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Linking Pre-Service Physics Teachers' Views About Experimental Physics with Their Lab Report Scores

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Abstract
The purpose of this study was to examine the relationship between pre-services physics teachers' views of experimental physics and the quality of their laboratory reports. A quantitative study with a descriptive and correlational design involving 26 pre-services physics teachers enrolled in a basic physics course focusing on kinematics experiments was conducted. The participants worked in small groups to design and conduct experiments, analyze the data, and write laboratory reports. The reports were assessed based on three indicators: systematics and completeness, content and conceptual depth, and writing style and neatness. Pre-service physics teachers' views about experimental physics were measured using the Colorado Learning Attitudes about Science Survey for Experimental Physics (E-CLASS). Data were analyzed using descriptive statistics and Spearman's rho correlation. The main finding shows that there is no significant correlation between E-CLASS scores and the laboratory reports quality. This indicates that favorable views about experimental physics do not necessarily translate into better performance in scientific reporting. These findings suggest a gap between epistemological beliefs and scientific communication skills, where understanding the nature of experimental physics does not automatically lead to the ability to express it effectively in written form. Therefore, laboratory instruction in teacher education programs should explicitly integrate support for experimental reasoning, data interpretation, and scientific writing, rather than emphasizing procedural completeness alone. Future research should involve larger and independent samples, apply individual-level assessment of laboratory performance, and examine instructional designs that intentionally connect epistemological development with experimental practice and scientific communication.

Keywords:
Epistemological Beliefs; Views about Experimental Physics; Kinematics; Laboratory Reports; Pre-Service Teachers

INTRODUCTION

For prospective physics teachers, mastering both theoretical and experimental aspects is essential to developing comprehensive pedagogical content knowledge. However, studies tend to focus on theoretical classroom learning, and research focusing on experimental learning is still relatively scarce (Wilcox & Lewandowski, 2017c). Experimental activities, both in-person and virtual, provide students with opportunities to actively participate in the scientific process (Pranata, 2024, 2025). Physics experiments help students connect theory with phenomena and engage in the scientific process. These activities provide opportunities for students to verify theories and support the development of scientific skills, such as using representations, observing, formulating explanations and models, designing experiments, collecting and analyzing data, and drawing conclusions (Etkina et al., 2006). Therefore, physics learning, especially in effective laboratories, should direct students to adopt the habits of mind that define experimental physicists (Etkina & Planinsic, 2024).

It is important for teachers to pay attention to students' views of a discipline because these views can influence the success of the learning process (Putri et al., 2024). However, previous studies have revealed that students often have different views than experts about physics (Adams et al., 2006) and experimental physicist (Wilcox & Lewandowski, 2017c;

Zwickl et al., 2014). The main problem regarding physics learning is the relationship between concepts and their application (Pranata et al., 2024) and the learning process through experiments that still focus on verification (Hammer, 1994; Holmes et al., 2017; Smith & Holmes, 2021). This has an impact on students' views of experimental activities (Karelina & Etkina, 2007), most students still view the main purpose of physics experiments as verification rather than exploration. This perspective has been extensively examined using the Colorado Learning Attitudes about Science Survey for Experimental Physics (E-CLASS) (Wilcox & Lewandowski, 2016b). Studies using E-CLASS show that many students have novice-like views of experimental activities even after participating in lab-based learning. This suggests that traditional labs may not sufficiently support students in changing their views on how experts work (Fox et al., 2021; Shi et al., 2020; Wilcox & Lewandowski, 2016a).

Laboratory experiments are students' primary exposure to experimental physics. These activities represents a significant part of the physics discipline and the main pathway for students to develop expert-like perspectives (Wilcox & Lewandowski, 2018). Taking notes and writing experiment reports are important activities (Borish et al., 2022). Experiment reports are authentic artifacts reflecting the activities carried out and the data collected and analyzed. They also serve as a form of written communication of experimental findings. Student performance in experimental activities is typically evaluated using lab reports, tests, and projects. Lab reports are generally the most common and widely used form of evaluation for experimental activities (Etkina et al., 2020). For instance, Harmer et al. (2024) collected experimental data from notes and lab reports in addition to conducting an E-CLASS survey. This suggests that students' written reports can serve as valuable data sources for examining how they think about and conduct experiments. Therefore, analyzing students' lab reports offers insights into their experimental reasoning and understanding.

Although epistemological beliefs are widely recognized as an important factor, little research has examined how students' views about experimental physics relate to their performance, particularly in written laboratory reports. Theoretically, students with expert-like views are more actively involved in experimental activities, persevere more (Wilcox & Lewandowski, 2017b), and produce higher-quality lab reports (Buggé, 2023). Conversely, students with novice-like views may focus on procedural accuracy or finding correct experimental results, neglecting deep reflection and analysis. While several studies have explored the relationship between epistemological beliefs and conceptual learning outcomes, research on the relationship between views about experimental physics and lab report performance is limited.

Understanding this relationship could reveal whether students' views about experimental physics align with scientific practices in laboratory experiments and provide insight into how to improve laboratory learning. Previous studies have examined changes in students' views before and after laboratory instruction. However, studies have not yet examined how students' views relate to their performance in experiments as assessed from their lab reports. In teacher preparation programs, this relationship is important because prospective teachers' understanding of and views on experiments influence how they design and teach physics through laboratory activities in schools. Therefore, this study aims to investigate the relationship between students' views about experimental physics, as measured by the E-CLASS, and their performance on written laboratory reports.

To address this gap, the present study formulates the following hypotheses. The null hypothesis states that there is no statistically significant correlation between pre-service physics teachers' views about experimental physics, as measured by E-CLASS scores, and the quality of their laboratory reports. The alternative hypothesis posits that there is a statistically significant positive correlation between E-CLASS scores and laboratory report quality, such that more expert-like views are associated with higher-quality reports. This explicit hypothesis framing enables a rigorous evaluation of whether alignment between epistemological beliefs and scientific practices is empirically supported. Therefore, this study

aims to investigate the relationship between pre-service physics teachers' views about experimental physics and their performance on written laboratory reports. The following section describes the methods used to test these hypotheses.

METHOD

This study employed a quantitative method with a descriptive and correlational design. The design was chosen because it allows exploration students' epistemological views and their performance on lab reports without manipulating variables and examination of the degree of association between both variables. The study involved one class of 26 students as pre-services physics teachers enrolled in a basic physics course. The students were divided into eight groups. Each group consisted of three to four students who carried out experiments and compiled reports together. Although students worked in groups, the E-CLASS scores were analyzed at the individual level, while lab report scores were assigned to groups.

The lab activities focused on kinematics to help students understand uniform and uniformly accelerated linear motion. Each group designed a simple experiment to obtain position and time data. They then analyzed the data to determine the relationship between position and time in relation to velocity and acceleration. This activity allowed students to practice taking measurements, processing data, and interpreting experimental results. Next, the practicum report was compiled. Therefore, the practicum report score applied equally to all group members. Two Teaching Assistants (TAs) assessed the practicum report. Each group was given the opportunity to revise their report based on the TAs' feedback.

The lab report was assessed based on three criteria: 1) systematics and completeness, 2) content and depth of concepts, and 3) writing style and neatness. The first criterion involves conformity with the report format, including chapters, subchapters, and detailed objectives. The second criterion focuses on the accuracy of the theory, data collection and processing, and the ability to interpret the results of the analysis. The third criterion assesses the consistency of using scientific and formal language and the document's professional, readable presentation. The final grade for the lab report is obtained by combining the final report grades from both groups from both TAs.

Other variables, such as students' views about experimental physics, were measured using the Colorado Learning Attitudes about Science Survey for Experimental Physics (E-CLASS). Zwickl et al. (2012) first developed and validated E-CLASS on a small scale. Then, it was validated on a larger scale involving various classes and institutions (Wilcox & Lewandowski, 2016b; Zwickl et al., 2014). The E-CLASS survey contains 30 statements with a 5-point response scale ranging from "strongly agree" to "strongly disagree." In E-CLASS scoring, the 5-point Likert scale is simplified to a 3-point scale by combining "strongly agree" and "agree" into "agree" and "strongly disagree" and "disagree" into "disagree," while "neutral" is retained. Student responses to each item are compared to the responses of experts, who are considered the assessment standard. A score of +1 is given for favorable responses, 0 for neutral responses, and –1 for unfavorable responses (Wilcox & Lewandowski, 2016b, 2017c). The total E-CLASS score is obtained by summing all items, ranging from –30 to +30. The total score describes the level of agreement between students' and experts' views regarding experiments in physics.

Descriptive statistics were used to analyze both sets of data (students' views about experimental physics and the quality of lab reports) to obtain an overview of both data sets. The results of the analysis are shown in the form of means, standard deviations, and data distributions. Before performing the correlation analysis, a normality test was used to determine the appropriate statistical test. If the data were normally distributed, the Pearson correlation test was used, otherwise, the Spearman rho correlation test was used. Given that laboratory report scores were assigned at the group level, the correlation analysis was conducted at the group level to ensure consistency of the unit of analysis. Individual E-CLASS scores were aggregated within each group using the mean score, resulting in eight paired

data points (one per group) for correlation analysis. All analyses were performed using Jeffreys's Amazing Statistics Program (JASP) version 0.19.3.0 (Goss-Sampson, 2024).

RESULTS AND DISCUSSION

After collecting data from lab reports and surveys about experimental physics, it was found that 3 students did not complete the survey. Therefore, the analysis only included data from 23 students. The complete results of the descriptive statistical analysis can be seen in Table A1 in the Appendix. Figure 1 shows a comparison of each student's mean lab report scores as a representation of the data analysis. Lab report scores were derived from three indicators: systematics and completeness, content and depth, and writing style. Figure 1 shows the lab report scores for each student, where the highest score was 92 and the lowest was 73. The average lab report score was 84.26, with a standard deviation of 5.22. These scores were a combination of three assessment indicators. The average value for each indicator was found to be 87.87, 79.22, and 85.87, respectively (Figure 2).

The first indicator, systematics and completeness, had the highest average score of 87.87 and a standard deviation of 4.22. This indicates that the students' reports were in accordance with the format and were systematic and complete. However, some parts were incomplete, such as methods that did not show the tools and materials used and results that were not interpreted. The third indicator, writing style and neatness, was also considered good, with an average of 85.87 and a standard deviation of 4.83. A common issue in the reports was that equations were not written using the equation feature, resulting in an unprofessional appearance. The second indicator, content and depth of concept, had a lower average score of 79.22, with a standard deviation of 9.30. Although no obstacles were found in the experimental procedures and data collection based on the teaching assistant's observations, students still had difficulty analyzing and representing data, especially in graph form. Difficulties with data analysis and graphing were also reported in previous studies (Pranata, 2025). It is important to ensure that the experiment report does not indicate completion. Writing experiment reports is a scientific writing strategy that improves learning quality and can stimulate improvement in scientific abilities (Buggé, 2023). A recent study on experimental procedures recommends using summary sentences in reports because they can enhance a basic understanding of the underlying logic of the scientific experiment (Rutberg & Jammula, 2026).

The average scores for each statement item and provides a basis for further exploring students' views as shown in Figure 4. A score of +1 indicates that all students' views are in line with the experts', while a score of -1 indicates that all students' views are not in line with the experts. Figure 4 shows that there are several items with a high level of agreement. Five statement items have scores close to 1 (0.96): items 1, 11, 18, 19, and 24. These items relate to understanding how experiments work, the importance of computers in data analysis, communicating results, working in groups, and confidence in conducting experiments. A high level of agreement was also found on several other items: 0.91 (items 13, 20, and 30), 0.87 (items 15 and 22), and 0.83 (items 6 and 10). In comparison, Wilcox & Lewandowski (2017c) found that students' and experts' views on experiments were in line on almost the same items, ranging from 11, 30, 1, 26, and 13.

Conversely, several items had low levels of agreement: items 3 (0.26), 21 (0.35), 27 (0.35), and 14 (0.39). Five items had negative levels of agreement. These items indicate that most students had views that differed from those of the experts. Item 17 had the most negative score at -0.87. Items 4 and 16 followed with the same score of -0.70. The other two negative items are number 29, with a score of -0.43, and number 25, with a score of -0.22. Items 4, 17, 29, and 16 were also among the items with the lowest level of agreement in a previous study (Wilcox & Lewandowski, 2017c). Item 17 relates to the idea that, when facing experimental difficulties, the first step is to consult the instructor. Most students agreed with this idea, but

experts did not. The first step should be to try to overcome the difficulties independently or in a group.

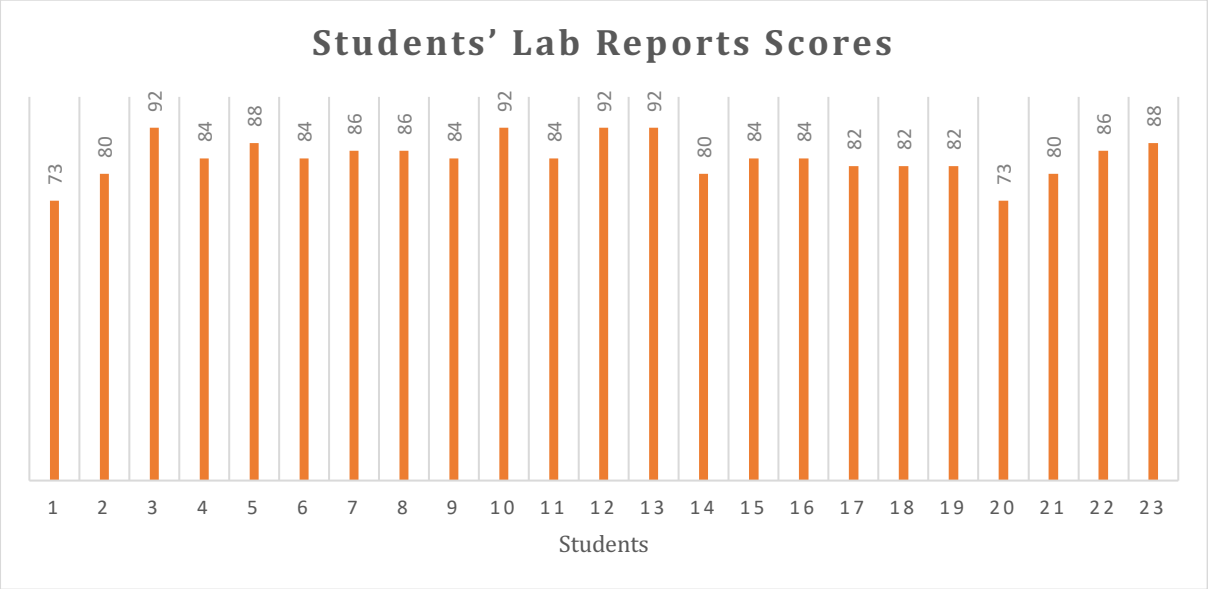

Figure 1. Students' Lab Reports Scores

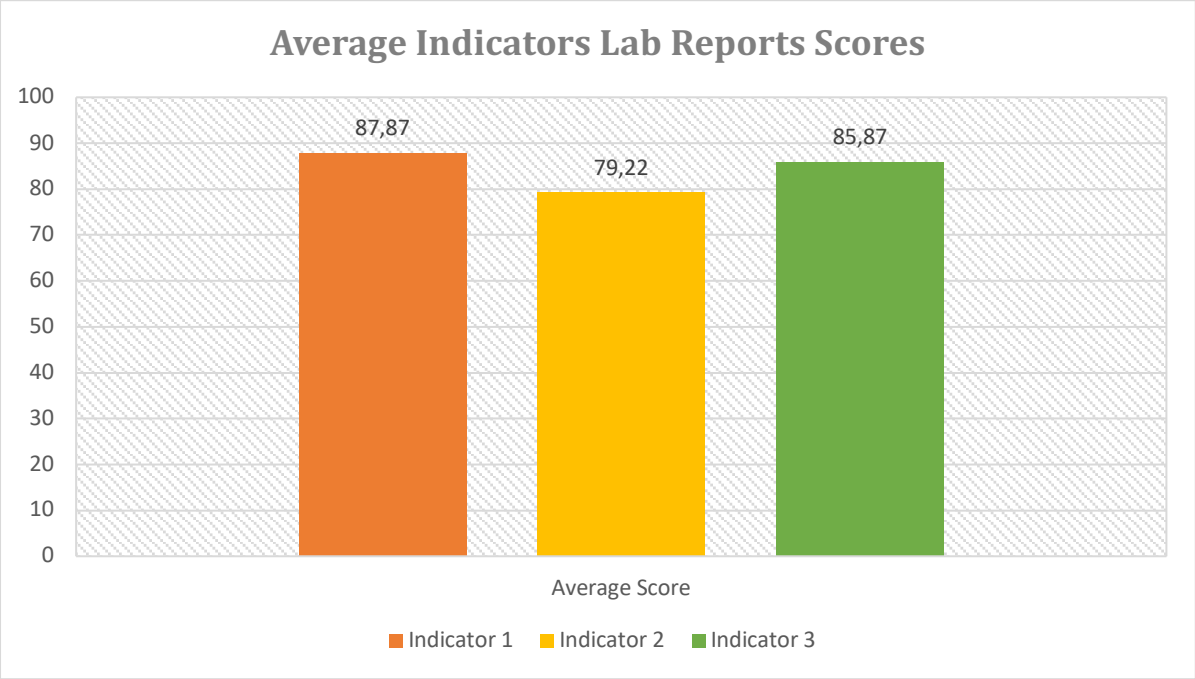

Figure 2. Average Indicator Lab Reports Scores Based on Indicators

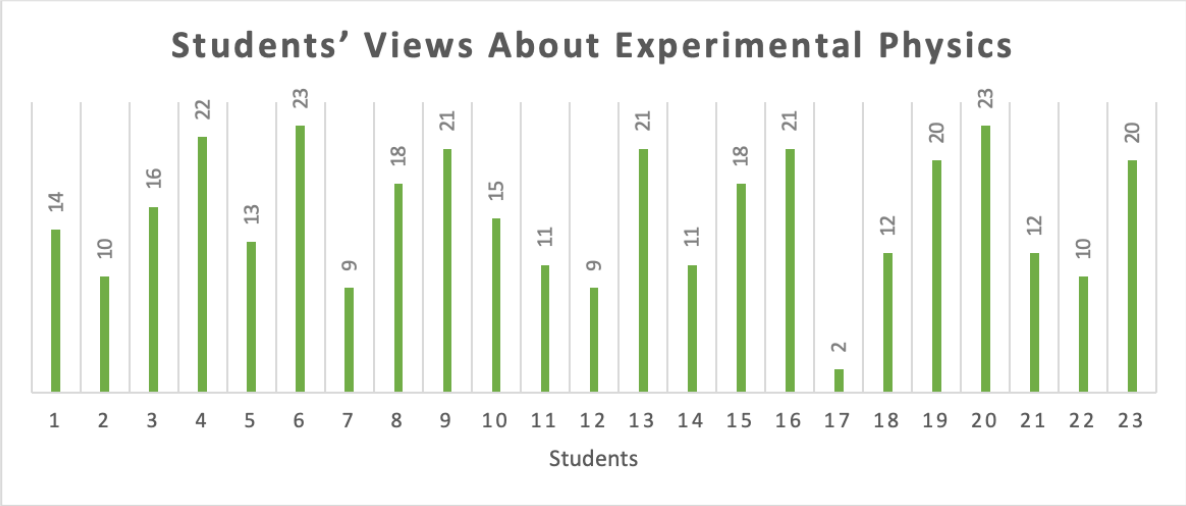

Figure 3. Students' Views About Experimental Physics Scores

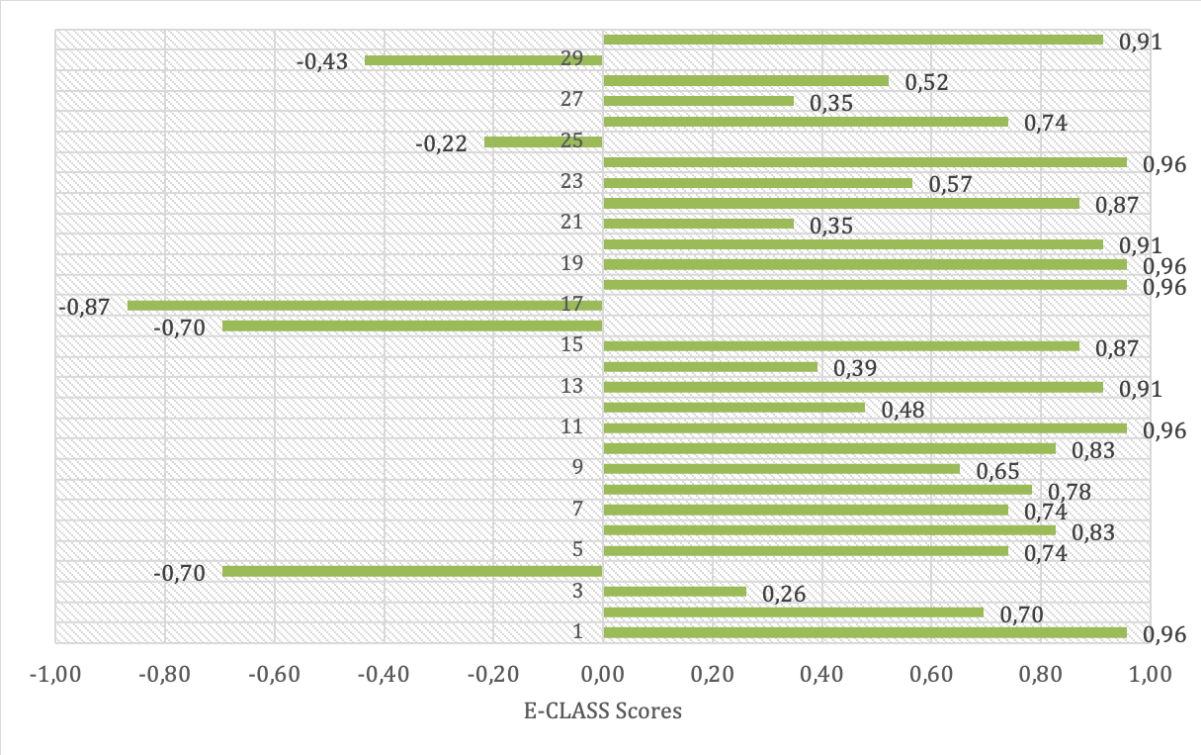

Figure 4. Students' Views About Experimental Physics Scores on Each Item

Furthermore, Item 16 shows that most students still view the purpose of conducting experiments as confirming known results. Item 4 shows that most students believe the purpose of communicating results is merely adjusting the section or format of the report. These views differ significantly from those of experts. Similar results were expressed by Zwickl et al. (2014) They found that, although 100% disagreed with the purpose of experiments being to confirm previous results, only 40% disagreed. Based on their findings, Fox et al. (2021) recommend that teachers design effective activities to support students in understanding the purpose of experiments and provide them with opportunities to do so. Zwickl et al. (2014) also found that only 5% disagreed with the statement that the purpose of communicating results is to solely adjust the section or format of the report. However, almost all experts (96%) disagreed with this statement. Additionally, items 29 and 25 showed that students were unable to analyze data without clear guidance and tended to solve problems randomly.

Although some items received low or even negative scores, most items received high scores. This indicates that students' views on experimental physics are not as negative as their level of agreement with experts, which is 65.37%. This data was collected after students participated in kinematics laboratory experiments. Previous studies have suggested that guided labs often do not encourage active engagement in the scientific process, thus failing to change students' views on the nature of physics experiments. These studies recommend providing learning through experiments in an open-ended format and focusing on developing laboratory skills (Wilcox & Lewandowski, 2016a) or scientific abilities to change students' views on physics experiments for the better (Wilcox & Lewandowski, 2017a). Furthermore, inquiry-based laboratory activities have been shown to improve students' views of experimental physics (Shi et al., 2020).

The next step is to explore the relationship between students' lab reports and their experimental physics scores. Before conducting a correlation test, it is necessary to present the data distribution as a basis for selecting the appropriate test. Based on a descriptive statistical analysis of skewness, kurtosis, and the Shapiro-Wilk test (see Table A1 in the Appendix), we can conclude that the average lab report score follows a normal distribution. However, students' views about experimental physics scores are not normally distributed. Thus, the correlation between the two was analyzed using a Spearman's rho test. Spearman's rho correlation was used to examine the relationship between E-CLASS total scores and laboratory report quality at the group level ($n_{group} = 8$). This approach was chosen to maintain independence of observations, as laboratory report scores were identical within groups. The results of Spearman's rho test are shown in Table 1.

Table 1. Correlation Test Results

Variable	Correlation Test	Average Lab Report	Lab Report C1*	Lab Report C2*	Lab Report C3*
Students' views about experimental physics (E-CLASS)	Spearman's rho	0.024	0.277	-0.310	0.405
	p-value	0.955	0.506	0.350	0.319

*C1 = systematics and completeness, C2 = content and depth of concepts, and C3 = writing style and neatness.

Table 2. Correlation between students' lab reports in avarege and the indicators

Variable	Correlation Test	Average Lab Report	Lab Report C1*	Lab Report C2*	Lab Report C3*
Average Lab Report	Spearman's rho	—			
	p-value	—			
C1 Lab Report	Spearman's rho	0.721	—		
	p-value	0.043	—		
C2 Lab Report	Spearman's rho	0.898	0.518	—	
	p-value	0.002	0.188	—	
C3 Lab Report	Spearman's rho	0.741	0.665	0.393	—
	p-value	0.035	0.072	0.336	—

*C1 = systematics and completeness, C2 = content and depth of concepts, and C3 = writing style and neatness.

It should be noted that the small number of groups limits the statistical power of the correlation analysis. Therefore, the findings should be interpreted with caution. The correlation analysis conducted at the group level revealed that there was no significant relationship between E-CLASS total scores and laboratory report quality ($\rho = 0.024, p = 0.955$). An insignificant relationship was also found between students' views about experimental physics and lab report indicators. These findings indicate that students' epistemological views about

experimental physics may not directly translate into the quality of their written lab reports. This might indicate that students' epistemological beliefs, as measured by E-CLASS, capture their conceptual stance toward experimentation, whereas lab report quality is more influenced by procedural or writing skills.

However, these findings need to be reconfirmed due to various limitations in this study. First, all group members received the same lab report scores, which could have introduced bias. It is possible that someone with low view scores could have high lab report scores, and vice versa. Group-based lab work often masks individual epistemological differences. Thus, future studies could independently assess lab reports and observe and assess students while they conduct experiments. Previous studies recommend that, when using group lab reports, teachers observe how each student contributes to the reports (Buggé, 2023). Second, the study only included one class of 26 students, three of whom did not have complete data. Further studies could involve a larger number of students and compare various approaches. Furthermore, Table 2 shows the results of the internal correlation test between the average scores of the lab reports and the lab report indicators.

Table 2 shows the results of the Spearman's rho correlation test between the average lab report scores and the three assessment indicators: C1 (systematics and completeness), C2 (content and depth of concepts), and C3 (writing style and neatness). The average lab report correlated very strongly and significantly with all three indicators. This indicates that these three aspects consistently contribute to the overall assessment of the report.

In contrast, the correlations among the indicators of lab reports themselves are not statistically significant, despite some moderate-to-strong correlation coefficients. For example, the relationship between C1 and C3 ($\rho = 0.665, p = 0.072$) and between C1 and C2 ($\rho = 0.518, p = 0.188$). This results suggests a potential trend between those indicators, yet the lack of statistical significance indicates that these relationships cannot be reliably generalized. The correlation between C2 and C3 is even weaker ($\rho = 0.393, p = 0.336$), further emphasizing the independence of these dimensions.

This pattern suggests that each indicator captures a distinct aspect of students' performance in lab report writing. In other words, students who demonstrate strong conceptual understanding do not necessarily exhibit equally strong skills in organizing their reports or presenting them neatly, and vice versa. S By comparison, previous studies have shown that thinking skills are not correlated with writing activities at the high school level, but a positive and significant correlation was found at the university level (Pranata & Novalia, 2025). This multidimensionality highlights the complexity of scientific writing, which integrates conceptual, structural, and communicative competencies. Previous studies have shown that writing activities initially have no effect on conceptual understanding. However, when writing activities are repeated with a clear purpose, their impact on conceptual understanding begins to emerge (Hand et al., 2004). Other studies recommend the importance of meaning-making, interactive processes, clear expectations, and metacognition in science writing activities (Gere et al., 2019). Another possible explanation for the non-significant inter-indicator correlations is the limited sample size, which may reduce statistical power and obscure meaningful relationships. Therefore, while some moderate correlations are observed, further studies with larger samples are needed to confirm these trends.

CONCLUSION

The results of the study indicate that the proposed alternative hypothesis is not supported, and the null hypothesis cannot be rejected. There is no significant correlation between pre-service physics teachers' views toward experimental physics and the quality of their lab reports. While some students have positive views on physics experiments, these views do not consistently reflect their ability to write scientific reports. This null result has important theoretical implications. It suggests that epistemological beliefs about experimental physics and the ability to communicate experimental work in written form may represent distinct

dimensions of competence. While E-CLASS captures students' views about the nature and purpose of experimentation, laboratory report quality appears to depend more on procedural knowledge, familiarity with report conventions, and scientific writing skills. In other words, a gap may exist between knowing what counts as good experimental practice and being able to express that understanding effectively in writing. This gap may explain why positive views do not automatically lead to higher-quality reports. Then the internal analysis of report indicators further supports this interpretation. Systematics and completeness show consistent contributions to overall report quality, whereas conceptual depth and writing quality are not always aligned. This indicates that students may be able to follow report structures without necessarily demonstrating deep conceptual reasoning or clear scientific communication.

Based on these findings, several implications for teacher education can be proposed. Physics teacher education programs should design laboratory report rubrics that explicitly emphasize experimental reasoning, data interpretation, and justification, rather than focusing primarily on procedural completeness. In addition, instructional support should be provided to help pre-service teachers translate their epistemological understanding into written scientific arguments, for example through structured scaffolding, model-based reporting tasks, or guided reflection on experimental decisions. Future research also should involve larger samples and prioritize individual-level assessment of laboratory performance to ensure more robust statistical analysis. Moreover, integrating inquiry-oriented laboratory designs with explicit support for scientific writing may help bridge the gap between epistemological beliefs, experimental practices, and scientific communication skills.

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