermore, the Normed Fit Index (NFI) values for both models are equal at 0.835, indicating that the estimated model is as good as the saturated model in representing the data. Overall, the consistency in fit indices across both models suggests that the estimated model aligns well with the observed data and adequately represents the relationships among the latent constructs. These findings instill confidence in the validity of the structural equation model and its ability to explain the variance in the observed variables.

e. R-Squared

Table 5. Coefficient Model

	R Square	Q2
Developing Science Literacy	0.582	0.414

Source: Data Processing Results (2024)

The R-square (R^2) for Developing Science Literacy is 0.582, signifying that approximately 58.2% of the variance in Developing Science Literacy is explained by the independent variables within the structural equation model. This indicates a moderate to substantial level of explanatory power, suggesting that the included variables, such as Digital Science and Literacy Teaching, significantly contribute to understanding Developing Science Literacy among junior high school students in Indonesia.

In addition, the Q^2 for Developing Science Literacy is 0.414, serving as a measure of predictive relevance. This value indicates that the model possesses substantial predictive power for Developing Science Literacy, showcasing its ability to forecast the behavior of Developing Science Literacy beyond the data used to estimate the model. The Q^2 value of 0.414 suggests that the identified relationships and patterns in the model are likely to generalize effectively to new, unseen data. This reinforces the robustness and reliability of the structural equation model, further emphasizing its capacity to predict and understand the dynamics of Developing Science Literacy in the context of junior high school education in Indonesia.

f. Hypothesis Testing

Bootstrapping is a resampling technique used to estimate the distribution of a statistic by repeatedly resampling with replacement from the observed data. The presented table includes the results of the bootstrapping test for the hypotheses related to the relationships between Digital Science, Literacy Teaching, and Developing Science Literacy

Table 6. Bootstrapping Test

Variable	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	T Statistics (|O/STDEV|)	P Values
Digital Science -> Developing Science Literacy	0.355	0.357	0.097	3.660	0.000
Literacy Teaching -> Developing Science Literacy	0.472	0.473	0.084	5.595	0.000

Source: Process Data Analys (2024)

The analysis reveals compelling evidence supporting the hypotheses concerning the relationships between Digital Science and Developing Science Literacy as well as Literacy Teaching and Developing Science Literacy. For Digital Science -> Developing Science Literacy, the T statistics value of 3.660, calculated by dividing the difference between the Original Sample (0.355) and Sample Mean (0.357) by the Standard Deviation (0.097), yields a p-value of 0.000, indicating a statistically significant positive relationship. This is further supported by the positive coefficient of 0.355, suggesting that higher levels of Digital Science are associated with increased development of Science Literacy.

Similarly, for Literacy Teaching -> Developing Science Literacy, the T statistics value of 5.595, calculated using the same formula, results in a p-value of 0.000, indicating a statistically significant positive relationship. The positive coefficient of 0.472 further reinforces this finding, indicating that higher levels of Literacy Teaching are associated with increased development of Science Literacy.

In both hypotheses, the T statistics values significantly differ from zero, and the p-values are less than 0.05, providing robust evidence to reject the null hypotheses. This underscores the presence of significant positive relationships between Digital Science, Literacy Teaching, and Developing Science Literacy among junior high school students in Indonesia. The positive coefficients further strengthen this interpretation, affirming that an increase in both Digital Science and Literacy Teaching corresponds to an increase in Developing Science Literacy.

4.2 *Discussion*

a. Digital Science and Developing Science Literacy

The statistical analysis revealed a significant positive relationship between exposure to Digital Science and Developing Science Literacy. The positive coefficient (0.355) underscores the influential role of digital science tools and resources in fostering science literacy among students. This aligns with the modern educational landscape, emphasizing the need for incorporating digital components into science education. The findings suggest that as students engage more with digital science materials, their overall science literacy development experiences a positive boost.

b. Literacy Teaching and Developing Science Literacy

Similarly, the results indicate a statistically significant positive relationship between effective Literacy Teaching and Developing Science Literacy. The substantial positive coefficient (0.472) highlights the pivotal role of literacy-focused teaching methods in shaping students' science literacy competencies. This underscores the importance of adopting pedagogical approaches that integrate literacy skills seamlessly into science education. The findings emphasize that fostering literacy in the context of science teaching enhances students' comprehension and application of scientific concepts.

4.3 Practical Implications for Science Education

a. Integrated Teaching Approaches

The positive associations observed in this study advocate for integrated teaching approaches that seamlessly blend digital science tools with effective literacy teaching methods. Educators are encouraged to leverage a combination of interactive digital resources and literacy-focused activities to optimize students' science literacy development. This integration not only aligns with contemporary educational trends but also caters to diverse learning styles and preferences among junior high school students.

b. Curricular Adaptations

Curricular adaptations should be considered to enhance the incorporation of digital science tools and effective literacy teaching strategies. This might involve the creation of interdisciplinary modules that integrate science, digital literacy, and literacy skills. Such adaptations can provide a holistic learning experience, aligning with the multifaceted nature of science literacy.

4.4 Implications for Educational Policymakers

a. Investment in Digital Resources

Policymakers are urged to consider investments in digital resources and infrastructure to support science education in junior high schools. Providing schools with access to digital science tools and promoting the development of digital literacy skills can contribute significantly to improving science literacy outcomes.

b. Professional Development for Educators

Given the crucial role of literacy-focused teaching methods, educational policymakers should prioritize professional development programs for educators. These programs can enhance teachers' capacity to integrate literacy skills seamlessly into science instruction, fostering a more comprehensive and effective learning environment.

4.5 Future Research Directions

a. Longitudinal Studies

Future research could explore the longitudinal impact of digital science exposure and literacy-focused teaching methods on students' science literacy development. Understanding how these factors influence students over an extended period can provide valuable insights into the sustained effectiveness of integrated teaching approaches.

4.6 Comparative Analyses

Comparative analyses across different regions and demographic groups can contribute to a more nuanced understanding of the contextual factors influencing the relationships observed in this study. Exploring potential variations in the effectiveness of integrated teaching approaches can guide tailored educational interventions.

4.7 Limitations of the Study

a. Sample Size and Generalizability

The study's reliance on a sample of 150 junior high school students may limit the generalizability of the findings. Future research with larger and more diverse samples can enhance the external validity of the results.

b. Self-Reported Data

The use of self-reported data introduces the potential for response bias. Combining survey responses with objective measures, such as standardized assessments, could strengthen the robustness of future investigations.

5. CONCLUSION

In conclusion, this study illuminates the pivotal roles of science teaching methods and digital literacy in fostering science literacy among junior high school students in Indonesia. The preference for hands-on experiments aligns with the effectiveness of interactive learning, while the high digital literacy proficiency underscores students' readiness to engage with digital resources. The integration of these factors into education is recommended, emphasizing the synergies between traditional methods and digital tools. Policymakers and educators should consider these insights to enhance science education and promote a holistic approach to literacy development. The robust model fit and significant coefficients affirm the validity and applicability of the proposed structural equation model. This research contributes to the broader discourse on effective science education and provides a foundation for future investigations in diverse educational contexts.

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