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# EFFECT OF LABORATORY PRACTICAL ACTIVITIES ON STUDENTS' ACADEMIC PERFORMANCE IN BIOLOGY: A CASE OF GHANAIAN SENIOR HIGH SCHOOLS

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***Abstract:*** *The study examines the impact of laboratory experiments on the academic performance of biology students in some selected senior high schools in the Bono Region of Ghana. The key objectives were to establish the key factors influencing the effectiveness of such experiments, determine their impact on students' performance, and examine how exposure to the real world enhances scientific attitudes. The study involved 250 students from SHS1 and SHS2. The data were collected through a structured questionnaire, and composite reliability measures were used to test the instrument's reliability. The descriptive and inferential statistical analyses were performed using IBM SPSS (version 27), whereas Smart PLS (version 4) was used to determine structural relationships between the variables. The findings indicated a high positive correlation between laboratory practical activities and the academic performance of students. Moreover, the data indicated that participation in these activities enhanced the development of students' scientific attitude to a great extent. The findings conform to those of previous studies, which support the contribution of practical activities in academic improvement and the formation of scientific attitudes. Based on these findings, this study recommends reinforcing laboratory facilities, increasing the number of practical classes, and continually training teachers so that the overall educational value gained from practical exercise in biology may be optimized.*

***Keywords:*** *Academic performance; biology; laboratory; practical; senior high school.*

## INTRODUCTION

Biology forms a critical component in shaping the social and economic development of a nation (Bello et al., 2020; Gazieva et al., 2023). The United States and other developed nations are considered to be highly developed to some extent due to the fact that they possess a strong scientific pillar, and one of them is biology. The world's education ministries thus emphasize science at a national policy level, and biology is encompassed (Ramirez et al., 2016). This focus is essential to the understanding of the richness of the physical world, learning about different species and habits of life, and encouraging inquiry, knowledge, and democratic values. With the speeding pace of progress in biology, there is an increased need to build new abilities, attitudes, and values in teaching the subject in secondary schools, particularly those that have to oversee practical biology work.

As Okeke (2009) argues, the central expectation for developing nations that wish to achieve rapid economic growth and enhanced living standards lies in efforts to enhance secondary school education and motivate students through the advancement of scientific development. In order to meet the growing demand for pharmacology and agro-biology services, there is a necessity to train qualified teachers who will accelerate student learning and promote specialization in these fields.

Laboratory practical exercises form the core of the benefits of theoretical knowledge as practice, and mastery of biological principles by students. By enabling students to get direct hands-on experience with material and processes, such practical exercises enhance interest and passion for the topic. By observing and studying phenomena happening in the real world, students make connections between theory and practice, thus validating their comprehension of biological ideas. Laboratory exercises also train students to use scientific equipment, collect and analyze data, interpret findings, and improve their critical thinking and problem-solving abilities. Furthermore, when students collaborate on experiment design and conduct, laboratory procedures foster teamwork and effective communication—skills that are critical for success in academic and professional settings.

A number of studies have examined the relationship between the academic success of students studying biology and their participation in laboratory practical's. For example, Lunetta, Holstein, and Clough (2013) observed that students engaged in laboratory activities had greater conceptual understanding and content retention compared to students who had been exposed to traditional classroom instruction alone. Laboratory exercises enable students to visualize abstract ideas and connect theoretical knowledge with practical application,

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thereby reinforcing comprehension and recollection. Russell and Weaver (2011) further found that laboratory practical exercises increase student motivation and interest in biology that can lead to better overall academic performance. When students are directly involved in lab experiments, they are more likely to be interested in the subject matter and more inclined to succeed academically.

Within the Ghanaian educational discourse, the contribution of laboratory practical activities towards the academic performance of Sunyani Senior High and Twene-Amanfo Senior High/Technical School biology students in the Sunyani East Municipality is of paramount importance. The issue is not in isolation; rather, it is within a broader context emphasizing the importance of biology education in Ghanaian senior high schools. This topic's intricacy is also brought forth by dimensions such as the pivotal role of biological classification in determining academic success. Scholars like Akotuko, Pappoe, Azure, and Ameyaw (2021) and Kanamitie, Nketsiah, and Asenso (2023) provide an elaborate explanation of these entwining factors, pointing to the issue's complex nature.

Some national and foreign research works continually indicate that lab activities greatly affect the academic achievement of biology students. Research conducted in various learning environments, both in the United States and in Australia, reveals that integrative approaches—such as the utilization of mobile augmented reality (MAR) in learning biology—consequently enhance students' academic performance, as well as positively affecting their attitudes regarding the use of digital technology (Cakir, Kokoc, Arsian, &Horzum, 2020). Further reinforcement from the research works of Byukusenge, Nsanganwimana, and Tarmo (2022) and Abidoye and Omotayo (2023) indicates the major role played by laboratory practicals in understanding, retention, and learning of crucial intellectual skills of learners, including practical knowledge and critical thinking.

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Ghana's education system presents country-specific illustrations of this challenge. For example, studies demonstrate that teacher training programs significantly enhance the academic achievement of senior high school students (Osei-Owusu, 2022). Moreover, studies on etiology, impact, and adaptation strategies of scientific anxiety among senior high school students in Ghana (Alimehmeti, Fia, & Paletta, 2024) illustrate the seriousness of the situation and its immediate impact on scholarship. Such findings, coupled with evidence of involvement by communities, schools, and parents in student scholarship (Flores & Perez, 2022), give concrete examples of the relevance of the problem within the Ghanaian context.

In Ghana's domestic educational setting—Sunyani Senior High and Twene-Amanfo Senior High/Technical School within Sunyani East Municipality—the issue poses distinct challenges and opportunities. Empirical evidence crafted to fit the Ghanaian educational setting is needed to effectively address these particular dynamics (Tordzro, Asamoah, & Ofori, 2021; Osei-Owusu, 2022). Because of the particular pedagogical and sociocultural dynamics at work, careful analysis of laboratory practical activities' influence on biology students' performance is in order.

This research was motivated by lacunae in literature that have been identified and by the need to make interventions in the knowledge of laboratory practical activity as a phenomenon and the influence on the academic performance of biology students at the research site. Through the filling of these lacunae in studies, the research has the potential to make interventions in reforms in teaching methods and education policy within Ghanaian senior high schools. Its significance is that it can boost theoretical and empirical understanding of efficient biology instruction. Thus, the primary objective of this research is to examine how laboratory practical exercises affect the academic performance of biology students at Sunyani Senior

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High and Twene-Amanfo Senior High/Technical School within the Sunyani East Municipality.

The following research questions directed the study:

1. What are the principal factors influencing the effectiveness of laboratory practical activities in enhancing the teaching of biology?
2. Do practical activities have a positive impact on students' performance in biology?
3. Will exposing students to laboratory activities help them develop scientific attitudes toward biology learning?

**METHODOLOGY**

This chapter presents how the study was conducted, with the justification for the approach and tools used. An explanatory research approach design was used in the investigation. This is because the study's main objective was to examine a particular situation or issue and offer a rationale for the patterns of correlations between variables that were already present (Mantula et al., 2024). The study population was all senior high school science students in the Sunyani East Municipality. However, the sample population involved second- and third-year science students in Sunyani Senior High and Twene-Amanfo Senior High/Technical School.These students were chosen because they had studied the majority of the senior high school biology syllabus and had written a number of examinations, which would enable the researchers to track their performance academically. Formulas for determining sample sizes that have been developed were employed in calculating the number of participants. Specifically, the formula proposed by Miller and Brewer (2003), $n = N / [1 + N(e^2)]$, was employed, where n is the sample size, N is the population (420), and e is the error term (0.05). Based on these parameters, the calculated sample size was 204. To compensate for potential attrition and

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missing data, the sample size was finalized at 250. Simple random sampling with replacement was then employed to select participants. Data were gathered using a structured questionnaire on a Likert-type scale of 1 (Strongly Disagree) to 5 (Strongly Agree).Prior to carrying out full-scale data collection, the questionnaire items were pilot-tested with three senior high schools with similar profiles to the selected schools for the purpose of establishing validity and reliability. Data analysis was also carried out using IBM SPSS (version 26) and SmartPLS (version 4), and partial least squares structural equation modeling (PLS-SEM) was the analytical tool employed to compute the inferential statistics required to address the research questions. PLS-SEM was particularly used to analyze the three research questions.

## RESULTS AND DISCUSSION

**Research Question 1: What are the principal factors influencing the effectiveness of laboratory practical activities in enhancing the teaching of biology?**

Table 1 provided descriptive statistics of the most important variables that affect the degree to which laboratory practical exercises contribute to biology teaching. On a number of measures, relatively high mean scores suggested that the respondents showed a positive leaning towards teaching approaches in the lab.A strong and stable consensus among students was reflected in the high mean scores of more than 4.4 for "I believe a student-centered learning environment enhances my critical thinking ability" and "Participating in formulating hypotheses and conducting experiments makes me more engaged in learning," with low standard deviations (0.66 and 0.68, respectively). This mirrors students' preference for participation and collaboration as opposed to old-fashioned instructor-oriented methods. Motivation of the student and teacher greatly contribute to student motivation. On the other hand, mean ratings of statements about the behaviors and support of instructors, i.e., "My

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motivation to learn is enhanced when instructors are enthusiastic and supportive" and "I am more active in lab activities when instructors create a student-centered learning environment," were higher with larger standard deviations (3.22 and 3.28, respectively).This disparity reflects students' varying experiences with and perceptions of the effectiveness of their teachers.

Facility provision in biology labs was another factor to be taken seriously. Response scores such as "Having good biology lab facility equipment enhances my learning experience" (3.90) and "Lab facility well-equipment enables me opportunities to gain biology laboratory skills" (4.03) depict that well-equipment lab facilities improve the learning experience from the respondents' perspective. But with the same mean scores and standard deviations of 1.0 to 1.2, there was also apprehension that lack of resources would prevent effective learning.

Efficient teaching of biology was seen to include lab assessments and feedback. On the basis of mean scores greater than 4.0 for items dealing with these variables, the respondents believed that frequent feedback and direct evaluations for lab skills were essential. A mean score of 4.26 for "Assessments centered on practical lab skills are as critical as theoretical knowledge assessments" emphasizing the need for practical competence over theoretical understanding highlighted the need for practical skills assessments.

Respondents also concurred that the listed traits are essential for laboratory practical activities' efficacy, as indicated by the total mean score of 4.02 with a standard deviation of 1.03. The comparatively low standard deviation suggests that respondents largely concurred with these areas.

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Table 1: Descriptive Statistics of Key Factors that Influence the Effectiveness of Laboratory Practical Activities

| Indicators | N | Mean | Std. Dev. |
|---|---|---|---|
| I feel that inquiry-based learning in biology labs helps me understand complex concepts better. | 250 | 4.37 | 0.97 |
| I prefer collaborative group work in lab sessions over individual work. | 250 | 4.54 | 0.68 |
| Participating in formulating hypotheses and conducting experiments makes me more engaged in learning. | 250 | 4.47 | 0.68 |
| I believe that a student-centered learning environment enhances my critical thinking skills. | 250 | 4.57 | 0.66 |
| I find that active exploration in biology labs deepens my interest in the subject. | 250 | 4.52 | 0.72 |
| The shift from traditional teaching to inquiry-based learning in biology labs has improved my problem-solving skills. | 250 | 4.52 | 0.77 |
| My motivation to learn increases when instructors are enthusiastic and supportive. | 250 | 3.22 | 1.45 |
| I am more engaged in lab activities when instructors facilitate a student-centered learning environment. | 250 | 3.28 | 1.41 |
| I feel more confident in labs when instructors are approachable and willing to answer questions. | 250 | 3.96 | 1.13 |
| Instructor behaviors significantly impact my interest in biology lab sessions. | 250 | 3.30 | 1.44 |
| I prefer labs where instructors encourage inquiry and exploration. | 250 | 3.75 | 1.22 |
| My engagement in biology labs is higher when there are interactive elements and hands-on activities. | 250 | 3.76 | 1.18 |
| Having access to well-equipped biology labs enhances my learning experience. | 250 | 3.90 | 1.05 |
| I believe the quality of lab equipment significantly impacts my understanding of biology. | 250 | 4.04 | 1.18 |
| Resource limitations in labs hinder my ability to effectively learn and conduct experiments. | 250 | 4.00 | 1.17 |
| Well-resourced labs provide me with opportunities to develop practical skills in biology. | 250 | 4.03 | 1.12 |
| The lack of essential resources in a lab leads to a superficial understanding of biological concepts. | 250 | 3.98 | 1.12 |
| I think that creative alternatives like DIY experiments are effective in resource-limited settings. | 250 | 3.96 | 1.01 |
| I find that specialized assessments for laboratory skills are necessary for effective biology education. | 250 | 3.98 | 1.02 |
| Regular feedback on my lab work helps me improve my practical skills. | 250 | 4.01 | 1.03 |
| I feel more confident in labs when I know my skills will be appropriately assessed. | 250 | 3.83 | 1.08 |
| The development of inquiry-based laboratory manuals has | 250 | 3.91 | 1.02 |

| | | | |
|---|---|---|---|
| enhanced my lab practices. | | | |
| Assessments focused on practical lab skills are as important as theoretical knowledge evaluations. | 250 | 4.26 | 0.86 |
| Continuous refinement of assessments and lab manuals based on feedback is crucial for effective learning. | 250 | 4.26 | 0.69 |
| **Overall Mean/Std. Dev.** | | **4.02** | **1.03** |

To identify the main factors that determine the effectiveness of practical activities in biology teaching, exploratory factor analysis was done. As indicated by Kaiser-Meyer-Olkin (KMO) measure and Bartlett's Test of Sphericity, exploratory factor analysis (EFA) that aimed to determine contributing factors to effectiveness of practical activities in biology instruction produced meaningful outcomes.

The measure of KMO, which verifies the quality to which the sample was selected to analyze, amounted to 0.817. As this is much higher than the commonly regarded cut off point of 0.6, factor analysis was performed on a sufficiently adequate and proper sample size. A KMO measurement in this range informs us that the data set has essential underlying structures, and hence the data set is apt to detect variables that determine the success of biology lab exercises. A valid investigation of the component structure is facilitated through the high KMO measurement, which signifies the existence of sufficient correlations among the variables.

An estimated chi-square value of 2511.102 based on 136 degrees of freedom and a Sig. value of 0.000 was computed using the Bartlett's Test of Sphericity. The test compares the hypothesis that the correlation matrix is an identity matrix, which would mean that the variables are unrelated and inadequate for structure detection. This null hypothesis is also rejected by the strong chi-square value and p-value less than 0.05, signifying that the variables are well-correlated and thus appropriate for factor analysis. This result of Bartlett's test also provides additional confirmation that the dataset is valid in identifying the variables

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with a meaningful influence on the extent to which biology education laboratory practical activities are effective.

Table 2: KMO and Bartlett's Test

| | | |
|---|---|---|
| Kaiser-Meyer-Olkin Measure of Sampling Adequacy. | | 0.817 |
| Bartlett's Test of Sphericity | Approx. Chi-Square | 2511.102 |
| | Df | 136.000 |
| | Sig. | 0.000 |

There were revealing outcomes of the Principal Component Analysis (PCA) utilized in analyzing the major variables determining the degree to which laboratory practical exercises contribute to the teaching of biology. As unveiled using the PCA, the study determined four principal components significantly accounting for the variance in the data set by analyzing the initial Eigenvalues, Extraction Sums of Squared Loadings, and Rotation Sums of Squared Loadings.

With an initial Eigenvalue of 5.6, the first component was the most impactful, explaining 33.2% of the variance. The high percentage recognizes a core area of influence on the laboratory practical activities' effectiveness and highlights the component's pivotal position within the data. The significance of the component was verified by the Extraction Sums of Squared Loadings, which recognized its cumulative influence across the research by sustaining its 33.2% contribution to the variance.

The second factor, which was second in ranking, explained 19.6% of the variance with an initial Eigenvalue of 3.3. Cumulative variance explained was 52.8% when this result was added to the first factor, revealing another important dimension in explaining the dynamics of laboratory practical sessions.The usefulness of this factor in the analysis was indicated by the stability of the percentage of variation explained before and after extraction.

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Cumulative variance explained increased to 62.9% as the third component of an initial Eigenvalue of 1.7 contributed 10.2% of the variance. The complexity in the variables that control the success of laboratory practicals in the learning of biology was more explained in this portion. Likewise, with an initial eigenvalue of 1.1, the fourth component added 6.4% to the variance, making a total of 69.3% of the variance explained by the four components collectively.

The partition of variance among these components was re-distributed to some extent for more meaningful outcomes after rotation, which attempts to clarify and simplify the factor structure. The individual contributions of the components to the variance were re-distributed after rotation, with the first component accounting for 22.0% and the remaining components accounting for 18.1%, 15.5%, and 13.7% of the variance, respectively. A cumulative variance explanation of 69.3% was obtained using this rotation method, showing the factors' wide-ranging impact on the dataset.

Table 3: Variance Explained

| Component | Initial Eigenvalues | | | Extraction Sums of Squared Loadings | | | Rotation Sums of Squared Loadings | | |
|---|---|---|---|---|---|---|---|---|---|
| | Total | % of Variance | Cumulative % | Total | % of Variance | Cumulative % | Total | % of Variance | Cumulative % |
| 1 | 5.6 | 33.2 | 33.2 | 5.6 | 33.2 | 33.2 | 3.7 | 22.0 | 22.0 |
| 2 | 3.3 | 19.6 | 52.8 | 3.3 | 19.6 | 52.8 | 3.1 | 18.1 | 40.1 |
| 3 | 1.7 | 10.2 | 62.9 | 1.7 | 10.2 | 62.9 | 2.6 | 15.5 | 55.6 |
| 4 | 1.1 | 6.4 | 69.3 | 1.1 | 6.4 | 69.3 | 2.3 | 13.7 | 69.3 |
| 5 | 0.9 | 5.3 | 74.6 | | | | | | |
| 6 | 0.7 | 4.3 | 78.9 | | | | | | |
| 7 | 0.6 | 3.4 | 82.3 | | | | | | |
| 8 | 0.5 | 3.1 | 85.4 | | | | | | |
| 9 | 0.5 | 2.7 | 88.1 | | | | | | |
| 10 | 0.4 | 2.3 | 90.4 | | | | | | |
| 11 | 0.4 | 2.1 | 92.5 | | | | | | |
| 12 | 0.3 | 1.8 | 94.3 | | | | | | |
| 13 | 0.3 | 1.6 | 95.8 | | | | | | |

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| | | | |
|---|---|---|---|
| 14 | 0.2 | 1.3 | 97.2 |
| 15 | 0.2 | 1.1 | 98.3 |
| 16 | 0.2 | 1.0 | 99.3 |
| 17 | 0.1 | 0.7 | 100.0 |

Extraction Method: Principal Component Analysis.

The Principal Component Analysis (PCA) Rotated Component Matrix following Varimax rotation provides a highly understandable image of the way various variables combine and influence the effectiveness of laboratory practice activity in improving the teaching of biology. The next four individual factors were observed to contribute differently towards learning outcomes within a lab setup: pedagogic approach, facilities and infrastructure available, appraisal and assessment, and learners' motivation and engagement.

The pedagogical approach dimension includes variables associated with the instruction methods applied within biology laboratory classes. The significance of active, hands-on pedagogic styles that generate student interest and involvement in the learning experience is reflected in high loadings on statements like developing hypotheses (0.855), changing to inquiry-based from traditional instruction (0.830), and active exploration (0.766).These indicate that techniques that promote student activity and questioning have a critical impact on improving learning by fostering students' enthusiasm in biology as well as problem-solving skills.

The second indicates the importance of laboratory resources and infrastructure. The need for highly facilitated laboratories in order to teach effectively is evidenced by items which reflect the influence of a shortage of resources (0.837) and the need for quality laboratory equipment (0.817) on learning. The need for proper investment in laboratory infrastructure is evidenced by the fact that resource availability does not only represent the capacity to conduct experiments but also the advancement of experimental abilities.

The importance of laboratory skill-specific assessments and feedback in laboratory teaching is the overarching topic of the assessment and evaluation section. Laboratory skill-specific assessment (0.783) and regular feedback (0.833) were most important determinants, suggesting that lab skill-specific assessment and regular feedback processes are extremely important to the acquisition of hands-on skills and enhancing learning. The incorporation of assessment procedures to complement contemporary pedagogical methods is also guaranteed by the focus on assessments and lab manuals appropriate for inquiry learning.

The last factor relates to the role of teacher and classroom environments in affecting students' motivation and engagement. The broad range of influence of instructor behavior and support on student participation and motivation in biology labs is highlighted by high loadings on measures such as instructor enthusiasm (0.883) and instructor-facilitated student-centered classrooms (0.912). This factor emphasizes the significance of developing a welcoming and stimulating laboratory environment to ensure maximum student enthusiasm and participation.

The Rotated Component Matrix of the PCA reveals that effective laboratory practicals in biology teaching are multifaceted, involving pedagogical methods, provision of resources, assessment processes, and motivational processes. These factors in combination play a crucial part in shaping students' laboratory experience, their involvement, understanding, and skill acquisition in biology.The findings suggest that the institutions and the teachers must adopt a comprehensive approach by putting stress on creative learning and teaching, resource availability, proper assessment, and maintaining an inspirational learning environment to increase the educational benefit of laboratory practice activities to the maximum.

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Table 4: Rotated Component Matrix

| | Component | | | |
|---|---|---|---|---|
| | 1 | 2 | 3 | 4 |
| **Pedagogical Approach** | | | | |
| Participating in formulating hypotheses and conducting experiments makes me more engaged in learning. | 0.855 | | | |
| The shift from traditional teaching to inquiry-based learning in Biology labs has improved my problem-solving skills. | 0.830 | | | |
| I find that active exploration in Biology labs deepens my interest in the subject. | 0.766 | | | |
| I feel that inquiry-based learning in Biology labs helps me understand complex concepts better. | 0.760 | | | |
| I prefer collaborative group work in lab sessions over individual work. | 0.758 | | | |
| I believe that a student-centered learning environment enhances my critical thinking skills. | 0.705 | | | |
| **Resource Availability and Infrastructure** | | | | |
| Resource limitations in labs hinder my ability to effectively learn and conduct experiments. | | 0.837 | | |
| I believe the quality of lab equipment significantly impacts my understanding of Biology. | | 0.817 | | |
| Well-resourced labs provide me with opportunities to develop practical skills in Biology. | | 0.771 | | |
| Having access to well-equipped Biology labs enhances my learning experience. | | 0.719 | | |
| **Assessment and Evaluation** | | | | |
| Regular feedback on my lab work helps me improve my practical skills. | | | 0.833 | |
| I find that specialized assessments for laboratory skills are necessary for effective Biology education. | | | 0.783 | |
| The development of inquiry-based laboratory manuals | | | 0.691 | |

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| | | |
|---|---|---|
| has enhanced my lab practices. | | |
| I feel more confident in labs when I know my skills will be appropriately assessed. | 0.613 | |
| **Student Engagement and Motivation** | | |
| I am more engaged in lab activities when instructors facilitate a student-centered learning environment. | | 0.912 |
| My motivation to learn increases when instructors are enthusiastic and supportive. | | 0.883 |
| Instructor behaviours significantly impact my interest in Biology lab sessions. | | 0.703 |

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
a Rotation converged in 5 iterations.

**Research Question 2:Do practical activities have a positive impact on students' performance in biology?**

With extremely low standard deviations (0.94 and 0.59, respectively) and mean scores of 4.22 and 4.29, the students were very confident in their comprehension of biological concepts. This reflects a strong and consistent perception of understanding for the majority of pupils. With mean scores of 4.50 and 4.07, the skill to utilize biological principles in resolving complex problems was also evaluated very well, indicating that laboratory exercises with hands-on activities are successfully strengthening the problem-solving ability of students. With mean scores of 4.36 and 4.57, it can be seen that the students are interested in learning new concepts in biology and have a positive attitude toward the subject. Likewise, mean scores of 4.43 and 4.37 show that the students find biology classes interesting and enjoyable. These results demonstrate the motivating effect of laboratory exercises in stimulating the interest of the students in the subject.With mean scores of 4.50 and 4.58 and

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comparatively low standard deviations (0.83 and 0.50), it's surprising that students also felt frustrated when faced with difficult biological concepts. This suggests a paradox in which despite overall high confidence and interest, students still encounter and acknowledge the difficulties of learning difficult biological concepts. The overall mean score of 4.39 and standard deviation of 0.71 for all items reflect a positive perception towards the contribution of laboratory practical activities to students' academic performance in biology. This means that students, on average, perceive these activities as contributing to their knowledge, application, and enjoyment of biology, albeit if they grapple with complex concepts.

Table 5: The descriptive statistics for items used to assess impact of practical laboratory activities on students' academic achievement.

| Indicator | N | Mean | Std. Dev. |
|---|---|---|---|
| I feel confident in my understanding of biological concepts. | 250 | 4.22 | 0.94 |
| I am able to apply biological principles to solve complex problems. | 250 | 4.50 | 0.63 |
| I am enthusiastic about learning new topics in Biology. | 250 | 4.36 | 0.72 |
| I find Biology lessons enjoyable and engaging. | 250 | 4.43 | 0.73 |
| I feel frustrated when facing challenging biological concepts. | 250 | 4.50 | 0.83 |
| I feel confident in my understanding of biological concepts. | 250 | 4.29 | 0.59 |
| I am able to apply biological principles to solve complex problems. | 250 | 4.07 | 0.97 |
| I am enthusiastic about learning new topics in Biology. | 250 | 4.57 | 0.50 |
| I find Biology lessons enjoyable and engaging. | 250 | 4.37 | 0.71 |
| I feel frustrated when facing challenging biological concepts. | 250 | 4.58 | 0.50 |
| Overall Mean/Std. Dev. | | 4.39 | 0.71 |

**Measurement Model Assessment**

The research made use of the Partial Least Square-Structural Equation Modeling (PLS-SEM) analytical tool in examining the impact of practical laboratory activities on the academic performance of students. Some of the underlying assumptions used in the analysis are

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multicollinearity, item loadings, construct validity and reliability, convergent validity (average variance extracted), and discriminant validity. In order to determine the exact interpretation of the structural model results and to confirm the validity and reliability of the study, Henseler et al. (2009) put these hypotheses to test.

**Multicollinearity**

Multicollinearity Rady, Kineber, Hamed, and Daoud, (2023), explain that multicollinearity among variables was characterized by values of variable inflation factor (VIF) greater than 10, which prohibited the achievement of feasible PLS-SEM models. The VIF values for the analysis that ranged between 1.413 and 3.880 explained that there was no multicollinearity among the variables. The tolerance values and VIF values for the predictor variables are illustrated in Table 6.

Table 6: Multicollinearity amongst variables

| Construct | Label | VIF |
|---|---|---|
| Academic Performance | AP1 | 2.132 |
| | AP2 | 1.947 |
| | AP3 | 2.599 |
| | AP4 | 1.881 |
| Practical Laboratory Activities | PLA3 | 2.628 |
| | PLA5 | 2.628 |

Source: Field Data, 2024

**Item Loading**

In ascertaining the item loadings, the initial method of evaluation was to explore the loadings of indicators for every construct. Item loadings were utilized in an effort to measure the caliber of indicators employed to quantify every construct in relation to the study. Henseler, Ringle, and Sinkovics, (2009) posit that, by and large, a construct is of good quality when its items have loadings ≥ 0.70. Therefore, items that were part of a component of each construct

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with less than 0.7 were eliminated from the model. This outcome could be explained by the fact that the items borrowed from the literature were not successfully able to operationalize the construct being investigated in the said field of study. Three of the ten indicators used in the measurement of the latent variables were dropped because they were not able to pass the test of indicator reliability. Four out of the five measures of academic performance survived. Two of the three indicators used to measure hands-on laboratory activity were kept. Figure 1 shows the indicator loadings of the kept items.

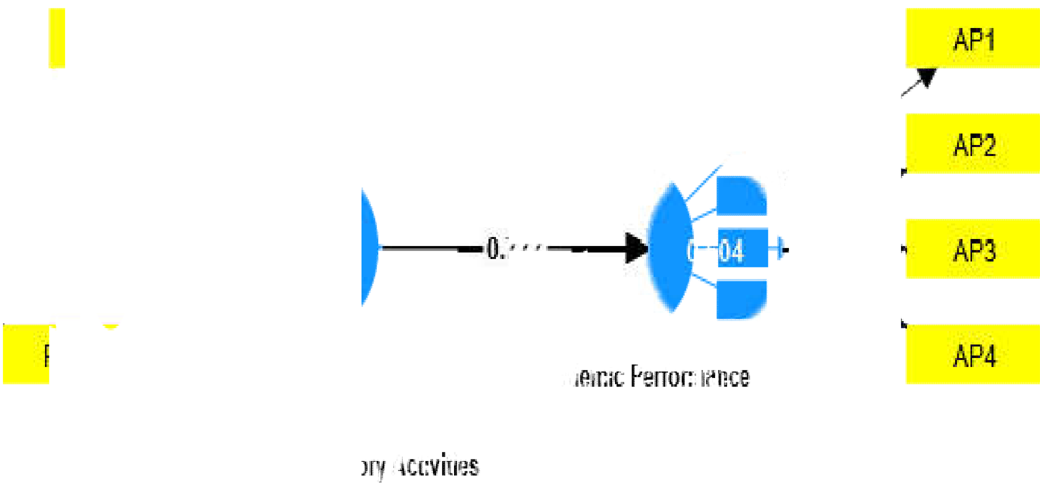


Figure 1: Item Loadings of Constructs

Table 7 displayed the factor loading for each indicator included. Consequently, the outer loadings having values below 0.70 were not included in the measurement models since such indicators contribute less to such factors.

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Table 7: Factor Loadings

| | Academic Performance | Practical Laboratory Activities |
|---|---|---|
| AP1 | 0.848 | |
| AP2 | 0.835 | |
| AP3 | 0.892 | |
| AP4 | 0.787 | |
| PLA3 | | 0.942 |
| PLA5 | | 0.948 |

Source: Field Data, 2024

**Internal Consistency Reliability**

Table 8 presented the results of other assessment criteria, including construct reliability and validity and convergent validity (average variance extracted).

Table 8: Assessing Internal Consistency Reliability

| | Cronbach's alpha | Composite reliability (rho_a) | Composite reliability (rho_c) | Average variance extracted (AVE) |
|---|---|---|---|---|
| Academic Performance | 0.863 | 0.873 | 0.906 | 0.708 |
| Practical Laboratory Activities | 0.881 | 0.883 | 0.944 | 0.893 |

Source: Field Data, 2023

Using composite reliability, the internal consistency reliability of the constructions employed in this research were examined. In contrast to Cronbach's alpha, Rossiter (2002) argues that the composite reliability estimate is a superior internal consistency measure. From the results in Table 8, the latent variables examined in this research are highly reliable because their loadings are above the cut off of 0.7 set by Bagozzi and Yi (1988). Practical lab exercises had the highest composite reliability score at 0.944. Performance in school is next at 0.906. These results indicate that the internal consistency of the model is reliable.

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**Discriminant Validity**

A construct's discriminant validity and capacity to explain unexplained events by other constructs in the model are supported by its discriminant validity (MacKinnon, 2008). Discriminant validity was established in the current study using the Fornell-Lacker criterion. Fornell and Larcker (1981) proposed the Fornell-Larcker criterion, which compares the correlations of the latent variables with the square root of the Average Variance Extracted (AVE) values. The square root of the Average Variance Extracted (AVE) of every construct must be greater than its highest correlation with any other construct, according to Hair et al. (2013). The results shown in Table 9 reveal that the square root of every variable is significantly greater than its correlations with other constructs being researched. This shows that every construct is unique and that no two constructions depict the same phenomenon.

Table 9: Fornell-Lacker criterion

| | Academic Performance | Practical Laboratory Activities |
|---|---|---|
| Academic Performance | **0.841** | |
| Practical Laboratory Activities | 0.777 | 0.945 |

*Bold values are the square root of each construct's AVE which is higher than their correlation with other constructs.*

Source: Field Data,2024

Henseler, Ringle, and Sarstedt (2015) recommend the assessment of the heterotrait-monotrait ratio (HTMT) of the correlations. Henseler et al. (ibid.) say that a latent construct has discriminant validity if its HTMT ratio is below 0.850. The values presented in Table 10 are HTMT values significantly lower than 0.850.

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Table 10: Heterotrait-Monotrait Ratio

| | Academic Performance | Practical Laboratory Activities |
|---|---|---|
| Academic Performance | | |
| Practical Laboratory Activities | 0.823 | |

Source: Field Data,2023

**Assessing the Structural Model**

Structural model analysis entails examination of the route coefficient, its significance, effect size, predictive relevance, coefficient of determination, and collinearity between constructs. As suggested by Nitzl (2016), both the direct and indirect models were applied in this study.

This part of the study presented the PLS-SEM estimate results for the model's predictive accuracy by means of the coefficient of determination (R2). Following the Stone-Giesser's test criterion, the other applicable estimations such as effect size (f2) and predictive relevance (Q2) were presented by the study. Table 10 revealed the findings.

Reporting the predictive ability of the Partial Least Squares (PLS) path, which is indicated by the R2 coefficient, is part of the assessment. The coefficient of determination (R2) is a statistical metric that measures the degree to which the predicted values of a regression model match the observed actual values. R2 is the total effect of the exogenous variable on the endogenous variable or variables. Hair, Hult, Ringer, and Sarstedt, (2014) state that the coefficient of determination (R2) can be used to assess structural models; values of 0.25, 0.5, and 0.75 are rated weak, moderate, and considerable, respectively.

Results in Table 11 and Figure 1 exhibit the path model, which contained one line of constructs used in the measurement on how practical laboratory exercises affect students' academic accomplishment. As with what could be indicated through direct effect, where it

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had explained 60.4% variation in what had been observed, results show that practical laboratory activities factors affected students' academic progression greatly.

Table 11: Coefficient of Determination

| | R-square | R-square adjusted |
|---|---|---|
| Academic Performance | 0.604 | 0.602 |

Source: Field Data,2024

According to Cohen's (1988) categorization, the path coefficient effect size can be considered small, medium, and large when the corresponding effect size measures are 0.02, 0.15, and 0.35. The effect size ($f2$) analysis results indicate that practical laboratory exercises have a large effect size (1.526) on academic performance. The result was displayed on Table 12.

Table 12: Effect Size

| | Academic Performance | Practical Laboratory Activities |
|---|---|---|
| Academic Performance | | |
| Practical Laboratory Activities | 1.526 | |

Source: Field Data,2024

The last question, Q2, is predictive relevance, and it measures a model's predictive relevance. Q2 also reflects the predictive value of the endogenous constructs. Q2 values greater than zero show that the model is predictively relevant and the values are accurately replicated. The Stone-Gesser's Q2 value larger than zero for a specific endogenous construct shows the model's predictive accuracy for that particular construct (Hair, Hollingsworth, Randolph, & Chong, 2017b; Sarstedt et al., 2017). From Table 13, although the p-values were significant. The structural model's acceptable predictive significance is supported by its Q2 value of 0.602.

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Table 13: Predictive Relevance

| | $Q^2$predict | RMSE | MAE |
|---|---|---|---|
| Academic Performance | 0.602 | 0.634 | 0.559 |

Source: Field Data,2024

**Assessing the impact of Practical Laboratory Activities on Students' Academic Performance (Path Coefficient)**

After that, the measurement model was validated to ensure that it fulfils the criterion of PLS-SEM. One of the aims was to examine the effect of hands-on laboratory practice on students' learning performance. Following Hair et al.'s (2019) suggestion, this was done by measuring direction and size using path coefficient (β) and degree of significance using t-statistics derived from 5000 bootstraps. Table 14 summarized the result of the first objective. The findings are summarised in Table 14 and Figure 2.

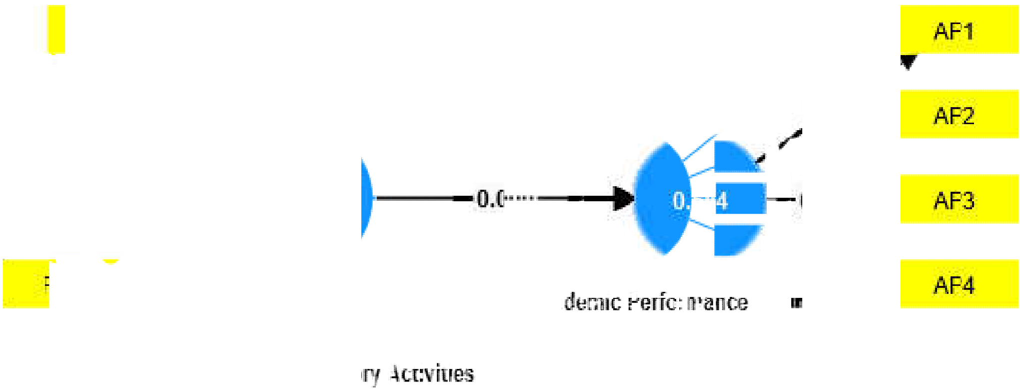


Fig 2: **Practical Laboratory Activities on Students' Academic Performance**

Table 14: Result of Structural Equation Model

| **Structural Path** | **(β)** | **T- Statistics** | **p values** |
|---|---|---|---|
| Practical Laboratory Activities-> Academic Performance | 0.777 | 36.998 | 0.000 |

Source: Field Data,2023

.

In Table 14, there is a great improvement in academic performance brought about by practical laboratory exercises (β=0.777; t=36.998; p=0.000<0.05). This is of great significance since the t-statistic of the model, that is, 36.998, significantly exceeds the bench mark of 1.96. Therefore, from the research, it is clear that practical laboratory exercises improve students' academic performance significantly. The improvement in academic performance and taking part in hands-on laboratory practices are strongly positively correlated, indicated by the 0.777 path coefficient showing that a 77.7% improvement in academic performance correlates with every one-unit increase in taking part in hands-on laboratory practices. The implication of this strong finding points to how valuable hands-on laboratory practices are toward improving academic performance.

Ude and Ebuoh (2019) in Nigeria found out that students trained through practical exercises performed well against their peers trained through normal methods, which supports the findings in Table 14. Their quasi-experimental study supports the findings of Table 14 that experiential learning in hands-on lab work greatly improves academic performance by validating the importance of experiential learning in developing a deeper insight and recall of biological concepts.

The effectiveness of interactive and collaborative learning settings is also borne out by a Rwandan study by Mukagihana, Nsanganwimana, and Aurah (2021) into the influence of animation-based instructions and small-group laboratory work. Their results, which showed that these methods greatly enhanced pre-service biology teachers' academic achievement, highlight how significant it is to use an assortment of interesting pedagogical strategies in biology classes.

Eduardo, Rosa, and Welker (2019) illustrated how self-experiments improve students' learning in laboratory classes in Brazil. The experimental research findings formulated that the grades of the students improved greatly after active learning. This includes self-directed

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experiments, which recognize the need for offering hands-on experiences to the students to increase understanding and academic achievement.

Liu et al. (2022) examined the effect of the "Industrial Innovation and Entrepreneurship Talent Cultivation" model on the performance and satisfaction of biology students, which once more supports the results in Table 14. Their findings demonstrated the advantages of new educational models over conventional laboratory experiments by indicating that incorporating industrial innovation and entrepreneurship concepts into biology education greatly improved the performance and satisfaction of students.

Bauer et al. (2020) examined the effect of the dual domain pedagogy's (DDP) on students' performance in biology lessons and found that it immensely reduced performance gaps among students of different racial backgrounds. This study underscores the necessity to address both cognitive and affective learning aspects with a view to enhancing academic performance and promoting educational equity.

Last, Rodriguez and colleagues' (2021) investigation of successful learning habits in upper-level microbiology courses found that spacing over the course of the semester was a strong predictor of final grades. This reaffirms the significance of promoting successful learning habits and strategies to increase student performance in upper-level biology courses.

**Research Question 3:Will exposing students to laboratory activities help them develop scientific attitudes toward biology learning?**

With a mean of 4.13 and standard deviation of 0.89, students endorsed a high interest in biology and related inclination towards open-mindedness, respectively. These results indicate a high intent to study and learn about the natural world and a willingness to evaluate new

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ideas and information. The fairly low standard deviation indicates that students highly agree on these attitudes.

The commitment to being objective in research, at a mean of 4.10, is closely followed by the use of critical thinking to evaluate and interpret scientific evidence in biology, which has a mean of 4.12. These demonstrate an outstanding degree of interaction with the scientific process and a focus on drawing conclusions on the basis of good evidence. The reason that all of these questions' standard deviations are below one is that it means that responders are in agreement that these are necessary skills. With mean scores of 4.10 and 4.20, respectively, the positive attitude toward biology and perceived benefit of inquiry-based and problem-based learning approaches to critical thinking skills are significant. The results demonstrate the promising influence of positive attitudes and contemporary teaching approaches in developing biological critical thinking skills.

The mean of frequent exposure to laboratory activities is 4.08, which implies good provision of practical work; the mean for comfort and confidence in participating in the laboratory is 4.07; equalized engagement in laboratory activities is also evidenced in following laboratory safety procedures and the perceived achievement of scientific knowledge and practical competency through laboratory activities; the means for these pointers range from 4.02 to 4.18 with different levels of standard deviation, which implies the presence of varying experiences for the students. With an overall standard deviation of 0.91, overall laboratory exposure satisfaction has a mean score of 4.13, which is very much a reflection of the overall parameters' mean score of 4.12. This implies that students have an overall good attitude towards laboratory sessions, which is crucial to the provision of a good biology learning environment.

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Table 15: Descriptive Statistics for Exposure of Students to Laboratory Activities and Develop Scientific Attitudes Towards Learning Biology

| Indicator | N | Mean | Std. Dev. |
|---|---|---|---|
| My curiosity in biology drives my desire to explore and understand the natural world. | 250 | 4.13 | 0.89 |
| I demonstrate open-mindedness by critically considering new information and ideas in biology. | 250 | 4.14 | 0.89 |
| I regularly engage in critical thinking to analyze and interpret scientific data in biology. | 250 | 4.12 | 0.89 |
| I strive to maintain objectivity in my biology studies, focusing on evidence-based conclusions. | 250 | 4.10 | 0.94 |
| My positive attitude towards biology enhances my motivation and participation in related activities. | 250 | 4.10 | 0.92 |
| Inquiry-based and problem-based learning approaches in biology improve my critical thinking skills. | 250 | 4.20 | 0.79 |
| My scientific literacy, including understanding biology concepts and processes, has been enhanced through my education. | 250 | 4.11 | 0.89 |
| I have frequent exposure to laboratory activities | 250 | 4.08 | 0.98 |
| I spend a significant amount of time engaged in laboratory activities | 250 | 4.18 | 0.85 |
| I feel comfortable and confident while participating in laboratory work | 250 | 4.07 | 0.97 |
| I am aware of and adhere to safety protocols during laboratory activities | 250 | 4.09 | 0.97 |
| Engaging in laboratory activities enhances my understanding of scientific concepts | 250 | 4.12 | 0.95 |
| I find laboratory activities interesting and engaging. | 250 | 4.16 | 0.78 |
| Participating in laboratory work has improved my practical skills. | 250 | 4.02 | 1.01 |
| I am satisfied with my overall exposure to laboratory activities. | 250 | 4.13 | 0.90 |
| Overall Mean/Std.Dev | | 4.12 | 0.91 |

**Measurement Model Assessment**

The Partial Least Square-Structural Equation Modeling (PLS-SEM) analysis tool was used in the study to examine how the performance of students in academics was affected by practical laboratory sessions. Multicollinearity, item loadings, construct validity and reliability, convergent validity (average variance retrieved), and discriminant validity were some of the assumptions used in the measurement. In order to determine the exact meaning of the results

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of the structural model and to ensure the validity and reliability of the study, Henseler et al. (2009) tested these hypotheses.

**Multicollinearity**

Multicollinearity According to Pallant (2007), multicollinearity among the variables was confirmed by variable inflation factor (VIF) greater than 10, which undermined the creation of effective PLS-SEM models. The VIF values of the analysis, which ranged from 1.413 to 3.880, confirmed that the variables were not multicollinear. The tolerance level and VIF values of the predictor variables are shown in Table 16.

Table 16: Multicollinearity amongst variables

| Construct | Label | VIF |
|---|---|---|
| Exposure to Practical Laboratory Activities | ELA5 | 2.180 |
| | ELA6 | 2.656 |
| | ELA7 | 1.985 |
| | ELA8 | 1.776 |
| Scientific Attitudes | SA1 | 2.565 |
| | SA2 | 2.342 |
| | SA3 | 2.475 |
| | SA4 | 2.146 |
| | SA5 | 2.437 |
| | SA6 | 2.237 |
| | SA7 | 1.933 |

Source: Field Data, 2024

**Item Loading**

To assess the item loadings, the initial assessment method was to examine the loadings of the indicators for each construct. Item loadings were utilized in an effort to measure the quality of the indicators used to measure each construct within the research context. Henseler et al. (2009) provide that, by default, a construct is considered good quality if the items representing it have loadings of ≥ 0.70. Therefore, elements in each construct with loadings lower than 0.7 were trimmed off the model. It is possible that the results ended up such with regard to the realization that maybe items selected from available literature could have failed to capture the subject of study under investigation for defined areas of research. Three of the

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15 indicators used to estimate the latent variables were excluded since they did not pass the indicator reliability test. Four of the five measures of academic performance were included. Two of the three indicators used to measure hands-on laboratory activity were included. Figure 3 shows the included items' indicator loadings.

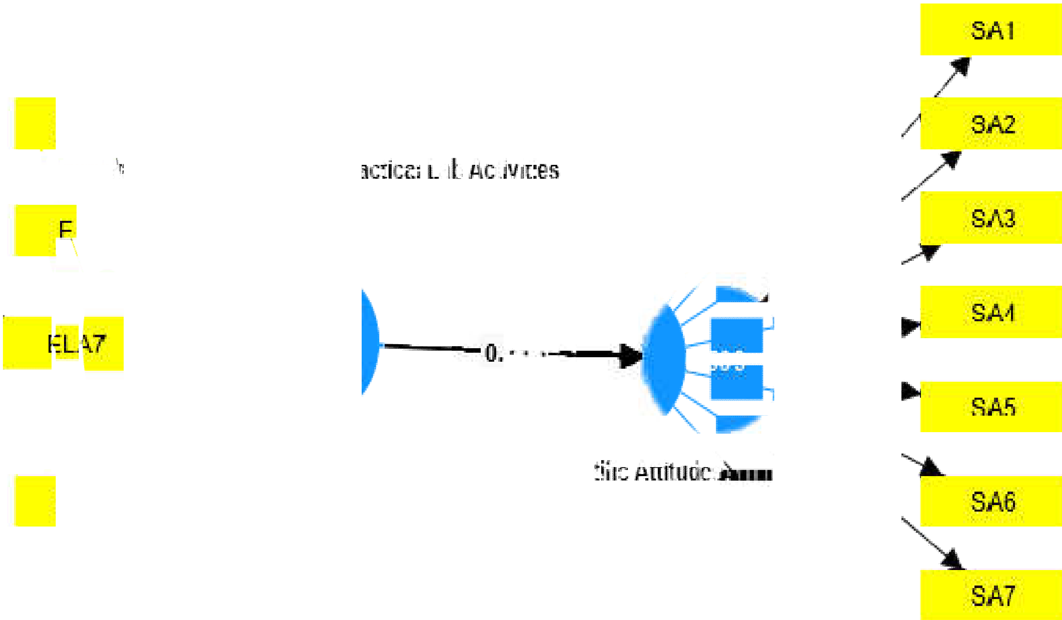


Figure 3: Item Loadings of Constructs

Table 17 indicated the factor loading of each indicator that was utilized. Thus, the factor loadings below 0.70 were excluded from the measurement models since these indicators play a lesser role in these factors.

Table 17: Factor Loadings

| | Exposure to Practical Lab Activities | Scientific Attitudes |
|---|---|---|
| ELA5 | 0.844 | |
| ELA6 | 0.884 | |
| ELA7 | 0.841 | |
| ELA8 | 0.807 | |
| SA1 | | 0.798 |
| SA2 | | 0.764 |
| SA3 | | 0.843 |
| SA4 | | 0.807 |
| SA5 | | 0.833 |

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| | |
|---|---|
| SA6 | 0.805 |
| SA7 | 0.748 |

Source: Field Data, 2024

### Internal Consistency Reliability

Table 18 presented the results of other assessment criteria, including construct reliability and validity and convergent validity (average variance extracted).

Table 18: Assessing Internal Consistency Reliability

| | Cronbach's alpha | Composite reliability (rho_a) | Composite reliability (rho_c) | Average variance extracted (AVE) |
|---|---|---|---|---|
| Exposure to Practical Lab Activities | 0.865 | 0.866 | 0.908 | 0.713 |
| Scientific Attitudes | 0.906 | 0.909 | 0.926 | 0.641 |

Source: Field Data, 2024

Using composite reliability, this study examined the internal consistency reliability of the constructs. As opposed to Cronbach's alpha, Rossiter (2002) argues that the composite reliability measure is a superior indicator of internal consistency. According to the results in Table 8, the latent variables under study in this research are reliable as their loadings are above the 0.7 cut-off point recommended by Bagozzi and Yi (1988). Biology had the highest composite reliability value (0.926) on the scientific attitudes. Hands-on exposure to laboratory activities had a composite reliability of 0.908. From the findings, it can be seen that there is internal consistency in the model.

### Discriminant Validity

The discriminant validity of a construct is establishing its uniqueness and capacity for representing events that other constructs within the model cannot (MacKinnon, 2008). Discriminant validity was developed in this study from the Fornell-Lacker criterion. Fornell

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and Larcker (1981) had developed the Fornell-Larcker criterion, which gives a cross-tab comparison of the correlations of the latent variables and the square root of Average Variance Extracted (AVE) values. The square root of the Average Variance Extracted (AVE) of each construct must be greater than its highest correlation with another construct, according to Hair et al. (2013). The values exhibited in Table 19 show that the square root of every variable is significantly larger than its correlations with the other constructs being researched. This suggests that each construct is unique and that no two constructions cover the same phenomenon.

**Table 19: Fornell-Lacker criterion**

| | Exposure to Practical Lab Activities | Scientific Attitudes |
|---|---|---|
| Exposure to Practical Lab Activities | **0.844** | |
| Scientific Attitudes | 0.713 | 0.800 |

*Bold value is the square root of each construct's AVE which is higher than their correlation with other constructs.*

Source: Field Data,2024

Henseler, Ringle, and Sarstedt (2015) propose testing the ratio of heterotrait-monotrait correlations. Henseler et al. (ibid.) indicate that a latent construct has discriminant validity if the ratio of the HTMT of the correlations is below 0.850. The values from Table 20 are HTMT values significantly smaller than 0.850.

Table 20: HeterotraitMonotrait Ratio

| | Exposure to Practical Lab Activities | Scientific Attitudes |
|---|---|---|
| Exposure to Practical Lab Activities | | |
| Scientific Attitudes | 0.800 | |

Source: Field Data,2023

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## Assessing the Structural Model

Structural model analysis involves evaluating the pathway coefficient, its significance, effect size, predictive relevance, coefficient of determination, and collinearity between constructs. As a precaution by Nitzl et al. (2016), direct and indirect models were used for this study.

This section gave the results of the PLS-SEM estimation of the model's predictability accuracy with the coefficient of determination (R2). Following Stone-Giesser's test criterion, the research also gave other similar estimations that include effect size (f2) and predictive relevance (Q2). Table 21 presented the results.

Reporting of the R2 coefficient, indicating the predictive ability of the Partial Least Squares (PLS) path, is part of the assessment. The coefficient of determination (R2) is a statistical metric that calculates the accordance between predicted values using a regression model and actual observed values. R2 is the total effect of the exogenous variable on the endogenous variable or variables. Hair et al. (2014) state that the coefficient of determination (R2) can be used to assess structural models; R2 values of 0.25, 0.5, and 0.75 are rated as weak, moderate, and substantial, respectively. The results in Table 21 and Figure 4 show the path model, a path of one construct used in examining how practical laboratory activities affect students' academic performance. The direct effect, which explained 50.9 percent of the variance depicted, shows that the determinants of practical laboratory activities affected students' academic performance.

Table 21: Coefficient of Determination

| | R-square | R-square adjusted |
|---|---|---|
| Scientific Attitudes | 0.509 | 0.507 |

Source: Field Data,2024

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Cohen (1988) classification indicates that when equivalent effect size metrics are 0.02, 0.15, and 0.35, respectively, the route coefficient effect size can be classified as small, medium, or large. From the effect size ($f^2$) research findings, scientific attitudes affect academic performance significantly (1.035). Table 22 presented the finding.

Table 22: Effect Size

| | Exposure to Practical Lab Activities | Scientific Attitudes |
|---|---|---|
| Exposure to Practical Lab Activities | | 1.035 |
| Scientific Attitudes | | |

Source: Field Data,2024

Finally, Q2 is predictive relevance, and it is an indicator of whether a model has or lacks predictive relevance. Q2 also establishes the predictive relevance of the endogenous constructs. Q2 values above zero indicate that the values are reconstructed well and the model has predictive relevance. The Stone-Gesser's Q2 value greater than zero for a specific endogenous construct confirms the validity of prediction by such a specific model (Hair, Hollingsworth, Randolph, & Chong, 2017b; Sarstedt et al., 2017). From Table 23, however, p-values were significant. The value of Q2 at 0.497 further affirms the reality that the structural model is of acceptable relevance for prediction.

Table 23: Predictive Relevance

| | $Q^2$predict | RMSE | MAE |
|---|---|---|---|
| Scientific Attitudes | 0.497 | 0.721 | 0.523 |

Source: Field Data,2024

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**Assessing the impact of Practical Laboratory Activities on Students' Academic Performance (Path Coefficient)**

The aim of this research question was to investigated how students' academic performance was affected by practical laboratory experiments. Path coefficient (β) and significance level with t-statistics derived from 5000 bootstraps were used to measure the direction and magnitude, as suggested by Hair et al. (2019). Table 24 displayed the outcome of objective one. The results are shown in Figure 4 and Table 24.

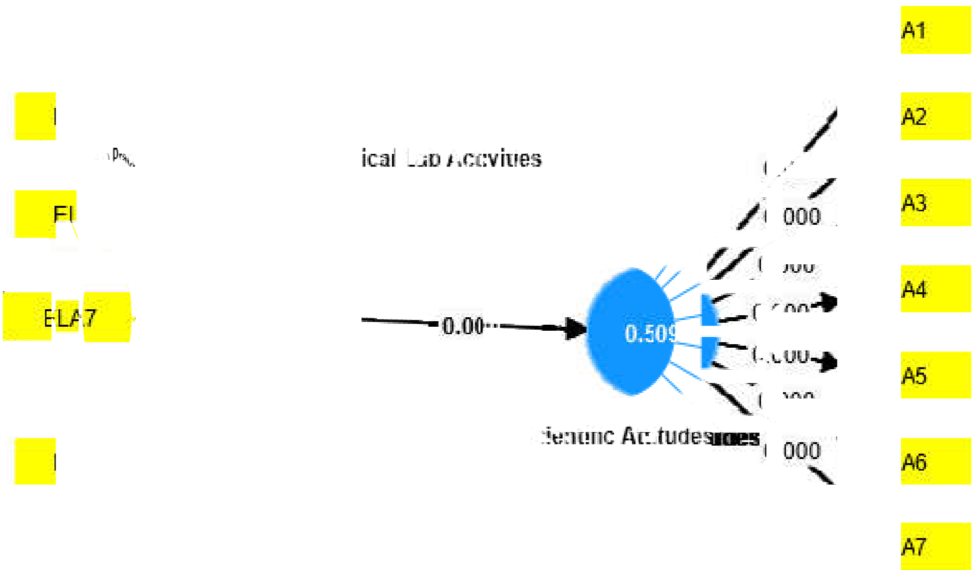


Figure 4: Path Diagram

Table 24: Result of Structural Equation Model

| Structural Path | (β) | T- Statistics | p values |
|---|---|---|---|
| Exposure to Practical Laboratory Activities-> Scientific Attitudes | 0.713 | 15.759 | 0.000 |

Source: Field Data,2023

From the analysis as seen in Table 24, the findings indicate that hands-on laboratory experience significantly enhances students' scientific attitudes with a path coefficient (β) of 0.713, t-statistic of 15.759, and p-value of 0.000, which is significantly less than the 0.05 threshold. The t-statistic value, which is much greater than the typical cut-off of 1.96, very

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strongly supports the positive impact of practical laboratory classes on the scientific attitudes of students. The statistical evidence further supports that practical laboratory classes are a strong predictor in the formation of positive scientific attitudes among students.

Exposure of students to hands-on laboratory practice and their attitude towards science is clearly positively correlated, as indicated by the coefficient of 0.713. This implies that students' attitude towards science improves by 71.3% when exposed to more laboratory experiments.This steep rise shows that hands-on, experiential learning within laboratory environments is an efficient way of instilling students' heightened awareness and expertise of scientific principles.

This intimate relationship shows that active laboratory experiments have an important role in developing scientific attitudes of students and enhancing students' learning achievements in science education. This also confirms that students' scientific attitudes would significantly and positively be affected by laboratory experiments.

Findings of the present study concur with findings of a study by Inayah et al. 2020. Computational simulations could be valuable complements to conventional laboratory classes, as perceived by Inayah, Rahman, Syahrul, and Hakim (2020), following research work conducted in Indonesia for virtual lab media usability to support scientific attitudes strengthening. Consistent with the more general finding that virtual and actual lab experiences are central in current biology education, study findings identify that virtual lab can play important roles in impacting students' perceptions of science.

This line of thinking was continued by Kapici, Akçay, and de Jong (2020), who compared the impact of virtual and hands-on laboratories on the attitudes of students towards science. Their study demonstrated the specific advantages of virtual laboratories in impacting students' attitudes and indicated that the incorporation of digital laboratory experiences into the curriculum can be especially effective in making students excited about the subject.

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To increase scientific attitudes and competencies, Souto, Silva, and Neves (2020) stressed the contribution of particular biological themes, such as iconological investigations. This perspective also supports the understanding that variety in laboratory activities boosts student attitude and interest in science through endorsing the merit of having topic-specific and varied practical exercises in biology education.

Manishimwe, Shivoga, and Nsengimana (2022) explored the effect of inquiry-based learning on students' attitudes toward biology. The study highlights the benefits of active learning approaches to laboratory teaching by demonstrating the capacity of inquiry-based approaches to motivate students' interest and construct positive attitudes towards the subject.

Finally, the motivational effect of an SSI-based lab curriculum was examined by Hewitt (2019). The findings indicate that SSI-based curricula not only increase students' motivation but also encourage more independent engagement in laboratory activities, demonstrating the potency of contextually relevant and thematic lab work to inspire and raise students.

Considered as a whole, these studies show the diversity of good laboratory teaching and its utmost significance in fostering scientific attitudes and competence. They warrant an instructional approach that maximizes the positive effects on students' scientific attitudes and achievement in biology by embracing traditional and innovative laboratory practices, such as hands-on, virtual, inquiry-based, and theme methods.

## CONCLUSION AND RECOMMENDATIONS

### Conclusion

The study analyzed the key determinants of the effectiveness of laboratory-based practical work in biological education. The four key factors—teaching methodology, infrastructure and resource availability, assessment and testing, and learners' motivation and engagement—were found via Principal Component Analysis to account for 69.3% of the overall variance, indicating their widespread influence on the effectiveness of laboratory-based learning.

Furthermore, the findings indicated the positive impact of hands-on laboratory activities on students' academic performance. Empirical findings revealed that students who were involved in laboratory activities showed significantly higher academic achievement.

Additionally, the findings revealed that exposure to authentic laboratory activities significantly enhanced students' attitudes toward science. The path coefficient and corresponding statistical results highlighted the critical role played by experimental hands-on laboratory work in shaping positive attitudes toward science and improving learning outcomes in science courses. The findings corroborated the existing literature by affirming the important role of experimental laboratory work towards shaping and improving the scientific attitudes of students.

**Recommendation**

From the findings of the research, the following suggestions were provided:

- Curriculum designers and lecturers should vary experiment types, provide well-defined guidelines, encourage inquiry-based learning, have continuous instructor engagement, and relate laboratory practice to theory.
- Lecturers and learning institutions should use frequent assessment, provide positive feedback, and use clear marks of assessment.
- Lecturers and learning institutions should encourage active student involvement and participation in laboratory work.
- Instructors need to integrate science communication skills into laboratory work.

**Suggestions for Future Research**

The long-term career selection and achievement implications of interactive laboratory experiences in biology for students must be studied in longitudinal research. Compare the effectiveness with which various teaching approaches—a few of which include inquiry-based learning, problem-based learning, and conventional teaching—strengthen students' scientific knowledge and attitudes in real biology labs. Investigate how the application of biology laboratory exercises might be incorporated into interdisciplinary science education programs through coordination with experts in other fields of science.

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