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Article

Students' Data Interpretation Skills in General Biology Labs: Analysis Based on Prior Knowledge and Implications for Scientific Literacy

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ABSTRACT

Data interpretation ability is an important component of scientific literacy that needs to be developed through practicum activities. Prior knowledge acts as a cognitive basis that enables students to understand scientific concepts, recognize experimental variables, and connect observation results with relevant theories in biology practical activities. This study aims to analyze differences in students' data interpretation abilities in General Biology practicums and examine the relationship between prior knowledge and data interpretation abilities from a scientific literacy perspective. This study is quantitative with a descriptive, comparative, and correlational design. The subjects were students in classes A, B, C, and D who participated in General Biology practicums. Prior knowledge data were obtained through a pretest, while data interpretation abilities were obtained through practicum results. Data analysis was carried out using normality tests, homogeneity tests, One Way ANOVA tests, Tukey Post Hoc follow-up tests, and Pearson correlation tests. The results showed that significant differences occurred between class D and classes A, B, and C, while there were no significant differences between classes A, B, and C. The results of the Pearson correlation test showed a significant positive relationship between prior knowledge and data interpretation abilities ($r = 0.62$; $p < 0.05$), which is included in the moderate to strong category. The practical implications of this study emphasize the importance of considering prior knowledge in teaching biology practicums through pre-learning activities and providing scaffolding during the practicum, so that students' data interpretation skills can develop optimally and support increased scientific literacy.

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INTRODUCTION

The success of a practicum is influenced by student readiness to participate in the practicum activities. Student readiness includes an initial understanding of the concepts to be learned and readiness to follow the practicum procedures. Students who are well prepared will more easily understand the objectives of the experiment, make accurate observations, and analyze the data obtained during the practicum activities (Seery, 2020). Student readiness plays

a role in minimizing errors during the practicum implementation, so that the observation and data collection process can be carried out more systematically (Al-Ghaithi et al., 2017). Student readiness before participating in the practicum is one of the important factors that can support the achievement of learning objectives through practicum activities.

Practicums are an important component in science learning that serve to bridge theoretical concepts with empirical experience. Practicum activities can help students gain conceptual understanding and develop science process skills such as observing, measuring, classifying, and analyzing data (Cook, 2020; Li et al., 2020). Practicum activities can provide opportunities for students to be directly involved in the scientific process, thereby improving critical thinking and problem-solving skills (Maria Farooq & Sher Zaman, 2024; Rahma Hidayati Darwis et al., 2024). Practicum activities in their implementation are still oriented towards completing procedures and verifying concepts, so they have not fully optimized the development of higher-order thinking skills, especially in the process of analyzing and interpreting data (Visser et al., 2018).

Data interpretation skills are an important factor developed through practicum activities. Data interpretation skills are the ability to understand, interpret, and explain the meaning of data obtained from an experiment (Santacruz-Castro, 2019). Students are expected to be able to identify patterns from observational data, explain relationships between variables, and draw conclusions based on scientific evidence obtained during practicum activities (No & Choi, 2021). Students' data interpretation skills in practice have not yet developed optimally, because practicum activities often focus more on implementing procedures than on analyzing and interpreting data, resulting in students being less trained in processing and interpreting data in depth (Jardim, 2021). Empirical findings show that most students still experience difficulties in interpreting previous research data reporting that only about 34% of students were able to correctly identify that a graph did not show variability (Stoczynski et al., 2026).

Data interpretation skills are an important part of scientific literacy, emphasizing an individual's ability to use scientific knowledge to explain phenomena and make decisions based on scientific evidence (Xie et al., 2022). Scientific literacy is an important competency in 21st-century science learning, encompassing not only conceptual mastery but also the ability to use scientific knowledge in various life contexts (Becker et al., 2021; Yuniasti et al., 2025). Scientific literacy, based on the scientific literacy framework developed by the Organization for Economic Co-operation and Development through the Programme for International Student Assessment (PISA), encompasses several key competencies: explaining phenomena scientifically, designing and evaluating scientific investigations, and interpreting scientific data and evidence (Oxford University Press (OUP), 2023). The competency to interpret scientific data and evidence is an important aspect (Sholikah & Pertiwi, 2021) because it enables students to understand scientific information presented in the form of data, tables, or graphs (Friedrich et al., 2024).

The relationship between prior knowledge and data interpretation skills has been supported by numerous studies over the past five years. Prior knowledge plays a crucial role in helping students develop an understanding of data, particularly in interpreting graphs and relationships between variables in a biological context (Altindis et al., 2024). Students with higher prior knowledge tend to have better analytical and interpretation skills, while those with lower prior knowledge consistently perform worse on scientific analysis-based tasks (Kiviluoma et al., 2026). The low prior knowledge held by most students also results in difficulties in understanding and relating concepts to observed data, so that prior knowledge becomes a key factor that determines the quality of data interpretation skills in biology practicum learning (Ahied et al., 2020).

The results of the study indicate that students' scientific literacy skills are still in the low to moderate category, especially in the aspects of data interpretation and scientific evidence. Several studies indicate that scientific literacy achievements are still in the low to moderate

category, even in certain aspects such as conceptual understanding and data interpretation are still at a suboptimal level (Hasanah et al., 2024; Qiao et al., 2024; Rahmadani, 2025). Other studies also show that most students are not yet able to interpret data analytically and are still at a basic level, thus indicating a gap between science learning objectives that emphasize scientific literacy and the abilities possessed by students in the field (Salma et al., 2019). Studies that specifically link prior knowledge with data interpretation abilities in the context of biology practicums are still limited.

Most previous studies have focused more on conceptual aspects or general cognitive learning outcomes, without deeply exploring how prior knowledge influences students' ability to interpret experimental data. Research linking these two variables to the context of practicum as an authentic learning environment has also been scarce, leaving a significant research gap in understanding the role of prior knowledge in contextual data interpretation skills in biology laboratory activities. This study offers novelty by analyzing the relationship between prior knowledge and data interpretation skills specifically in biology practicum settings, and examining its implications for the development of scientific literacy. This contribution is expected to enrich the science education literature, particularly in designing more effective practicum learning based on students' cognitive readiness.

Based on the problems that arise, research is needed that examines students' data interpretation abilities in practicum activities and their relationship with students' prior knowledge. This research is important to provide an overview of students' data interpretation ability profiles as part of scientific literacy, as well as to determine whether there are differences in data interpretation abilities between classes and the relationship between prior knowledge and students' data interpretation abilities. How are students' data interpretation abilities in General Biology practicums, differences in data interpretation abilities between classes, and the relationship between students' prior knowledge and data interpretation abilities from a scientific literacy perspective?

METHODS

The study used a quantitative approach with a descriptive-comparative and correlational design. Quantitative because it aims to examine the relationship between variables and compare groups objectively using numerical data (Creswell, 2011). The descriptive approach was used to describe the profile of students' data interpretation abilities, while the comparative approach was used to determine differences in data interpretation abilities between classes. The correlational approach was used to analyze the relationship between students' prior knowledge and data interpretation abilities from a scientific literacy perspective. The research was conducted in all classes taking the General Biology practicum course in the Untirta Science Education Study Program, namely four classes. The research procedure was carried out through several stages, namely the preparation stage, implementation, data collection stage, data processing and analysis stage, interpretation of results are presented in Picture 1.

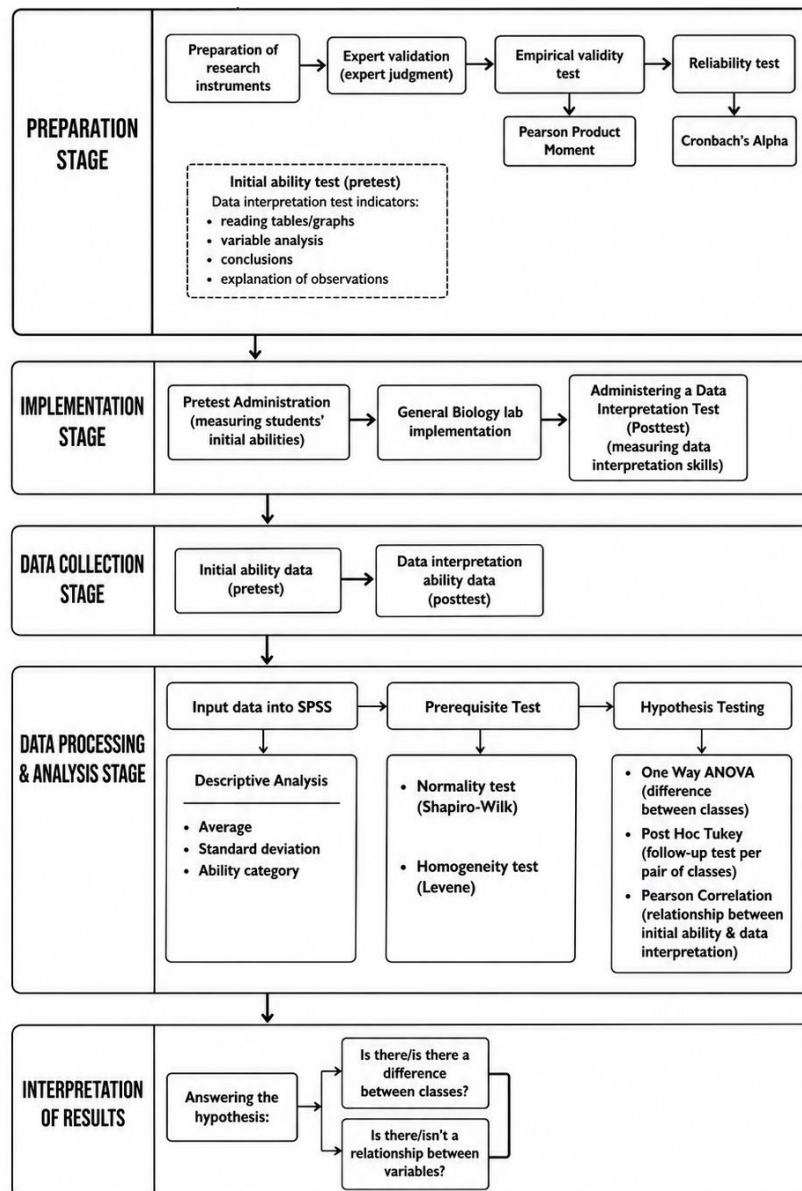


Figure 1. The Research procedure

RESULTS AND DISCUSSION

The results of the descriptive analysis of students' data interpretation abilities in General Biology practicums based on initial readiness and its implications for scientific literacy are presented in Table 1.

Table 1. Descriptive Analysis

Class	N	Mean	Standart Deviation
A	30	78.45	6.12
B	30	80.12	5.87
C	30	79.87	6.03
D	30	72.30	7.15

Table 1 shows that the average data interpretation skills of students in classes A, B, C, and D were 78.45, 80.12, 79.87, and 72.30, respectively. Classes A, B, and C had high averages, while class D had a lower average, indicating differences in data interpretation skills between classes. The differences found were then tested for normality and homogeneity. The results of the normality test of students' data interpretation skills in the General Biology practicum based on initial readiness and its implications for scientific literacy are shown in Table 2.

Table 2. Normality Test Results

Class	Statistics	Sig. (p-value)	Description
A	0.928	0.087	normal distribution
B	0.948	0.229	normal distribution
C	0.942	0.151	normal distribution
D	0.962	0.337	normal distribution

Table 2 shows the results of the normality test using Shapiro-Wilk in classes A, B, C, and D, each having a significance value of 0.087, 0.229, 0.151, and 0.337. The results of the normality test indicate that all classes, namely classes A, B, C, and D, have a significance greater than 0.05 ($p > 0.05$), so that the data is normally distributed and continued for a homogeneity test. The results of the homogeneity test of students' data interpretation abilities in the General Biology practicum based on initial readiness and its implications for scientific literacy are shown in Table 3.

Table 3. Homogeneity Test Results

F	Sig.
1.30	0.277

Table 3 shows the results of the homogeneity of variance test using the Levene Test, namely a significance value of 0.277 greater than 0.05 ($p > 0.05$), which means that the variance between groups is homogeneous, thus fulfilling the prerequisite test for conducting the One Way ANOVA test. The results of the One Way ANOVA test of students' data interpretation abilities in General Biology practicums based on initial readiness and its implications for scientific literacy are shown in Table 4.

Table 4. One Way ANOVA Test Results

Source of Variation	JK	df	MK	F	Sig.
Between groups	842,15	3	280,72	5.67	0.001
In groups	5832,40	116	50.28		
Total	6674,55	119			

Table 4 shows the significance value of the One Way ANOVA test of students' data interpretation ability in General Biology practicum based on initial readiness and its implications for scientific literacy, which is 0.001. The significance result shows less than 0.05, so a further Post Hoc Tukey test was continued to determine which class pairs were significantly different. The results of the Post Hoc Tukey further test are shown in Table 5.

Table 5. Tukey Post Hoc Test Results

Comparison	Mean Difference	Sig.	Description
A-B	-1.67	0.623	Not Significant
A-C	-1.42	0.711	Not Significant
A-D	6.15	0.002	Significant
B-C	0.25	0.982	Not Significant
B-D	7.82	0.001	Significant
C-D	7.57	0.001	Significant

Table 5 shows the results of the Tukey Post Hoc test for classes A, B, C, and D, which indicate significantly different group pairs. A significant difference occurred between class D and classes A, B, and C, as evidenced by significance values of 0.002, 0.001, and 0.001, respectively, which are all less than 0.005. Insignificant differences were shown between class A and class B and C, as evidenced by significance values of 0.623 and 0.711, and between class B and class C, with a significance value of 0.982, which is greater than 0.005. Overall, the results of the Tukey Post Hoc test indicate a relationship between classes, although not all classes because the characteristics of student abilities between classes are not completely different. Therefore, a Pearson correlation test was conducted to determine the relationship between initial ability and data interpretation ability, the results of which are shown in Table 6.

Table 6. Pearson Correlation Test Results

Variable	R (Pearson)	Sig.	Description
Prior Knowledge – Data Interpretation	0.62	0.000	Significant

Table 6 shows the significance value of the Pearson correlation test, which is 0.000, less than 0.005, indicating a positive relationship between initial ability and data interpretation ability, with a correlation coefficient value of 0.62, which is considered a moderate to strong relationship. The results of the Pearson correlation test indicate that the higher the student's initial ability, the higher their ability to interpret data from the practicum.

The ability to interpret data in practical activities is an essential skill in science learning that covers various aspects of scientific thinking (Skills et al., 1863). Data interpretation ability is the ability of students to understand, analyze, and interpret experimental data into meaningful information (Dermanis et al., 2007; Pols et al., 2021). Data interpretation ability is important for students to have because it is part of scientific literacy that allows students to explain scientific phenomena and make evidence-based decisions (Bremmer & Nijs, 2020; Khadija Muhammad Hussain Marvi et al., 2025). Data interpretation ability can help students identify patterns, understand relationships between variables, and evaluate the accuracy of data obtained from experimental results (Hendra Candra et al., 2025; Kotronoulas et al., 2023). Data interpretation ability plays a role in improving students' ability to communicate scientific results systematically and logically, both in writing and presentations (Fatihah et al., 2022; Gizaw & Sota, 2023). Data interpretation ability is important to prepare students to face the challenges of the 21st century that demand the ability to process information and make data-based decisions (Purwanto et al., 2023). Data interpretation ability can be applied when students have completed observations and begin processing and analyzing data obtained during practical work because it provides direct empirical experience (Wola et al., 2023). Data interpretation skills are acquired by students through reading tables and graphs, identifying patterns, analyzing relationships between variables, comparing results with theory, and drawing conclusions based on scientific evidence (Gardner et al., 2024; Kranz et al., 2023; Pranata, 2025; Winne, 2022). Data interpretation skills not only demonstrate an understanding of experimental results, but also reflect students' critical and analytical thinking skills in integrating conceptual knowledge with practical experience as part of strengthening scientific literacy (Fairuz et al., 2019; Suwono et al., 2023). Students' data interpretation skills show differences in each class even though the practical activity treatment is the same (Barbara et al., 2011). These findings align with previous research showing that achievement in data interpretation skills is influenced not only by practicum activities but also by internal factors such as students' prior knowledge and cognitive abilities. Other studies have also reported that students with better prior knowledge tend to demonstrate higher data interpretation skills, while students with lower prior knowledge have difficulty connecting data to scientific concepts (Kiviluoma et al., 2026). However, unlike some studies that show relatively uniform improvement in skills after practicum, the results of this study indicate that variations between classes persist, thus confirming that uniform treatment does not always result in equal achievement. This suggests that cognitive readiness factors and student learning characteristics play an important role in determining the quality of data interpretation skills (Reski et al., 2024).

Differences in students' data interpretation abilities in the General Biology practicum indicate variations in their scientific literacy achievements (Maraza-Quispe et al., 2024; Syahirah et al., 2025). It is important to identify differences in students' data interpretation abilities because they indicate that the learning process through practicums has not yet produced uniform outcomes for all students. The uneven achievement of data interpretation abilities is caused by differences in initial abilities, levels of learning readiness, and student engagement during practicum activities (Sadsad & Roman, 2025; Susanto, 2022). Differences in data interpretation abilities between classes indicate the need for more adaptive learning strategies oriented toward developing scientific literacy, such as implementing inquiry-based learning, using a problem-based approach, providing scaffolding during the practicum process, and strengthening prior knowledge before the practicum (Saleh et al., 2022). The necessary strategies can help students understand concepts more deeply, increase active engagement

during the practicum, and train their ability to process and interpret data systematically. Strengthening prior knowledge before the practicum through pre-lab activities is important to optimally prepare students to face the practicum activities (Rayment et al., 2023). Adaptive and structured learning can support the improvement of data interpretation abilities as part of scientific literacy more evenly across all students (Schlatter et al., 2022).

Students' prior competency before participating in a practicum is an important factor influencing the success of science learning because it serves as the foundation for understanding the concepts, procedures, and objectives of the practicum (Schneider & Simonsmeier, 2025). This initial competency reflects the level of understanding of basic concepts that students possess before entering the practicum, thus serving as a foundation for understanding the objectives, procedures, and concepts involved in the experiment (Hattan et al., 2024). Students with good initial competency tend to be better prepared to follow each stage of the practicum, from understanding instructions, making observations, to analyzing and interpreting data appropriately (Fromm et al., 2025). This initial competency before participating in the practicum also plays a role in helping students connect conceptual knowledge with empirical phenomena observed during the practicum, thus making the learning process more meaningful (Walid et al., 2023). Students with low initial competency tend to have difficulty understanding basic concepts, which results in less than optimal ability to analyze and draw conclusions from experimental data, thus becoming a key factor in supporting the development of students' science process skills and overall scientific literacy (Maraza-Quispe et al., 2024; Trullàs et al., 2022). Strengthening initial competency through activities such as pretests or introductory learning is an important step in supporting the optimal development of students' science process skills and scientific literacy (Hasan & Gani, 2022).

The relationship between students' prior knowledge and data interpretation skills from a scientific literacy perspective demonstrates a close relationship between conceptual knowledge and science process skills (Syahwati & Arif, 2022). The relationship between students' prior knowledge and data interpretation skills is important because scientific literacy emphasizes not only mastery of concepts but also the ability to use that knowledge to analyze and interpret scientific data appropriately (Bremmer & Nijs, 2020). Scientific literacy skills, especially data interpretation skills, cannot develop optimally without the support of strong prior knowledge because they function as a cognitive basis for understanding the meaning of data and connecting it to relevant scientific concepts (Dietrich et al., 2019). Prior knowledge also determine the quality of scientific thinking processes, including identifying patterns, evaluating data accuracy, and integrating observational results with theory. Therefore, data interpretation skills do not only depend on practical experience alone but are also greatly influenced by the conceptual readiness of students before the practical activities take place. Students with better prior knowledge tend to be better able to identify data patterns, understand relationships between variables, and draw conclusions based on scientific evidence. Prior knowledge serve as a foundation for developing more complex scientific thinking skills, so strengthening prior knowledge is a strategic step in improving students' overall scientific literacy. Students tend to only be able to read data superficially without being able to analyze the relationship between variables or draw conclusions based on evidence without adequate conceptual understanding (Benson & Young, 2024).

Biology laboratory instruction should explicitly incorporate *pre-lab* activation of prior knowledge and structured data-analysis scaffolding to address heterogeneous student readiness. Further studies should examine additional determinants (e.g., motivation, engagement, instructional design) using experimental or mixed-methods approaches across broader contexts. This study provides empirical evidence that prior knowledge significantly predicts data interpretation skills, underscoring its central role in optimizing scientific literacy outcomes in laboratory settings.

CONCLUSION

The results of the study indicate that students' prior knowledge significantly influences their data interpretation skills in General Biology practicums. Students with better prior knowledge tend to be better able to understand, analyze, and interpret data in depth and draw conclusions based on scientific evidence. The findings confirm that prior knowledge serves as a cognitive foundation in the development of data interpretation skills as an essential part of scientific literacy. The implication of this study is the need for learning designs that focus not only on the implementation of practicums but also on strengthening students' prior knowledge before the practicums take place, for example through pretests, concept reinforcement, or scaffolding-based learning. Improved prior knowledge is expected to support the optimization of students' data interpretation skills and overall scientific literacy.

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