Jurnal Penelitian dan Pengkajian Ilmu Pendidikan: e-Saintika
https://journal-center.litpam.com/index.php/e-Saintika/index

March 2026 Vol. 10, No. 1
e-ISSN: 2615-6881
pp. 214-236

Assessing Laboratory Behavior in Genetic Practicals: A Study on Pre-Service Biology Teachers

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Received: October 2025; Revised: December 2025; Published: March 2026

Abstract

Laboratory behavior refers to attitudes and actions in the laboratory, including planning and design, manipulative skills, conducting experiments, observation and data recording, data interpretation, and responsibility, initiative, and work habits. Laboratory behavior plays an essential role in the development of experimental skills, especially in Genetics courses. This study aims to describe the laboratory behavior of biology education students (N=99) who have taken the Genetics course. The study uses a quantitative descriptive approach using self-assessment questionnaires, peer assessments, observation sheets, and practical report rubrics. The scores from the four assessment sources were averaged equally, with each source contributing the same weight to the final score. The results show that student laboratory behavior falls into the "Needs Improvement" category, with an average achievement percentage of 62.50%. The average achievement percentages for each indicator are as follows: planning and design, 62.57%; experiment implementation, 62.35%; observation and data recording, 59.22%; data interpretation, 59.31%; and responsibility, initiative, and work habits, 64.71%. These results indicate that students' laboratory behavior needs improvement and should be enhanced through effective practical learning, supported by learning models and media that are appropriate to the needs and real situations in the laboratory.

Keywords: Laboratory Behavior; Genetic Practicals; Laboratory Practicum; Pre-Service Biology Teachers

How to Cite: Kharomah, S., Susanto, H., & Zubaidah, S. (2026). Assessing Laboratory Behavior in Genetic Practicals: A Study on Pre-Service Biology Teachers. *Jurnal Penelitian Dan Pengkajian Ilmu Pendidikan: E-Saintika*, *10*(1), 214-236. https://doi.org/10.36312/e-saintika.v10i1.3736

10.36312/e-saintika.v10i1.3736

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INTRODUCTION

21st-century learning requires science students to grasp not only theoretical concepts but also to exhibit good scientific practices in laboratory settings (Hubbard et al., 2024). This focus is crucial in science education, especially in addressing real-world problems and issues, such as those in genetics (Chengere et al., 2025). The field of genetics is continually advancing, helping uncover biological phenomena and address contemporary challenges (Razavi et al., 2019; Kanai et al., 2018). These challenges include trait inheritance, genetic variation, genetic diseases, and genetic engineering (Little & Colegrave, 2016; Poczai & Santiago-Blay, 2021). Consequently, genetics has become a vital component of biology education at the higher education level (Whitley et al., 2020). Thus, paying attention to students' behavior in the laboratory is an essential aspect of the learning process in genetics (Hofstein & Lunetta, 2004b).

Laboratories not only serve as learning environments for students but also play an important role in solving various problems related to genetic concepts (May et al., 2023). Through practical activities, students can understand abstract genetic concepts by applying them concretely in experiments. The success of genetics learning is determined by two main factors: students' understanding of concepts and the laboratory behavior they exhibit (Myrick et al., 2013; Abraham et al., 2014). Therefore, students' laboratory work behavior is an essential aspect of the learning process in genetics.

Laboratory behavior refers to attitudes and actions in the laboratory that include planning and design, manipulative skills: conduct of experimental, observation and data recording, data interpretation, as well as attitudes of responsibility, initiative, and work habits (Lunetta et al., 1981). Venant et al. (2017) define laboratory behavior as students' interactions and actions during practical learning. Cai et al. (2021) also define laboratory behavior as the actions, interactions, and cognitive strategies students use during laboratory learning. This behavior reflects how students conduct experiments, communicate with teams and instructors, and understand experimental concepts and data (Ribau, 2020).

Planning and design encompass students' ability to create clear and complete practicum plans. Manipulative skills: the conduct of experiments refers to students' ability to use the practicum equipment and complete all practicum steps. Observation and data recording encompass students' ability to make accurate observations and record all practicum results. Meanwhile, data interpretation refers to students' ability to understand, analyze, and accurately explain data. Responsibility, initiative, and work habits demonstrate students' ability to complete practical work, work well in teams, observe safety protocols, and be independent (Lunetta et al., 1981).

Various studies show that good laboratory behavior contributes to a deeper understanding of concepts and the success of Genetics practical work (Yu et al., 2023; Bazie et al., 2024; Nyansa et al., 2024). Planning and design are aspects of laboratory behavior that play an important role in understanding genetic concepts (Militello et al., 2016). In addition, aspects of laboratory behavior that contribute to the success of genetics practicums are observation and interpretation of practicum data (Zhao et al., 2016). These findings demonstrate that laboratory behavior is important for pre-service biology teachers (Haw et al., 2022 ; Digarbayeva et al., 2024).

Despite its significance, the assessment of student laboratory behavior remains largely neglected, as practicum evaluations predominantly emphasize summative outcomes (Kloser et al., 2022). Critical elements such as data recording accuracy, scientific responsibility, and adherence to experimental procedures are frequently omitted from assessment criteria (Moore et al., 2024). This is evidenced by research conducted by Buroidah et al. (2023), which states that the assessment used in genetics practicum learning is an essay test. Fostier et al. (2015) also reported a hybrid assessment strategy that combines paper-based crossing tasks with computer-based electronic assessment to evaluate student performance in a genetics practicum. Consequently, students tend to prioritize achieving final results over active engagement in the practical process, leading to insufficient development and exposure of laboratory behavior as an integral component of scientific training (Madsen et al., 2023).

Research evaluating the laboratory behavior of biology students is still rare. Previous studies have focused on assessing final reports, experimental results, and

understanding of concepts related to practical work (Maričić et al., 2020). Evaluations of laboratory behavior, particularly in genetics practical work, are still limited (Simão et al., 2022; Vedova et al., 2025). Previous research on laboratory behavior by Okebukola (1985) used only one assessment method, an observation sheet. Furthermore, Miller et al. (2009) used two assessments, namely lab reports and self-assessments, to measure students' laboratory behavior in genetics practicums. Many studies have not fully captured the complexity of laboratory behavior using a multi-source assessment. Additionally, Wu (2013) used lab reports and observations to measure students' laboratory skills in genetics practicums, while Nousek-McGregor et al. (2025) used direct observation, supplemented by a skills checklist, to measure students' laboratory skills. These studies primarily focused on single-source assessments or dual-source assessments.

This study combines several assessments, including self-assessment, peer-assessment, observation, and lab reports, offering a more comprehensive evaluation of students' laboratory behavior. Peer-assessment was deliberately added because genetics practicums are often conducted in groups (Day et al., 2015). Therefore, peer-assessment can effectively capture students' contributions and team performance (Mumpuni et al., 2022). This multi-assessment approach provides a more holistic understanding of students' laboratory behavior, focusing not only on the final result but also on the process and collaborative aspects of the practicum.

Based on this background, the study aims to assess the laboratory behavior of pre-service biology teachers in Genetics courses by focusing on five indicators: planning and design; manipulative skills (conducting experiments); observation and data recording; data interpretation; and responsibility, initiative, and work habits. These indicators will be evaluated through four sources of assessment: self-assessment, peer assessment, observation, and lab reports. This descriptive study will provide an overview of students' laboratory behavior during practical work and serve as a foundation for designing laboratory environments and teaching strategies that enhance learning outcomes in genetics education.

METHOD

Research Design

This study uses a quantitative descriptive method to describe the laboratory behavior of pre-service biology teachers during genetics practicums. The quantitative descriptive method was chosen because the purpose of this study is to provide a clear, objective description of student laboratory behavior. This method allows researchers to comprehensively assess student laboratory behavior, identify areas for improvement, and provide an empirical basis for further research (Creswell, 2012). The stages of this study are presented in Figure 1.

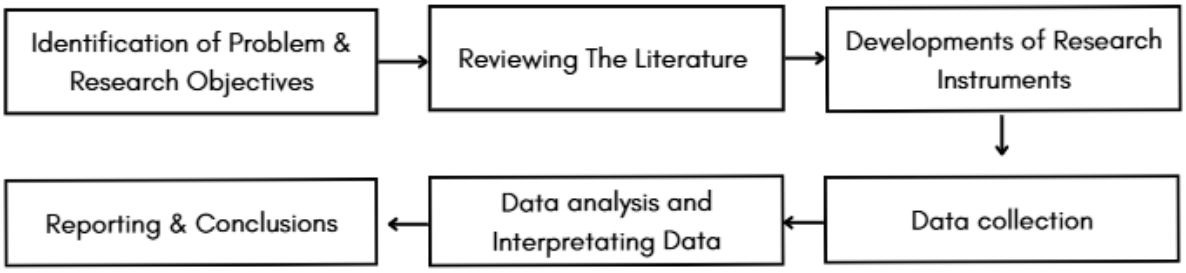


Figure 1. Research flowchart

Data were collected at specific stages of the genetics practicum throughout the semester, covering several important topics in genetics, including the proof of Mendel's laws of inheritance, crossing-over, nondisjunction, and lethal interactions. The practicum was conducted using Drosophila melanogaster test animals. Data collection occurred during the stages of practicum presented in Table 1.

Table 1. Stages of practicum

Week	Stage
2	Identification of D. melanogaster strains
3	Media preparation for culture
4-5	D. melanogaster culturing
6-7	Crossing D. melanogaster according to the practicum topic
8-13	Data collection of offspring resulting from the cross
14-15	Presenting the results of the practicum

Observations were conducted for each student within each group, ensuring that each student's behavior was assessed independently. The unit of analysis for this study is the individual student, with scores based on individual observations within groups. To ensure consistency in data collection, observers were calibrated prior to the practicum to align their perceptions and assessment criteria.

Population and Sample

The population in this study comprised all students enrolled in the Biology Education program at the State University of Malang during the 2024/2025 academic year. The sample consisted of 99 students from this program who were registered in the Genetics course during the even semester of the 2024/2025 academic year. Purposive sampling was employed to select participants based on the inclusion criteria as presented in Table 2.

Table 2. Inclusion criteria of sample involved

N of sample	Inclusion criteria
99	• Enrolled in the Genetics course during the 2024/2025 academic year. • Attended at least 80% of the lab sessions to ensure adequate exposure to the practical work. • Submitted all required practical reports as part of the course requirements. • Provided informed consent for the use of their coursework data in this research.

These students were chosen due to their direct experience, which provided valuable insights into their laboratory behavior. Therefore, the sample was considered to be representative of the population relevant to the research focus. Regarding ethical considerations, informed consent was obtained from all participants via an online Google Form survey. Before data collection, participants were provided with a link to the Google Form, which included detailed information about the purpose of the study, how their data would be used, and their rights as participants.

Research Instrument

This study employed four types of assessments based on laboratory behavior indicators outlined by Lunetta et al. (1981), namely: (1) Planning and Design, (2) Manipulative Skills: Conduct of Experiment, (3) Observation and Recording of Data,

(4) Interpretation of Data, and (5) Responsibility, Initiative, and Work Habits. The assessment instruments included: (1) a self-assessment questionnaire to evaluate students' perceptions of their own laboratory behavior, (2) peer assessments to gather evaluations from group members, (3) direct observation sheets completed by laboratory assistants during the practicum, and (4) a practicum report rubric for assessing students' final reports. Details of the instrument used in this study are provided in Table 3, while an example of observation sheets is provided in Figure 2.

Table 3. Details of instrument

Indicator	Number of Items	Example Item	Rater Source	Rating Scale	Administration Timing
Planning and Design	4	"Students develop a plan based on the identification of problems and variables."	• Self-assessment • Peer-assessment • Observation • Practicum report	0-10	• Second week of the semester (Observation) • End of semester (Self/peer/ practicum report)
Manipulative Skills: Conduct of Experiment	4	"Students maintain accuracy in measuring and using measuring instruments during experiments."	• Self-assessment • Peer-assessment • Observation • Practicum report	0-10	• During practicum (observation) • End of semester (Self/peer/ practicum report)
Observation and Recording of Data	5	"Students use tables or systematic formats to record experimental data"	• Self-assessment • Peer-assessment • Observation • Practicum report	0-10	• During practicum (observation) • End of semester (Self/peer/ practicum report)
Interpretation of Data	5	"Students use graphs, tables, or other visualisations to help explain the results of experiments."	• Self-assessment • Peer-assessment • Observation • Practicum report	0-10	• Week 14-15th (Observation) • End of semester (Self/peer/ practicum report)
Responsibility, Initiative, and Work Habits	5	"Students demonstrate a sense of responsibility for the practical tasks assigned to them"	• Self-assessment • Peer-assessment • Observation • Practicum report	0-10	• Throughout the practicum (observation) • End of semester (Self/peer/ practicum report)

No	Name	*Planning and design*	*Manipulative skills and conduct of Experiment*									*Observations and Recording of Data*			*Interpretations of Data and Experiment*	*Responsibility, initiative, Habits*
			Media preparation			Strain Identifications	*D. melanogaster* culturing			Crossing *D. melanogaster*							
			I	II	III		I	II	III	I	II	III	I	II	III		
1.																	
2.																	
3.																	
4.																	
5.																	

Figure 2. Observation sheets

Validity and Reliability

Each instrument underwent content validity testing by a panel of 3 experts in genetics and biology education. The Content Validity Index (CVI) for each instrument was calculated. All instruments received I-CVI = 1 and S-CVI/ave = 1, indicating that all items in the instruments were highly relevant and comprehensive for measuring the targeted laboratory behavior indicators.

Construct Validity

To assess construct validity, item-total correlations were calculated for each of the five laboratory behavior indicators provided in Table 4.

Table 4. Construct validity

Indicator	**Self-assessment**		**Peer-assessment**		**Observation**		**Practicum Report**	
	Total correlations	**α**	**Total correlations**	**α**	**Total correlations**	**α**	**Total correlations**	**α**
Planning and Design	0.815-0.921	0.951	0.902-0.941	0.971	0.710– 0.796	0.915	0.801-0.858	0.924
Manipulative Skills: Conduct of Experiment	0.843- 0.893	0.943	0.862-0.944	0.964				
Observation and Recording of Data	0.838- 0.892	0.949	0.936-0.954	0.979				
Interpretation of Data	0.868-0.916	0.961	0.911-0.950	0.978				
Responsibility, Initiative, and Work Habits	0.811-0.895	0.953	0.857-0.947	0.968				

The reliability values in Table 4 show that the instrument used is highly reliable. For inter-rater reliability, the Intraclass Correlation Coefficient (ICC) was used to assess agreement among multiple raters. Since peer-assessment involves multiple raters (3-4 peers per student), ICC was calculated for this assessment method. The results showed excellent agreement between raters, with an ICC of 0.989 (95% Confidence Interval: 0.987 - 0.991). The sample size for the peer-assessment analysis involved 99 students, with a total of 363 ratings.

Data Collection

Data for this study were collected using the previously described instruments. Self-assessment allowed students to evaluate their own laboratory behavior. This questionnaire, administered at the end of the semester, utilized a 0-10 rating scale adapted from Lunetta et al. (1981). For peer assessment, group members (3-4 students per group) assessed one another's laboratory behavior. This evaluation also employed the 0-10 rating scale and was conducted at the end of the semester. Laboratory assistants conducted observations throughout the practicum. Each assistant was responsible for observing several groups of students with the same practical topic, for example, proving Mendelian laws. The report assessment rubric was used to evaluate students' final reports upon completion of the practicum. This assessment, conducted by lecturers, focused on the quality of the reports, including students' ability to present data, interpret experimental results, and conclude. It also included evaluations of responsibility and task completion accuracy.

Data Analysis

The data were analyzed using descriptive statistics. The average percentage for each laboratory behaviour indicator was calculated across the assessment types: self-assessment, peer assessment, direct observation, and the practicum report rubric. Furthermore, the final results were categorized according to the laboratory behavior criteria adapted by Lunetta et al. (1981), as shown in Table 5.

Table 5. Category of laboratory behavior

Percentage (%)	Category
$90 \leq X \leq 100$	Very Good
$70 \leq X < 90$	Good
$50 \leq X < 70$	Needs Improvement
$30 \leq X < 50$	Poor
$1 \leq X < 30$	Very Poor
$X = 0$	Not Implemented

A score of 0 or "Not Implemented" is given to students who did not complete any of the practical steps specified in the assessment. This means that the student did not participate in or complete the individual tasks or experiments specified in the practical. Furthermore, to explore differences between assessment sources (e.g., self-assessment vs observation), paired t-tests or Wilcoxon signed-rank tests were conducted.

RESULTS AND DISCUSSION

This section presents the results of descriptive statistical analysis of student laboratory behavior. Descriptive statistical analysis includes the mean, standard deviation, minimum, and maximum values of student laboratory behavior as presented in Table 6.

Table 6. Descriptive statistical analysis of student laboratory behavior

	N	Min	Max	Mean	SD	Confidence Interval for Mean(95%)	
						Upper	Lower
Laboratory Behavior	99	33.28%	84.85%	62.50%	9.22%	64.3	60.6

As shown in Table 6, the average laboratory behavior of students is 62.50%, which is categorized as "Needs Improvement." The lowest recorded percentage is 33.28%, indicating that students' laboratory behavior is categorized as "Poor." Contrarily, the highest recorded percentage is 84.85%, which is classified as "Good." The standard deviation of 9.22% suggests moderate variation in student laboratory behavior. To provide a more straightforward overview, the average percentage for each laboratory behavior indicator was analyzed.

Student Laboratory Behavior on Each Indicator

The overall distribution of student laboratory behavior across indicators is presented in Figure 3 and Table 7.

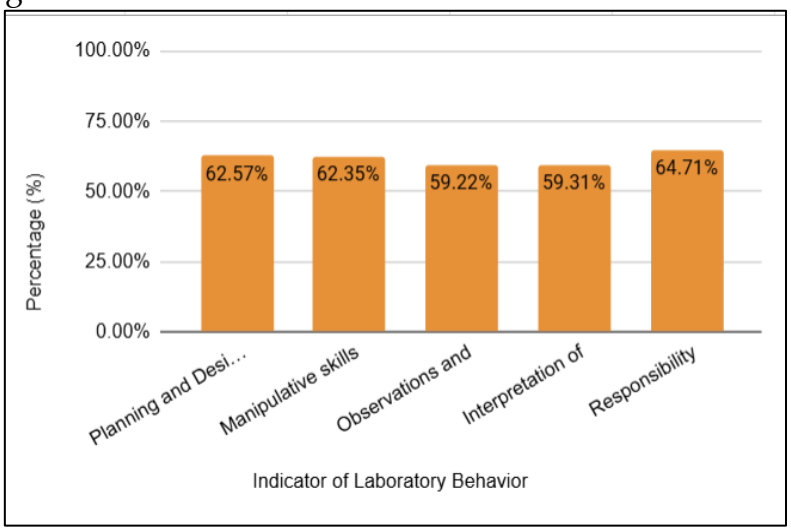


Figure 3. Percentage of student laboratory behavior for each indicator

Based on Figure 3 and Table 7, the percentage of laboratory behavior in the Planning and Design indicator is 62.57%, placing it in the “Needs Improvement” category. Manipulative Skills: Conduct of Experiment scored 62.35%, also in the “Needs Improvement” range, suggesting some difficulty in executing experiments. Observations and Recording Data (59.22%) and Interpretation of Data (59.31%) both fall under the “Poor” category, indicating significant challenges in these areas. However, Responsibility, Initiative, and Work Habits scored the highest at 64.71%, placing it in the “Needs Improvement” category, reflecting a good level of involvement but still with room for growth.

Table 7. Percentage of students’ laboratory behavior

Indicator	Percentage (%)
Planning and Design	62.57
Manipulative Skills: Conduct of Experiment	62.35
Observations and Recording Data	59.22
Interpretation of data	59.31
Responsibility, initiative, and work habits	64.71

Comparison of Student Laboratory Behavior from Four Sources of Assessment

To obtain a more comprehensive understanding of these conditions, the percentages of students' laboratory behavior across the four assessment types are compared in Figure 4 and Table 8.

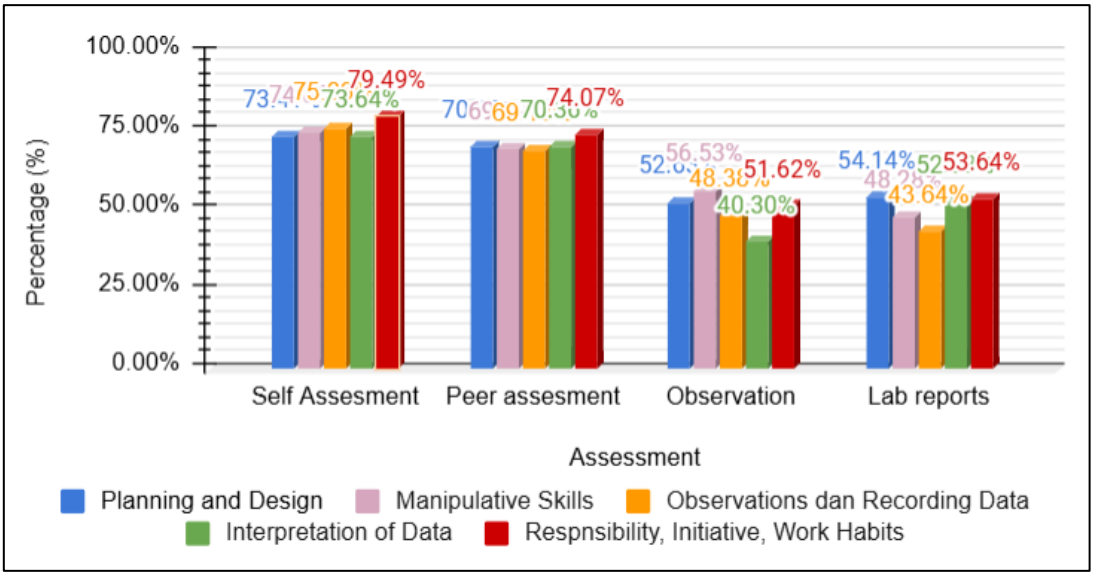


Figure 4. Differences in laboratory behavior percentages across self-assessment, peer assessment, observation, and lab reports

The data show that students tend to report higher laboratory behavior percentages in self-assessment than in other sources. For example, Planning and Design received a 73.41% in self-assessment, compared to 70.10% in peer-assessment, 52.63% in observation, and 54.14% in lab reports. Similarly, for Manipulative Skills: Conduct of Experiment, self-assessment scored 74.80%, while peer-assessment was 69.79%, observation 56.53%, and lab reports 48.28%. The highest ratings for Responsibility, Initiative, and Work Habits were in self-assessment (79.49%), followed by peer-assessment (74.07%), observation (51.62%), and lab reports (53.64%). These results suggest that students tend to give themselves higher ratings than those from peers, observers, and final reports. To assess differences in laboratory behavior between self-assessment and other assessments, a Wilcoxon test was conducted, followed by an effect size (r) measurement in Table 9.

Table 8. Differences in laboratory behavior percentages across self-assessment, peer-assessment, observation, and lab reports

Source	Planning and Design		Manipulative Skills: Conduct of Experiment		Observations and Recording Data		Interpretation of data		Responsibility, initiative, and work habits	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Self-Assessment	73.41%	0.15	74.80%	0.14	75.66%	0.12	73.64%	0.14	79.49%	0.12
Peer-assessment	70.10%	0.14	69.79%	0.14	69.18%	0.14	70.36%	0.13	74.07%	0.13
Observation	52.63%	0.19	56.53%	0.13	48.38%	0.19	40.30%	0.16	51.62%	0.22
Lab reports	54.14%	0.19	48.28%	0.16	43.64%	0.21	52.93%	0.09	53.64%	0.19

Based on Table 9, there was a significant difference in students' laboratory behavior between self-assessment and peer assessment across all indicators, but the effect size was small. In the comparison between self-assessment and observation, there is a significant difference with a large effect size ($r > 0.50$). Similarly, in the

comparison between self-assessment and lab reports, there is a significant difference with a large effect size (r > 0.50).

Table 9. Wilcoxon test and effect test (r)

Source	Planning and Design		Manipulative Skills: Conduct of Experiment		Observations and Recording Data		Interpretation of data		Responsibility, initiative, and work habits	
	Sig.	*r*	Sig.	*r*	Sig.	*r*	Sig.	*r*	Sig.	*r*
Self-Assessment x Peer-assessment	0.030	**-0.28**	0.017	-0.24	0.002	-0.30	0.031	-0.02	0.001	-0.34
Self-Assessment x Observation	0.000	-0.67	0.000	-0.67	0.000	-0.77	0.000	-0.79	0.000	-0.76
Self-Assessment x Lab reports	0.000	-0.62	0.000	-0.77	0.000	-0.82	0.000	-0.77	0.000	-0.78

Distribution of Laboratory Behavior Categories for Each Indicator

To further explore the need for development in students' laboratory behavior, this study analyzed the distribution of students across achievement categories for each indicator. The results of this analysis are presented in Figure 5 and Table 10.

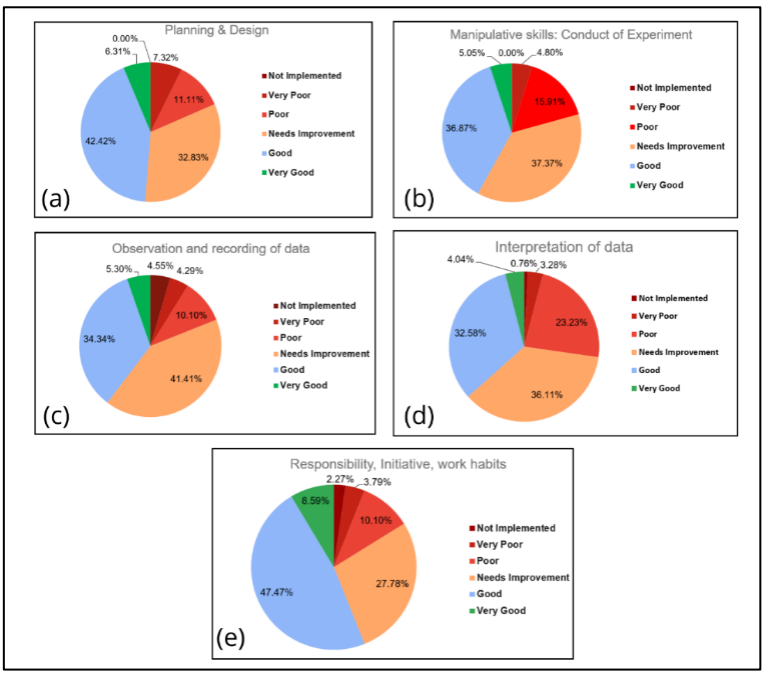


Figure 5. Distribution of laboratory behavior categories for each indicator: (a) Planning and Design, (b) Manipulative skills: Conduct of Experiment, (c) Observation and Recording Data, (d) Interpretation of Data, (e) Responsibility, Initiative, Work Habits

Based on Figure 5 and Table 10, the majority of students' laboratory behavior fell into the "Needs Improvement" category across most indicators: Planning and Design (32.83%), Manipulative Skills: Conduct of Experiment (37.37%), Observation and Recording of Data (41.41%), and Interpretation of Data (36.11%). The "Poor" and "Very

Poor" categories showed notable percentages, particularly for Manipulative Skills and Observation and Recording of Data, reflecting challenges in practical skills and data accuracy. In the Interpretation of Data indicator, 23.23% were rated as "Poor", and a small percentage (0.76%) was classified as "Not Implemented". The "Responsibility, Initiative, and Work Habits" indicator had the highest percentage in the "Good" category (47.47%), while 27.78% were rated "Needs Improvement" and 2.27% "Not Implemented".

Table 10. Distribution of laboratory behavior categories for each indicator

Category	Planning & Design	Manipulative skills: Conduct of Experiment	Observation and recording of data	Interpretation of data	Responsibility, Initiative, work habits
Not Implemented	0.00%	0.00%	4.55%	0.76%	2.27%
Very Poor	7.32%	4.80%	4.29%	3.28%	3.79%
Poor	11.11%	15.91%	10.10%	23.23%	10.10%
Needs Improvement	32.83%	37.37%	41.41%	36.11%	27.78%
Good	42.42%	36.87%	34.34%	32.58%	47.47%
Very Good	6.31%	5.05%	5.30%	4.04%	8.59%

Discussion

Student Laboratory Behavior on Each Indicator

Planning and Design is a critical phase in a laboratory practicum (Curtis et al., 2025; Ta et al., 2025). This stage involves formulating hypotheses, designing procedures, and selecting appropriate tools and materials (Hofstein & Lunetta, 2004a). Beyond that, students also need to consider factors such as time, variables to be measured, experimental controls, and data collection procedures. (Casadevall et al., 2014; Holder & Marino, 2017). Planning and Design skills can be cultivated through problem-based practical learning, which engages students in the experimental design process and helps them improve their ability to formulate hypotheses and construct appropriate experimental methodologies (Duncan, 2023; Goodey & Talgar, 2016). Based on Figure 3, the percentage of laboratory behavior in the Planning and Design indicator is 62.57%, placing it in the “Needs Improvement” category. The suboptimal laboratory behavior observed in this indicator aspect may be attributed to the limited opportunities for students to design their own practicum independently (Kerans et al., 2025). Factors such as poor time management and inadequate practicum scheduling could also contribute to the suboptimal performance in this area (Gupta et al., 2024). Additionally, reliance on a “cookbook” approach to practical work may hinder the development of students' experimental design skills (Wu, 2013).

Planning and Design play a pivotal role in determining students' success in utilizing laboratory tools and materials and in conducting practical practicum activities (Fernandes, 2024; Beerepoot et al., 2024). The results indicate that the percentage of student laboratory behavior for the Manipulative Skills: Conduct of Experiment indicator is 62.35%, placing it in the “Needs Improvement” category. This indicator encompasses students’ ability to use laboratory tools and materials appropriately, execute experimental procedures efficiently, and manipulate

experimental variables according to a predetermined plan (Hofstein & Lunetta, 2004a). Direct engagement with laboratory equipment and materials is a practical approach for strengthening students' laboratory behavior within this indicator (Trapani & Clarke, 2012). The students' limited ability in this indicator is likely due to insufficient experience with laboratory tools and materials. Supporting this view, (Mistry & Gorman, 2020) reported that inadequate training and limited exposure to laboratory equipment negatively influence students' practical skills.

Furthermore, the lowest percentage was found in the *Observation and Recording of Data* indicator (59.22%), which is categorized as "Needs Improvement". Observation and data recording are fundamental competencies in biological laboratory practice (Kohlhauf et al., 2011; Walker, 2014; Klemm et al., 2020). Accurate observation and comprehensive data recording must include all outcomes obtained during the practicum, even those that deviate from initial predictions (Lunetta et al., 1981). Data recording should be organized systematically using tables or graphical representations (Nishida et al., 2020; Love et al., 2019; Goldshaft, 2024). The suboptimal laboratory behavior of students, as measured by the Observation and Data Recording indicators, may be due to a lack of understanding of basic experimental concepts or to unsystematic procedures in Genetics practicums (Schang et al., 2023; Kranz et al., 2023). This limitation leads students to be inconsistent in their observations and data recording, both in technique and data format, which becomes a bad habit that can affect data quality (Stevenson et al., 2018; Wilcox et al., 2021). Research by Abbasi et al. (2024) also confirms that the absence of a laboratory data recording management platform can lead to inconsistent data recording among students. Errors in observation and recording data will affect the interpretation and conclusions drawn from a practical experiment (Koonchanok et al., 2023; Cox, 2024).

Similar to the Observation and Recording of Data, the Interpretation of Data indicator received a score of 59.31%, which is considered "Needs Improvement". Interpreting genetic data requires a solid understanding of genetic concepts and the ability to connect data to relevant theories (Buske & Bartholomei-Santos, 2021). Students need to go beyond relying on quantitative results to identify patterns and explain them within a broader context (Quintáns et al., 2014). The low scores in this indicator likely stem from a limited conceptual understanding of genetics as Donohue et al. (2021) noted that misinterpretation often occurs due to insufficient knowledge of genetic concepts. Additionally, insufficient data computation skills hinder students' ability to interpret genetic data accurately (Smith et al., 2015).

Meanwhile, the Responsibility, Initiative, and Work Habits indicators showed the highest percentage, 64.71% but still fell into the "Needs Improvement" category. These indicators represent students' attitudes toward responsibility, initiative, and work habits, including independence, concern for safety, and consistency in laboratory work (Lunetta et al., 1981). The structured group-based implementation of genetics practicum learning can encourage collaborative discussion and initiative among group members (Aikens & Kulacki, 2023). Emotional bonds among group members and a well-defined division of labor can strengthen each member's sense of responsibility (Mey, 2021). The results of this study indicate that students may have tried to be responsible, but their implementation was inconsistent across stages. This is likely due to students' dependence on lecturer instructions, lack of initiative in the team, and passive attitudes towards work safety procedures (Scherz, 2018; Wang et al., 2019; Lal et al., 2020). Furthermore, unclear communication and poor division of

labor among team members can contribute to suboptimal performance in the Responsibility, Initiative, and Work Habits indicators (Taylor & Beus, 2025).

Comparison of Student Laboratory Behavior from Four Sources of Assessment

Based on Figure 4, the percentages of laboratory behavior in peer assessment, observation, and lab reports are generally lower than in self-assessment. This disparity is likely due to the subjective nature of self-assessment, where students may assign themselves higher ratings (Inayah et al., 2017; Li et al., 2023). Nevertheless, self-assessment remains valuable in this study as it provides insight into students' reflective awareness of their own behavior. In contrast, peer assessment is conducted by group members, observers carry out observation, and lab report assessments are completed by lecturers, reducing the potential for subjectivity (Khan et al., 2017; Seery et al., 2017). As a result, laboratory behavior in these three assessments tends to be rated lower.

The results of the comparison test in Table 9 show significant differences between self-assessment and other assessment sources across all indicators. The effect size between self-assessment and other assessment sources is also relatively large (-0.02 to -0.082). The indicators that show the most significant overestimation in self-assessment are Observation and Recording Data, Interpretation of Data, and Responsibility, Initiative, and Work Habits. In Observation and Recording Data, the effect size between self-assessment and other assessment sources ranges from -0.30 to -0.082, indicating that students tend to give higher ratings of their ability to observe and record data, even though peer assessment, observation, and practicum reports show lower results. In Interpretation of Data, the effect size between self-assessment and other assessment sources ranges from -0.02 to -0.079, indicating that students give higher ratings to their ability to interpret data than to other assessments. On the Responsibility, Initiative, and Work Habits indicators, the effect size between self-assessment and other assessment sources ranged from -0.34 to -0.078, indicating students' subjectivity in assessing themselves in terms of responsibility in practical work. In contrast, other assessments tended to be lower.

Table 8 shows that several indicators, including Observation and Recording of Data (48.38% in observation; 43.64% in lab reports), Manipulative Skills: Conduct of Experiment (48.28% in reports), and Interpretation of Data (40.30% in observation), fall into the "Poor" category. These results indicate that students' behavior and habits in observing, recording, interpreting data, and conducting experiments remain suboptimal (Pols et al., 2021). Such deficiencies could impede the practical learning process, which should focus on data accuracy, procedural precision, and valid analysis of results (Rodgers et al., 2022). Therefore, it is essential to develop students' laboratory behavior in Genetics practicums.

Distribution of Laboratory Behavior Categories for Each Indicator

According to Figure 5, the majority of students' laboratory behavior fell into the "Needs Improvement" category. This category was evident across the indicators of *Planning and Design* (32.83%), *Manipulative Skills: Conduct of Experiment* (37.37%), *Observation and Recording of Data* (41.41%), and *Interpretation of Data* (36.11%). In the *Interpretation of Data* indicator, 23.23% of students were classified as "Poor," and 0.76% were classified as "Not Implemented". A relatively high percentage in the "Poor" and "Very Poor" categories was also shown in the *Manipulative Skills: Conduct of Experiment* and *Observation and Recording of Data*, reflecting students' weak practical skills and

limited accuracy in handling practical data. Furthermore, in the *Observation and Recording of Data*, 4.55% of students were classified as "Not Implemented," indicating that they did not perform the observation and data recording tasks. This finding not only underscores students' poor performance in observing and recording practical data but also highlights their lack of responsibility toward the assigned practical work (Powell et al., 2024).

Responsibility, initiative, and work habits received the highest percentage in the "Good" category (47.47%). However, 27.78% of students were classified as "Needs Improvement," while a small percentage (2.27%) fell into the "Not Implemented" category. These results suggest that although students demonstrate a stronger sense of responsibility compared to other aspects, their consistent work habits and initiative have not yet been fully established (An et al., 2021). The low percentages of students in the "Good" and "Very Good" categories across all laboratory behavior indicators may be attributed to a lack of structured learning, comprehensive practicum guidelines, and systematic data recording platforms (Burke & Biberman, 2017; Juergens et al., 2018 Çakiroğlu et al., 2020). Buroidah et al. (2022) Further indicates that the absence of detailed practicum guidelines and a systematic approach to practicum learning contributes to students' inadequate understanding and performance in Genetics courses.

The results of the study indicate that students' laboratory behavior in Genetics courses requires further development. To address these issues, practical learning should not focus solely on the outcomes but also emphasize the processes that shape students' skills, attitudes, and laboratory work habits (Rogers & Fraser, 2023; Anwar et al., 2024). Improvements can be achieved by implementing a more structured, science-based practical learning model that ensures students fully grasp the objectives, procedures, and stages of the experiments (Pazos et al., 2019; Davis-Berg & Rafacz, 2021). Additionally, integrating digital-based interactive learning media has been widely recommended to enhance science education (Susanto et al., 2024; Isaac & Cruz, 2024). In practical learning, the use of media such as digital practical guides, spreadsheets, or other data recording media can help improve students' laboratory behavior, especially in the indicators of Manipulative Skills: Conduct of Experiment and Observation and Recording Data. Through these various efforts, it is anticipated that students will be encouraged to engage more actively, be more meticulous, and take greater responsibility in their practical work.

This study has several limitations that should be addressed. First, it was conducted in a specific setting, focusing solely on biology students enrolled in Genetics courses, which limits its generalizability to a broader population. Second, the focus was solely on Genetics practicum activities, limiting the generalizability of the findings to other biology practicum courses. Third, the study evaluated only five indicators of laboratory behavior, without considering other skills that may influence the learning process. In addition, although laboratory assistants assessed multiple student groups working on the same practicum topics and observed no substantial group-level variation, this study did not formally use multilevel analyses to examine potential rater or group effects. Therefore, further research is recommended to assess laboratory behavior in the context of other biology practicums, broaden the range of research subjects, and employ analytical approaches that further explore rater- and group-level influences.

CONCLUSION

The results of this study confirm that all aspects of student laboratory behavior in the Genetics course still need further development. The average student laboratory behavior achievement in the Genetics course is 62.50%, placing it in the "Needs Improvement" category. The indicators with the lowest percentages are Observations and Recording Data (59.22%) and Interpretation of Data (59.31%). At the same time, the highest percentage is in Responsibility, Initiative, and Work Habits (64.71%), but they are still in the "Needs Improvement" category. Analysis of the distribution of laboratory behavior scores shows that most students are in the "Needs Improvement" to "Poor" category across most indicators. There is even a "Not Implemented" category for the Observation and Data Recording aspect. These results indicate that, overall, the laboratory behavior of pre-service biology teachers needs to be developed through various strategies and practical learning media.

RECOMMENDATION

Based on the research findings, several steps can be taken to improve students' behavior in the laboratory. First, implementing a problem-based or project-based practical learning model can enhance students' experimental and data analysis skills. Additionally, providing systematic practical guidelines and utilizing technology for data management will facilitate easier recording and reflection on their work. The use of standardized data templates is also recommended to help students observe and record practical data. Training in the use of laboratory equipment and materials is also essential for improving students' practical skills. Encouraging a sense of responsibility and initiative can be achieved through structured group work and clear role allocation. Finally, future research should include other practicum courses and additional skills to develop a more comprehensive understanding of laboratory behavior.

Acknowledgment

We want to express our gratitude to the Department of Biology at the State University of Malang for granting permission to conduct this research. We would also like to thank the biology education students who contributed to this research.

Funding Information

This research was supported by the Research and Community Service Institute (LPPM) of Malang State University with research funding as stated in decision number 24.2.780/UN32.14.1/LT/2025.

Conflict of Interest Statement

Authors state no conflict of interest.

Data Availability

Data availability is not applicable to this article because no new data were created or analyzed in this study.

Author Contributions Statement

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
Sinta Kharomah	✓	✓				✓			✓					
Hendra Susanto	✓									✓		✓		
Siti Zubaidah			✓		✓					✓	✓	✓		

C : **C**onceptualization
M : **M**ethodology
I : **I**nvestigation
R : **R**esources
Vi : **Vi**sualization
Su : **Su**pervision

So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
P : **P**roject administration
Fu : **Fu**nding acquisition

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