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Effect of Laboratory Work on the Development of Scientific Attitude among Biology Students

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Abstract: ***Science education extends beyond the transmission and acquisition of scientific facts and concepts. One of its fundamental purposes is to develop in learners the intellectual dispositions and habits of mind required to approach problems scientifically. Scientific attitude, reflected through curiosity, objectivity, critical thinking, open-mindedness, logical reasoning, intellectual honesty, scientific inquiry, and evidence-based decision-making, is therefore an important outcome of meaningful science education. Laboratory work provides a distinctive learning environment in which students can encounter scientific phenomena directly through observation, experimentation, measurement, data collection, analysis, interpretation, and communication. The present study investigated the effect of laboratory work on the development of scientific attitude among Biology students. A pre-test–post-test experimental approach was adopted. The sample consisted of 50 secondary-level Biology students selected through stratified sampling, comprising 20 students from CBSE schools, 15 from ICSE/CISCE schools, and 15 from Government schools. A researcher-developed Scientific Attitude Scale consisting of 40 items and a Laboratory Engagement Checklist were used for data collection. The Scientific Attitude Scale covered eight dimensions: curiosity, objectivity, critical thinking, open-mindedness, logical reasoning, scientific inquiry, intellectual honesty, and evidence-based decision-making. The laboratory intervention included specimen observation, microscope handling, temporary slide preparation, osmosis and transpiration investigations, photosynthesis and respiration experiments, enzyme investigations, classification activities, data interpretation, group investigations, inquiry-oriented practical exercises, and scientific laboratory report preparation. The illustrative dataset reported in the dissertation showed an increase in the mean scientific attitude score from 120.46 in the pre-test to 150.72 in the post-test, representing a mean gain of 30.26 points. Improvement was reported across all eight dimensions of scientific attitude, with scientific inquiry showing the highest illustrative gain. A positive association between laboratory engagement and scientific attitude was also reported, with an illustrative Pearson correlation coefficient of r = 0.63. The findings suggest that laboratory work can provide a meaningful context for developing scientific dispositions when practical activities are structured around questioning, investigation, evidence, interpretation, reflection, and scientific communication rather than being restricted to predetermined procedures. The study emphasizes the need to reposition Biology laboratories as environments for scientific inquiry and intellectual development.***

Keywords: Biology Education, Laboratory Work, Scientific Attitude, Inquiry-Based Learning, Practical Work, Scientific Inquiry, Secondary Students, Laboratory Engagement

1. Introduction

Education is a continuous process through which learners develop knowledge, skills, values, attitudes, and competencies necessary for effective participation in society. In contemporary educational thinking, learning is increasingly viewed as an active process in which students construct understanding through meaningful experiences rather than simply receiving information from teachers or textbooks. This shift has particular significance in science education because science is fundamentally concerned not only with what is known but also with how knowledge is generated, examined, tested, communicated, and revised.

Science education therefore has a dual responsibility. On one hand, it enables learners to understand scientific concepts, principles, theories, and processes. On the other hand, it should develop the habits of mind that enable learners to approach questions rationally and investigate phenomena systematically. A scientifically educated individual should be capable of questioning unsupported claims, observing carefully, distinguishing evidence from assumption, considering alternative explanations, interpreting information critically, and modifying conclusions when new evidence warrants such modification.

Scientific attitude represents an important component of this broader goal of science education. It refers to a collection of intellectual dispositions that influence the manner in which individuals approach scientific problems, information, evidence, and explanations. Scientific attitude includes characteristics such as curiosity, objectivity, open-mindedness, critical thinking, logical reasoning, intellectual honesty, perseverance, willingness to inquire, and respect for empirical evidence. It should therefore not be confused simply with students' liking or disliking of science as a school subject. Rather, it concerns the way students think and behave when confronted with questions and problems requiring scientific reasoning.

Biology provides particularly rich opportunities for the development of scientific attitude. As an empirical science concerned with living organisms and their interactions, Biology relies heavily on observation, experimentation, classification, measurement, field investigation, microscopy, data collection, analysis, and interpretation. Students can therefore encounter many aspects of scientific inquiry directly through Biology laboratory activities.

Laboratory work provides an important bridge between theoretical Biology and empirical investigation. Through practical activities, students may observe specimens, prepare slides, conduct experiments, record measurements, compare observations, identify patterns, formulate explanations, and evaluate predictions. These experiences can make abstract biological concepts more meaningful while simultaneously providing opportunities to practise scientific ways of thinking.

However, the presence of laboratory work alone does not automatically guarantee the development of scientific attitude. The educational value of practical work depends substantially on its design, implementation, and cognitive demands. A laboratory activity in which students simply follow predetermined instructions and reproduce an expected result may offer relatively limited opportunities for independent scientific reasoning. In contrast, inquiry-oriented practical work can encourage students to formulate questions, develop hypotheses, select or modify procedures, analyse evidence, interpret unexpected findings, and justify conclusions.

Previous research cited in the dissertation supports the importance of inquiry-oriented practical learning. Jeffery et al. (2016) reported positive changes in students' attitudes and views toward science following participation in a guided-inquiry Biology laboratory course, particularly in confidence and interest in scientific inquiry. Sandika and Fitrihidajati (2018) similarly reported that inquiry-based learning in Biology education could support the development of scientific attitude and creative thinking.

The development of scientific attitude is also likely to be cumulative rather than the result of a single educational intervention. Hansen and Birol (2014), in a four-year longitudinal study, found significant movement toward more expert-like attitudes among Biology students, although some dimensions, particularly those associated with problem solving, were less responsive. This suggests that scientific attitude is a complex construct influenced by the quality and continuity of students' educational experiences.

Recent evidence included in the dissertation further emphasizes the potential of inquiry-oriented laboratory teaching. A 2025 quasi-experimental study reported improvements in secondary students' attitudes toward Biology following guided inquiry-based laboratory instruction compared with traditional laboratory instruction. The dissertation also cites a 2026 study indicating that although both cookbook and inquiry approaches could improve immediate academic performance, inquiry-oriented instruction provided stronger evidence of deeper conceptual understanding and meaningful engagement with scientific methods. These considerations provide the basis for examining laboratory work not merely as a method for reinforcing Biology content but as a possible mechanism for developing scientific attitude among school students.

2. Conceptual Understanding of Scientific Attitude

Scientific attitude is a multidimensional construct. It reflects the learner's tendency to approach knowledge and problems through rational, evidence-oriented, and systematic processes. The present study conceptualized scientific attitude through eight dimensions:

2.1 Curiosity

Curiosity refers to the willingness to ask questions, explore biological phenomena, seek explanations, and investigate situations that may not have immediately obvious answers.

2.2 Objectivity

Objectivity refers to the ability and willingness to base conclusions on observations and evidence rather than personal preferences, preconceived ideas, or expected outcomes.

2.3 Critical Thinking

Critical thinking involves examining evidence carefully, identifying relationships, questioning assumptions, comparing explanations, and evaluating the validity of conclusions.

2.4 Open-Mindedness

Open-mindedness involves willingness to consider alternative explanations and modify one's views when evidence contradicts an earlier assumption.

2.5 Logical Reasoning

Logical reasoning enables students to connect observations and evidence systematically and reach conclusions that follow from the available information.

2.6 Scientific Inquiry

Scientific inquiry involves questioning, hypothesizing, investigating, collecting evidence, analysing findings, and constructing explanations.

2.7 Intellectual Honesty

Intellectual honesty involves reporting observations and findings accurately, including unexpected or inconvenient results, rather than altering observations to fit an expected answer.

2.8 Evidence-Based Decision-Making

This dimension refers to the willingness to use empirical evidence and reasoned analysis when evaluating alternatives and making conclusions.

The dissertation's Scientific Attitude Scale was specifically organized around these eight dimensions.

3. Laboratory Work as a Context for Scientific Learning

Laboratory work has traditionally been an important component of science education. Its purposes include developing practical skills, reinforcing theoretical understanding, demonstrating scientific principles, and introducing students to scientific methods.

In Biology education, laboratory experiences may include microscopy, specimen observation, temporary slide preparation, physiological investigations, ecological observations, classification exercises, experimentation, and interpretation of biological data.

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The educational contribution of laboratory work becomes particularly significant when students are required to make intellectual decisions during practical activities. For example, asking students to predict an experimental outcome before conducting an investigation requires them to use prior knowledge. Asking them to compare their predictions with actual observations requires evidence evaluation. Asking them to explain unexpected results requires reasoning and open-mindedness. Requiring them to report findings accurately develops intellectual honesty.

Thus, the relationship between laboratory work and scientific attitude depends not only on the amount of laboratory exposure but also on the quality of students' engagement with practical learning.

4. Inquiry-Based Laboratory Learning

Inquiry-based laboratory learning differs substantially from conventional "cookbook" practical instruction.
In a traditional practical activity, students may receive:
- A fixed procedure;
- Predetermined materials;
- A known expected result; and
- A prescribed conclusion.

In an inquiry-oriented laboratory, students are provided with greater opportunities to:
- Formulate questions;
- Make predictions;
- Develop hypotheses;
- Decide how evidence can be collected;
- Interpret observations;
- Analyse unexpected results;
- Discuss alternative explanations; and
- Construct evidence-based conclusions.

Inquiry-oriented laboratory work therefore increases the cognitive component of practical learning.

The dissertation's review of literature identifies evidence that guided inquiry in Biology laboratories can positively influence students' confidence, interest, attitudes, and views toward science.

This distinction is central to the present study. The purpose was not simply to determine whether students had access to laboratory facilities but to examine the potential effect of structured laboratory engagement on scientific attitude.

5. Research Gap

Although previous research has established connections between inquiry-based learning, laboratory experiences, and attitudes toward science, several areas require further investigation.

First, a considerable proportion of research has focused on undergraduate students or broad science-learning contexts rather than secondary Biology students.

Second, research frequently examines general attitudes toward Biology or science rather than specific scientific dispositions such as objectivity, intellectual honesty, scientific inquiry, and evidence-based decision-making.

Third, laboratory work is sometimes treated as a single instructional category without sufficiently distinguishing routine procedural practical work from inquiry-oriented laboratory experiences.

The present study addresses these concerns by examining laboratory work in relation to the development of scientific attitude among secondary-level Biology students.

6. Objectives of the Study

The study was conducted with the following objectives:
- To study the level of scientific attitude among secondary school Biology students.
- To study the effect of laboratory work on the development of scientific attitude among secondary school Biology students.
- To compare the scientific attitude of students engaged in regular laboratory activities with those having minimal practical exposure.

7. Hypotheses

The following null hypotheses were formulated:
H_{01}: There is no significant difference between the pre-test and post-test scientific attitude scores of Biology students.
H_{02}: Laboratory work has no significant effect on the development of scientific attitude among Biology students.
H_{03}: There is no significant relationship between laboratory engagement and scientific attitude among Biology students.

8. Research Methodology

8.1 Research Design

The study employed a pre-test–post-test experimental approach. A pre-test was administered before the laboratory intervention, students participated in structured laboratory experiences, and a post-test was subsequently administered to examine changes in scientific attitude.

The design was appropriate because the primary purpose of the study was to examine change in a measurable educational outcome following exposure to a planned laboratory programme.

8.2 Population

The population comprised secondary-level Biology students studying in selected CBSE, ICSE/CISCE, and Government schools in the selected study area.

8.3 Sample and Sampling Procedure

A sample of 50 students was selected through stratified sampling.

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Table 1: Distribution of Sample

School Type	Number	Percentage
CBSE	20	40%
ICSE/CISCE	15	30%
Government	15	30%
Total	**50**	**100%**

The distribution ensured representation from three different school contexts.

9. Variables of the Study

Independent Variable

Laboratory Work
The laboratory programme consisted of structured Biology activities involving observation, experimentation, data recording, analysis, inquiry, discussion, and reflection.
Dependent Variable

Scientific Attitude
Scientific attitude was examined through the following eight dimensions:
- Curiosity
- Objectivity
- Critical thinking
- Open-mindedness
- Logical reasoning
- Scientific inquiry
- Intellectual honesty
- Evidence-based decision-making

10. Tools for Data Collection

10.1 Scientific Attitude Scale

A researcher-developed Scientific Attitude Scale containing 40 items was used to assess students' scientific attitude.

Each item was scored using a five-point Likert scale ranging from **Strongly Agree to Strongly Disagree**. The maximum possible score was 200. Five items were assigned to each of the eight dimensions.

The scale therefore provided a multidimensional measure of scientific attitude rather than treating the construct as a single undifferentiated characteristic.

10.2 Laboratory Engagement Checklist

A Laboratory Engagement Checklist was used to document students' participation during practical activities.

The checklist included indicators related to:
- Observation;
- Questioning;
- Hypothesis Formation;
- Experimentation;
- Data Recording;
- Analysis;
- Collaboration; And
- Reflection.

This tool complemented the Scientific Attitude Scale by providing information about students' observable engagement during laboratory experiences.

11. Laboratory Intervention Programme

The laboratory programme was designed to provide students with opportunities for active participation in biological investigation.

The activities included:
- Observation of plant and animal specimens
- Microscope handling
- Temporary slide preparation
- Osmosis investigations
- Transpiration activities
- Photosynthesis-related investigations
- Respiration experiments
- Enzyme activity investigations
- Classification and identification
- Data recording and interpretation
- Group-based investigations
- Inquiry-oriented practical exercises
- Preparation of scientific laboratory reports

During these activities, students were encouraged to:
- observe carefully;
- ask scientific questions;
- formulate hypotheses;
- record observations accurately;
- interpret experimental data;
- draw evidence-based conclusions;
- discuss findings collaboratively; and
- reflect on experimental outcomes.

The intervention therefore incorporated both practical skills and cognitive processes associated with scientific inquiry.

12. Data Collection Procedure

The researcher first obtained the necessary institutional permission and informed students about the purpose and procedure of the study.

The Scientific Attitude Scale was administered as a pre-test. Students then participated in the planned laboratory programme.

Their engagement was documented through the Laboratory Engagement Checklist and teacher/researcher observations.

After completion of the laboratory intervention, the Scientific Attitude Scale was administered again as a post-test.

The collected data were coded, organized, and prepared for statistical analysis.

13. Statistical Analysis

The dissertation proposed the use of descriptive and inferential statistical techniques.

Descriptive statistics included:

- Mean
- Standard deviation
- Percentage
- Mean gain

A paired-sample comparison was used to examine pre-test and post-test differences. Pearson's correlation coefficient was used to examine the relationship between laboratory engagement and scientific attitude.

14. Results and Interpretation

14.1 Overall Scientific Attitude

The illustrative dataset reported in the dissertation showed the following results:

Table 2: Overall Pre-Test and Post-Test Scientific Attitude Scores

Measure	Pre-Test	Post-Test
N	50	50
Mean	120.46	150.72
Standard Deviation	10.26	—
Maximum Score	200	200
Percentage of Maximum	60.23%	75.36%
Mean Gain	—	30.26

The mean scientific attitude score increased from **120.46** in the pre-test to **150.72** in the post-test. The corresponding mean gain was **30.26 points**. Relative to the pre-test mean, the reported gain represents approximately **25.12%**.

These figures are explicitly described in the dissertation as an **illustrative dataset** and should therefore be replaced with the verified statistical output if the paper is being submitted as an empirical journal article.

The direction of change nevertheless indicates the intended pattern of improvement following laboratory participation.

15. Dimension-Wise Analysis of Scientific Attitude

Table 3: Dimension-Wise Mean Scores

Dimension	Pre-Test Mean	Post-Test Mean	Gain
Curiosity	15.5	20	4.5
Objectivity	15.8	20.1	4.3
Critical Thinking	15.1	19.6	4.5
Open-Mindedness	15.6	19.8	4.2
Logical Reasoning	15.2	19.9	4.7
Scientific Inquiry	14.9	19.7	4.8
Intellectual Honesty	16	20.5	4.5
Evidence-Based Decision-Making	15.3	19.9	4.6

The illustrative results indicate improvement across all eight dimensions.

The highest reported gain was in **scientific inquiry**, followed by **logical reasoning** and **evidence-based decision-making**. This pattern is theoretically meaningful because these dimensions are directly exercised when students are required to formulate questions, investigate phenomena, interpret data, and draw conclusions.

The improvement in curiosity suggests that laboratory experiences may create situations that encourage students to explore biological phenomena beyond the immediate textbook explanation. Similarly, gains in objectivity and intellectual honesty are consistent with activities requiring students to record actual observations rather than simply reproduce expected results.

The improvement in critical thinking and logical reasoning may be associated with the requirement to interpret experimental findings and explain relationships between observations and biological concepts.

Again, these numerical values are identified by the dissertation as illustrative and should be verified before publication.

16. School-Wise Analysis

Table 4: School-Wise Pre-Test and Post-Test Means

School Type	N	Pre-Test Mean	Post-Test Mean	Gain
CBSE	20	121	151.8	30.8
ICSE/CISCE	15	122	152.27	30.27
Government	15	118.2	147.73	29.53

The illustrative results show improvement across all three school categories.

The gain was highest among the CBSE group, followed closely by the ICSE/CISCE group, while the Government-school group also demonstrated a substantial positive change. The relatively similar gains across the groups suggest that structured laboratory engagement may have potential across different school contexts.

However, no causal comparison between school categories should be made without appropriate inferential statistical testing. The dissertation itself presents these figures as illustrative.

17. Relationship Between Laboratory Engagement and Scientific Attitude

The dissertation reported an illustrative Pearson correlation coefficient of:
r = 0.63

This represents a positive association between laboratory engagement and scientific attitude. In descriptive terms, students demonstrating greater engagement in laboratory activities tended to have higher scientific attitude scores.

The result is theoretically consistent with the proposition that active participation in observation, questioning, experimentation, data recording, analysis, collaboration, and reflection provides opportunities for students to practise scientific dispositions.

Nevertheless, correlation alone does not establish causation. The reported relationship should therefore be interpreted as an association rather than independent proof that laboratory engagement caused the differences in scientific attitude.

18. Discussion

The findings of the study provide support for the view that laboratory work can serve as an important context for developing scientific attitude among Biology students.

The increase in scientific attitude following laboratory participation is consistent with the findings of Jeffery et al. (2016), who reported positive changes in students' attitudes and views toward science following participation in a guided-inquiry Biology laboratory course. Their work particularly emphasized confidence and interest in scientific inquiry.

The present findings are also consistent with Sandika and Fitrihidajati (2018), whose research highlighted the role of inquiry-based Biology learning in developing scientific attitude and creative thinking.

The findings can further be interpreted in relation to Hansen and Birol (2014), whose longitudinal research indicated that students' attitudes toward Biology can develop over extended educational experiences. Their findings also demonstrate that not every dimension of scientific attitude develops at the same rate, highlighting the complexity of the construct.

The dissertation also cites Chengere et al. (2025), who reported that guided inquiry-based laboratory instruction improved secondary students' attitudes toward Biology compared with traditional laboratory instruction.

Taken together, these findings suggest that the educational effectiveness of laboratory work depends substantially on its pedagogical structure.

A laboratory activity can be highly practical but relatively low in cognitive demand if students merely follow a predetermined procedure. Conversely, a laboratory activity can become a powerful environment for scientific thinking when students are asked to predict, investigate, observe, analyse, explain, communicate, and reflect.

This distinction has important implications for Biology teachers. Consider, for example, an experiment involving osmosis. In a procedural approach, students may simply follow instructions and record the expected observation. In an inquiry-oriented approach, students might first predict what will happen under different conditions, justify their predictions, conduct the investigation, compare actual observations with predictions, identify possible sources of variation, and explain the findings using the concept of water potential or concentration gradient. The second approach creates substantially greater opportunities for scientific reasoning.

The same principle applies to microscopy. Students can simply learn to operate a microscope and identify a specimen, or they can be asked to compare specimens, formulate questions about structural differences, record observations systematically, and explain how observed structures relate to biological functions.

Consequently, the laboratory should be viewed as a cognitive as well as a practical learning environment.

The reported improvement in scientific inquiry is particularly significant because inquiry represents the process through which many other dimensions of scientific attitude are exercised. Asking a question requires curiosity; formulating a hypothesis requires reasoning; collecting evidence requires objectivity; interpreting unexpected findings requires open-mindedness; reporting observations accurately requires intellectual honesty; and drawing conclusions from data requires evidence-based decision-making.

Thus, laboratory work can potentially create an integrated environment in which multiple dimensions of scientific attitude develop simultaneously.

19. Major Findings

The major findings reported in the dissertation can be summarized as follows:
- Students demonstrated a moderate initial level of scientific attitude.
- The illustrative mean scientific attitude score increased from 120.46 to 150.72 following laboratory participation.
- The illustrative mean gain was 30.26 points.
- Improvement was observed across all eight dimensions of scientific attitude.
- Scientific inquiry showed the highest illustrative gain.
- Logical reasoning and evidence-based decision-making also demonstrated considerable improvement.
- Students became more actively involved in observation, experimentation, data recording, and interpretation.
- Laboratory engagement demonstrated a positive relationship with scientific attitude.
- Improvement was observed among students from CBSE, ICSE/CISCE, and Government schools.
- The overall pattern supports the potential value of inquiry-oriented laboratory work in Biology education.

20. Educational Implications

20.1 Implications for Biology Teachers

Biology teachers should use laboratory periods as opportunities for scientific thinking rather than treating them merely as sessions for completing practical records.

Teachers can begin laboratory activities by asking students:
- What do you think will happen?
- Why do you think it will happen?
- What evidence would support your prediction?
- What could cause a different result?
- How reliable are your observations?
- What conclusion can reasonably be drawn from the evidence?

Such questioning can increase the cognitive value of practical work.

20.2 Implications for Students

Students should be encouraged to take an active role in laboratory investigations. They should be given opportunities to formulate questions, make predictions, test explanations, collect evidence, analyse results, communicate findings, and reflect on experimental outcomes.

The objective should be to develop students who can think scientifically rather than students who can merely reproduce laboratory procedures.

20.3 Implications for Curriculum Planners

Biology curricula should provide sufficient time and flexibility for inquiry-oriented laboratory activities. Practical work should be integrated with theoretical concepts rather than being treated as an isolated component of the curriculum.

20.4 Implications for Schools

Schools should provide adequate laboratory infrastructure, appropriate biological materials, functioning equipment, safety provisions, and professional-development opportunities for teachers.

20.5 Implications for Assessment

Assessment should move beyond evaluating whether students obtained the expected practical result. It should also assess:
- Observation;
- Questioning;
- Reasoning;
- Experimental design;
- Interpretation;
- Evidence evaluation;
- Scientific communication; and
- Reflection.

These implications are consistent with the recommendations presented in the dissertation.

21. Limitations of the Study

The study has several limitations.

First, the sample consisted of only 50 students. Consequently, the findings cannot automatically be generalized to all secondary-level Biology students.

Second, the study was restricted to selected CBSE, ICSE/CISCE, and Government schools within the target study area. Differences in regional context, school resources, curriculum implementation, and teacher practices may produce different outcomes elsewhere.

Third, scientific attitude was measured partly through a self-report scale. Students' responses may therefore be influenced by social desirability, self-perception, or their understanding of the questionnaire items.

Fourth, several factors other than laboratory work may influence scientific attitude. These include teacher characteristics, previous laboratory experience, availability of laboratory infrastructure, academic achievement, peer interactions, family environment, and student motivation.

Finally, the duration of the intervention may not have been sufficient to determine whether changes in scientific attitude are maintained over an extended period.

22. Suggestions for Further Research

Future investigations may extend the present study in several directions.
1) Conduct similar studies using larger and more diverse samples.
2) Include schools from different geographical regions.
3) Compare students from CBSE, CISCE, and State Board systems.
4) Compare traditional laboratory instruction with inquiry-based laboratory instruction using a controlled experimental design.
5) Conduct longitudinal studies to examine the stability of changes in scientific attitude.
6) Examine the effect of laboratory work on scientific reasoning and problem-solving ability.
7) Investigate the role of teacher competence and professional development in laboratory-based learning.
8) Compare physical laboratory experiences with virtual and digital laboratory experiences.
9) Use mixed-method approaches involving questionnaires, interviews, observations, reflective journals, and student laboratory reports.
10) Identify which specific Biology laboratory activities contribute most strongly to different dimensions of scientific attitude.

23. Conclusion

The present study examined the effect of laboratory work on the development of scientific attitude among Biology students. The research was based on the premise that science education should develop not only conceptual understanding but also the intellectual dispositions required for scientific thinking.

The laboratory provides a unique environment for this purpose. It enables students to encounter biological phenomena directly and engage in observation, questioning, experimentation, evidence collection, analysis, interpretation, discussion, and conclusion formation. Through these experiences, students can encounter science as a process rather than merely as a body of established facts.

The findings reported in the dissertation indicate an overall positive pattern of development in scientific attitude following structured laboratory participation. Improvement was reported across curiosity, objectivity, critical thinking, open-mindedness, logical reasoning, scientific inquiry, intellectual honesty, and evidence-based decision-making. The reported positive association between laboratory engagement and scientific attitude further highlights the importance of active student participation in practical learning.

The most important implication of the study is that **laboratory work should not be reduced to routine procedural exercises**. Practical activities have greater educational potential when students are intellectually involved in determining what to investigate, predicting outcomes, collecting and interpreting evidence, evaluating explanations, and communicating conclusions.

A Biology laboratory should therefore function as a space for **questioning, investigating, reasoning, evidence evaluation, reflection, and scientific communication**.

In this sense, laboratory work contributes to a broader educational purpose: helping students develop the capacity to think scientifically. Such a capacity is valuable not only for success in Biology but also for scientific literacy, rational decision-making, problem-solving, and responsible participation in a society increasingly influenced by scientific and technological developments.

The study therefore supports the integration of carefully planned, inquiry-oriented laboratory experiences into Biology education. When practical work is connected meaningfully with theory and accompanied by questioning, reflection, and evidence-based reasoning, the laboratory can become a powerful pedagogical environment for developing scientific attitude among students.

Author Declaration

Conflict of Interest: The author declares that there is no conflict of interest associated with this study.

Funding: No external funding was reported for this study.

Ethical Consideration: The study involved school students and was conducted for educational research purposes. Appropriate institutional permissions and participant-related ethical procedures should be reported in accordance with the requirements of the institution and target journal.

Data Availability: The underlying dissertation dataset may be made available subject to institutional requirements and protection of participant privacy.

Important Note for Journal Submission

The dissertation itself identifies the numerical dataset in the Results section as **illustrative**. Therefore, before submitting this paper to a peer-reviewed journal, the numerical tables should be replaced or confirmed using the **actual raw-data analysis** from the dissertation. In particular, the final manuscript should contain verified:

- Pre-test mean and standard deviation;
- Post-test mean and standard deviation;
- Mean difference/gain;
- Paired-*t* value;
- Degrees of freedom;
- *p* value;
- Effect size, preferably Cohen's *d*;
- Correlation coefficient and significance level; and
- Reliability/validity statistics for the Scientific Attitude Scale.

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