International Journal on Science and Technology (IJSAT)
E-ISSN: 2229-7677 ● Website: www.ijsat.org ● Email: editor@ijsat.org

Influence of Laboratory Engagement Duration on Students' Performance in Science Assessments

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Abstract

This study investigated the influence of laboratory engagement duration on students' performance in science examinations, addressing a persistent gap in science education research, particularly within resource-constrained contexts. Guided by Constructivist Learning Theory, Experiential Learning Theory, and Time-on-Task Theory, the study employed a convergent mixed-methods design to examine both the quantitative relationship between laboratory time and academic performance, and the qualitative experiences that shape students' practical learning. A sample of 200 students and selected teachers participated through questionnaires, examination score checklists, interviews, and laboratory observations. Descriptive statistics revealed moderate levels of laboratory engagement and average science achievement. Pearson correlations showed significant positive associations between weekly laboratory hours, number of experiments conducted, and examination scores ($p < 0.01$). Multiple regression analysis further indicated that weekly laboratory hours ($\beta = 0.42$, $p < 0.001$), number of experiments ($\beta = 0.21$, $p = 0.005$), and teacher support ($\beta = 0.18$, $p = 0.017$) significantly predicted science performance, while resource availability was not a significant predictor. Qualitative findings reinforced these results, highlighting those students perceived laboratory activities as crucial for conceptual understanding, motivation, and the ability to apply scientific ideas. However, constraints such as limited equipment, overcrowded classes, and restricted instructional time hindered effective engagement. Overall, the study concludes that extended, meaningful laboratory participation significantly enhances science achievement, but its impact is moderated by contextual challenges. The findings provide practical implications for curriculum planning, teacher professional development, and resource allocation, underscoring the need for increased and well-structured laboratory opportunities to strengthen science learning outcomes.

Keywords: Laboratory Engagement, Science Achievement, Experiential Learning, Time-on-Task, Constructivist Approach

1. Introduction

Laboratory-based instruction has long been recognized as a central element of effective science education, providing students with opportunities to investigate scientific concepts through direct interaction, observation, and inquiry. Empirical research consistently demonstrates that active engagement in practical work enhances conceptual understanding, promotes scientific reasoning, and fosters positive attitudes toward science learning (Hofstein & Lunetta, 2004; Millar, 2010). Students who participate meaningfully in laboratory activities are better able to bridge theoretical knowledge with observable phenomena, leading to deeper comprehension and improved academic outcomes (Bennett, Lubben, & Hogarth, 2007). As such, the duration and quality of laboratory engagement have emerged as critical indicators of the effectiveness of science instruction.

Despite these recognized benefits, many educational systems, particularly in developing regions, struggle to provide sufficient laboratory exposure. Constraints such as inadequate facilities, limited consumable materials, high teacher workloads, and curriculum overcrowding frequently reduce the time allocated to practical investigations (Asare & Nti, 2014). Even in schools with laboratory infrastructure, practical sessions are often rushed, poorly structured, or dominated by preparation for high-stakes examinations, raising concerns about whether insufficient laboratory engagement contributes to persistent low performance in science as documented by national and international assessments (TIMSS, 2019; WAEC, 2022).

Although practical work is generally assumed to enhance achievement, relatively few studies have empirically examined the direct relationship between the amount of time spent in laboratory activities and students' performance on science examinations, particularly in basic and secondary schools in sub-Saharan Africa (Ogunniyi, 2009). This gap leaves uncertainty regarding the optimal duration of laboratory exposure required to produce measurable learning gains and whether merely increasing lab hours translates into improved academic outcomes. In response, the present study investigates the relationship between the time students spend in laboratory activities and their performance on science examinations, with the aim of providing evidence to guide curriculum planning, inform instructional time allocation, and support investments in practical science resources. Ultimately, the study seeks to determine whether extended and well-structured laboratory engagement can serve as an effective strategy for enhancing students' achievement in science.

Purpose of the Study

The study aims to investigate the relationship between the duration of students' participation in laboratory activities and their performance in science examinations. It specifically examines whether extended, meaningful laboratory engagement enhances academic achievement and to what extent practical involvement predicts examination outcomes. The findings are expected to provide empirical evidence on whether laboratory time translates into measurable learning gains and to offer insights for curriculum planning, instructional improvement, and resource allocation in science education.

Significance of the Study

This study is significant because it addresses a notable gap in the literature on science education, particularly in contexts where student performance in science remains consistently low (Hofstein & Lunetta, 2004; Ogunniyi, 2009). Although laboratory activities are widely regarded as beneficial for learning, there is limited empirical evidence examining the extent to which the duration of practical engagement directly affects outcomes on formal assessments (Bennett, Lubben, & Hogarth, 2007). The findings of this research are expected to provide educators, curriculum developers, and policymakers with insights into whether extending laboratory time can serve as a viable strategy for enhancing science achievement. Furthermore, the results can inform teachers' instructional planning, helping them balance theoretical instruction with hands-on practice to strengthen conceptual understanding and improve academic performance. Beyond individual classrooms, the study contributes to the broader discourse on STEM education in developing countries, where resource limitations often constrain opportunities for practical learning. By generating evidence-based guidance, the research has the potential to influence curriculum reforms, inform equitable allocation of resources, and support school-level strategies that optimize laboratory engagement for improved science learning outcomes.

Justification of the Study

This study is warranted on the basis that laboratory-based instruction is a cornerstone of effective science education, yet many schools face challenges in providing adequate time and resources for hands-on activities. Although the pedagogical advantages of laboratory engagement are well-documented, the extent to which the duration of practical sessions translates into improved performance on formal examinations remains insufficiently explored, particularly in resource-limited contexts (Hofstein & Lunetta, 2004; Bennett, Lubben, & Hogarth, 2007). Understanding this relationship is critical for determining whether investments in laboratory facilities, equipment, and instructional scheduling yield measurable academic benefits. In numerous educational systems, persistently low science achievement continues to impede students' access to STEM pathways, highlighting the need to identify factors that can enhance learning outcomes (Ogunniyi, 2009; Asare & Nti, 2014). Accordingly, this study provides empirical evidence to inform decisions regarding curriculum time allocation, teacher professional development, and school-level planning for practical science instruction. By elucidating the impact of laboratory engagement duration on student achievement, the research offers actionable insights for improving the effectiveness of science teaching and fostering stronger academic performance.

Research Question

1. In what ways does the duration of students' participation in laboratory work relate to their achievement in science examinations, and how do learners explain the contributions of practical activities to their understanding of scientific ideas?
2. What contextual conditions and challenges influence students' involvement in laboratory sessions, and how are these factors statistically associated with differences in their science examination performance?

Hypothesis

H_1: There is a statistically significant relationship between the amount of time students spend on laboratory activities and their performance in science examinations.

H_0**:** There is no statistically significant relationship between the amount of time students spend on laboratory activities and their performance in science examinations.

Conceptualizing Laboratory Activities in Science Education

Laboratory activities constitute a central component of science curricula, providing students with authentic opportunities to conduct experiments, record observations, manipulate scientific equipment, and engage in inquiry-based investigations. Such hands-on experiences are crucial for fostering deep conceptual understanding, as they enable learners to explicitly connect theoretical principles with practical scientific methodologies (Hofstein & Lunetta, 2004). Beyond domain-specific knowledge, laboratory work develops essential skills, including accurate measurement, systematic data analysis, methodological rigor, and higher-order critical thinking, all of which are integral to scientific inquiry. Millar (2010) emphasizes that laboratory instruction is most effective when carefully designed to help students relate empirical observations to underlying scientific concepts. Furthermore, structured practical experiences positively influence learners' attitudes toward science, enhancing enthusiasm, intrinsic motivation, confidence, and sustained engagement with the subject. Therefore, both the quantity and quality of laboratory time are critical determinants of instructional effectiveness, underscoring the need to identify and implement conditions that optimize practical engagement and, in turn, improve science learning outcomes.

Importance of Laboratory Time in Enhancing Science Learning

The duration of students' participation in laboratory activities is a critical factor in promoting inquiry, reinforcing conceptual understanding, and enhancing academic achievement in science. Research demonstrates that greater exposure to practical work enables learners to grasp complex or abstract scientific concepts more effectively (Bennett, Lubben, & Hogarth, 2007). Extended, well-organized laboratory sessions provide opportunities for learners to engage in full inquiry cycles—planning experiments, conducting procedures, observing outcomes, and reflecting on results—which fosters deeper understanding and improves retention. Abrahams and Millar (2008) emphasize that practical work achieves its greatest impact when students are afforded sufficient time to manipulate materials, reflect on their observations, and relate findings to theoretical expectations. Conversely, brief or hurried sessions limit discussion, analysis, and consolidation of concepts, thereby reducing the educational value of laboratory engagement. In educational contexts characterized by low science performance, insufficient laboratory time has been identified as a significant contributing factor (Asare & Nti, 2014). Therefore, increasing students' practical exposure is not only a pedagogical imperative but also a potential strategy for enhancing science achievement, particularly in developing countries where instruction often prioritizes theoretical content over hands-on learning.

Factors Influencing Students' Engagement in Laboratory Activities

Students' engagement in laboratory activities is influenced by a combination of contextual, institutional, and instructional factors. At the school level, limitations such as insufficient laboratory equipment, scarcity of consumable materials, and overcrowded classrooms can substantially restrict opportunities for meaningful hands-on learning (Ogunniyi, 2009). Teacher-related variables—including pedagogical expertise, confidence in conducting experiments, and attitudes toward practical instruction—also play a critical role in shaping the design and implementation of laboratory sessions (Kim & Tan, 2011). Additionally, curriculum demands and time constraints often curtail the duration and frequency of practical activities, as educators must navigate the tension between covering extensive theoretical content and providing adequate laboratory experience (Onwu & Stoffels, 2005). In some educational systems, examinations that prioritize theoretical knowledge further disincentivize teachers from allocating sufficient time to practical work, thereby limiting students' exposure to experimental learning. Recognizing these barriers is essential, as they directly affect the degree to which learners can engage effectively in laboratory activities and reap the associated educational benefits

Laboratory Activities and Student Achievement in Science

A considerable body of scholarship highlights the positive influence of practical engagement on students' performance in science. Hofstein and Lunetta (2004) contend that laboratory-based instruction enhances learners' capacity to transfer and apply scientific ideas within assessment situations. Additional studies similarly demonstrate that hands-on investigations strengthen problem-solving skills and support long-term retention of scientific knowledge (Hofstein & Mamlok-Naaman, 2007). Empirical findings further indicate that increased time spent conducting experiments is often associated with higher scores on standardized science assessments (Bennett et al., 2007). Engagement in experimental work has also been linked to heightened science self-efficacy, a psychological factor shown to correlate strongly with academic achievement (Bandura, 1997).

Despite these positive trends, the magnitude of the relationship between practical work and performance is not uniform across settings, particularly in environments where laboratory facilities are inadequate or where practical activities are poorly integrated with theoretical instruction. Such variations point to gaps in the existing evidence base, especially in developing-country contexts where practical science education tends to be constrained by limited resources. This study therefore seeks to contribute to the literature by determining whether the amount of laboratory time meaningfully predicts students' science examination performance within these under-resourced educational settings.

THEORETICAL FRAMEWORK FOR THE STUDY

A strong theoretical framework is essential for explaining the mechanisms through which laboratory engagement influences science achievement. This study draws on the following theories:

Constructivist Learning Theory (Piaget; Vygotsky)

Constructivist Learning Theory, grounded in the work of Piaget and Vygotsky, posits that learners generate meaning by actively interacting with their environment rather than absorbing information passively. Within this perspective, laboratory experiences provide authentic contexts in which students can explore materials, test ideas, and revise their thinking through inquiry-oriented actions. Such engagement reflects Piaget's (1970) view that cognitive growth occurs as learners encounter situations that challenge existing mental structures, prompting processes of assimilation, accommodation, and the attainment of new equilibrated understandings. Vygotsky's (1978) socio-cultural lens further expands this view by emphasizing the role of social interaction in learning; laboratory group work encourages peer dialogue, guided support, and co-construction of meaning within the zone of proximal development. Consequently, extended time spent in laboratory investigations becomes a crucial mechanism for deepening students' learning, as it promotes both individual cognitive restructuring and socially mediated knowledge development.

Experiential Learning Theory (Kolb, 1984)

Kolb's Experiential Learning Theory frames learning as a continuous, cyclical process in which individuals move through four mutually reinforcing phases. It begins with concrete experience**,** where learners directly engage with unfamiliar situations; progresses to reflective observation**,** involving deliberate contemplation of the experience; advances to abstract conceptualization**,** during which reflections are transformed into broader principles or theoretical understandings; and culminates in active experimentation**,** where these newly formed ideas are applied and tested in real contexts (Kolb, 1984). Science laboratory work naturally aligns with each phase of this cycle. Students interact physically with materials and procedures, generating first-hand experiences; they then assess and interpret their observations, formulate underlying explanations or hypotheses, and finally apply these insights by designing or modifying experimental procedures. Providing students with sufficient laboratory time ensures that they complete the full experiential sequence, thereby strengthening the depth of conceptual understanding, improving analytical and investigative skills, and ultimately contributing to stronger performance on science-related academic tasks (Kolb, 1984; Moon, 2013).

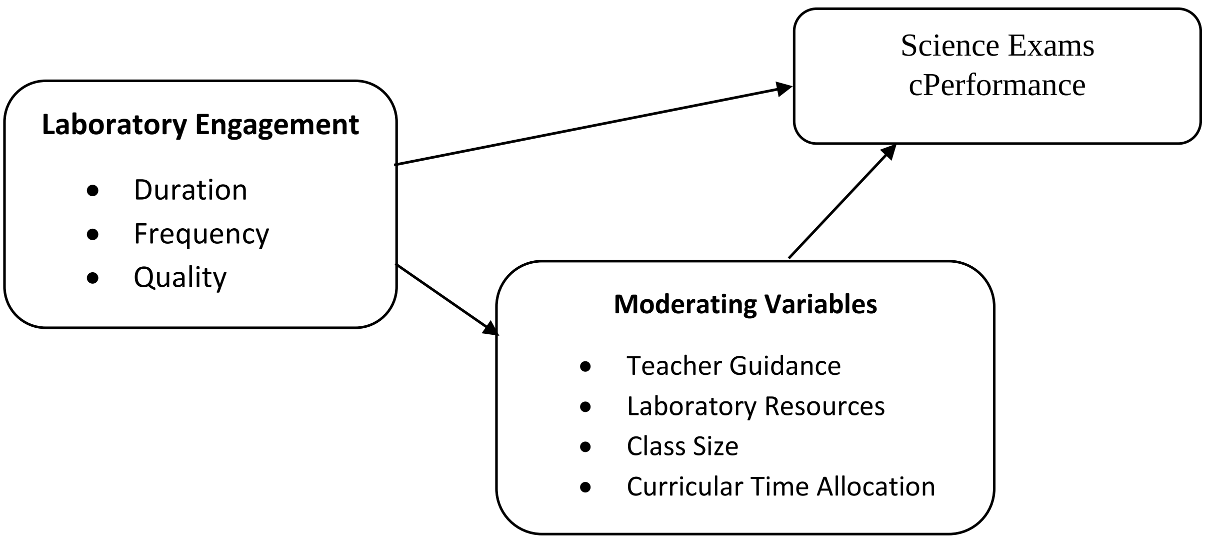
Time-on-Task Theory (Carroll, 1963)

Carroll's Model of School Learning proposes that student achievement is largely a function of the proportion of time learners devote to academic tasks relative to the amount of time they need to fully master those tasks. In this model, learning improves when the time available for engagement aligns with the time required for comprehension, suggesting that increased exposure to meaningful instructional activities strengthens learning outcomes (Carroll, 1963). Within this framework, extended participation in hands-on scientific laboratory work offers repeated opportunities for practice, feedback, and the gradual internalization of skills and concepts. Such sustained engagement enhances the likelihood that students will achieve the intended learning goals by allowing them to revisit procedures, refine their understanding, and correct misconceptions. Therefore, the present study is grounded in the assumption—supported by empirical evidence—that increased laboratory time is a significant predictor of improved academic performance in science, as numerous studies have demonstrated a strong association between time-on-task and gains in measurable student achievement (Carroll, 1963; Fisher & Berliner, 1985)

Synthesis of Theoretical Framework

Integrating insights from constructivist theory, experiential learning models, and time-on-task perspectives, the theoretical framework argues that laboratory work provides a fertile context in which learners actively build scientific understanding through hands-on engagement and reflective analysis. Constructivist perspectives emphasize that meaningful knowledge emerges when learners interact directly with phenomena and reorganize their thinking (Piaget, 1970; Vygotsky, 1978), while experiential learning theory highlights the importance of cycling through concrete experience, reflection, conceptualization, and experimentation (Kolb, 1984). Time-on-task research further underscores that adequate instructional time is essential for mastery and sustained academic growth (Carroll, 1963). When these principles are combined, laboratory sessions become critical learning spaces that allow students to investigate scientific problems, reflect on outcomes, and refine conceptual understanding over sufficient periods of engagement. As a result, extended participation in laboratory activities strengthens conceptual depth, improves scientific reasoning and technical skills, and translates into higher achievement on formal science assessments. This integrative stance therefore positions meaningful laboratory engagement as a central mechanism linking experiential processes with measurable academic performance.

CONCEPTUAL FRAMEWORK



The conceptual framework guiding this study illustrates the anticipated relationship between students' engagement in laboratory activities and their achievement in science examinations, while also acknowledging the role of key instructional and contextual influences. Drawing on Constructivist Learning Theory (Piaget, 1970; Vygotsky, 1978), Experiential Learning Theory (Kolb, 1984), and Time-on-Task Theory (Carroll, 1963), the framework provides an integrated lens for understanding how practical, hands-on learning experiences shape academic outcomes. At the core of the model is the independent variable—time allocated to laboratory activities—which captures the duration, frequency, and quality of students' participation in practical sessions and reflects the depth of experiential engagement. Previous empirical work indicates that sustained involvement in laboratory tasks supports experimentation, reflection, and conceptual consolidation, thereby strengthening scientific understanding. The dependent variable is students' performance in science examinations, typically assessed through standardized tests or formal school assessments, and is expected to improve when laboratory engagement enhances conceptual mastery, analytical thinking, and the application of scientific principles. The framework also incorporates moderating variables such as teacher guidance, availability of laboratory resources, class size, and curricular time allocation, all of which can either facilitate or constrain the effectiveness of laboratory learning. These factors may shape the extent to which increased laboratory time translates into measurable academic gains. Overall, the framework posits that well-structured and adequately supported practical activities deepen students' understanding and motivation, ultimately leading to higher examination performance, while contextual conditions determine the strength of this relationship.

Study Gaps

Despite the acknowledged advantages of laboratory activities in science education, significant gaps remain in the research that justify this study. Most existing studies focus on the mere presence of practical work rather than quantitatively examining how the duration of laboratory engagement influences learning outcomes, with limited empirical evidence directly linking time spent in the lab to science examination results. Additionally, the literature predominantly reflects research from well-resourced, high-income countries, leaving a contextual void regarding the effectiveness of laboratory activities in resource-constrained settings such as sub-Saharan Africa and Ghana. Methodologically, there is a scarcity of mixed-methods research that combines quantitative data with qualitative insights into students' experiences and perceptions, hindering a comprehensive understanding of laboratory work's impact. Furthermore, critical moderating factors such as teacher preparedness, availability of laboratory resources, class size, and curriculum allocation remain underexplored, despite their potential to influence the relationship between practical engagement and student achievement. Finally, while laboratory work is known to enhance conceptual understanding, few studies explicitly investigate its link to high-stakes examination performance, resulting in uncertainty about its effect on measurable academic success.

METHODOLOGY

Research Paradigm

This study was anchored in the pragmatic research paradigm, which recognizes that no single methodological tradition is sufficient for addressing complex educational problems. Pragmatism emphasizes the use of multiple approaches to generate practical, contextually relevant evidence. It was adopted because the study aimed not only to measure the statistical relationship between laboratory engagement time and students' achievement but also to understand how learners and teachers interpret the contribution of practical work to science learning. The paradigm therefore enabled the integration of quantitative measurements with qualitative explanations, allowing for a richer and more nuanced understanding of how laboratory experiences influence performance in science examinations.

Research Design

A convergent mixed-methods design was employed to obtain complementary insights into the influence of laboratory engagement on students' science performance. This design allowed quantitative and qualitative data to be collected concurrently, analyzed separately, and merged during interpretation to enhance the validity of the conclusions. The quantitative strand utilized a correlational survey approach to determine whether variations in time spent on laboratory activities statistically predict differences in examination scores. In parallel, a qualitative descriptive case study design was used to explore how contextual conditions such as teacher preparedness, availability of equipment, and class size shape the nature and effectiveness of laboratory sessions. The convergence of these designs enhanced the depth and credibility of the findings.

Population and Sampling

The study population consisted of all science students and science teachers within the selected educational district. From this population, a representative sample was obtained using multiple sampling strategies. Schools were first stratified based on resource availability to ensure that different institutional contexts were captured. Students were then selected through simple random sampling to allow equal chances of participation, while teachers and specific student groups with direct laboratory experience were purposively chosen for interviews and discussions because of their ability to provide in-depth perspectives. This combination of probability and non-probability sampling ensured a balanced sample for both quantitative and qualitative components.

Data Collection Instruments

Data were collected using four main tools: structured questionnaires, an examination score checklist, semi-structured interview guides, and laboratory observation schedules. The questionnaire gathered information on students' duration, frequency, and perceived quality of laboratory engagement. The examination checklist recorded standardized performance scores from school assessments to quantify academic achievement. The interviews elicited students' and teachers' reflections on how practical activities shape understanding, motivation, and examination preparation. Direct observations were conducted in laboratory sessions to document the actual amount of time spent on tasks, the level of hands-on involvement, and the adequacy of available resources. These diverse instruments provided robust and triangulated evidence.

Validity and Reliability

To ensure the credibility of the instruments, all tools underwent expert review to establish content and construct validity. Feedback from science education specialists guided revisions that improved clarity, appropriateness, and alignment with the study variables. A pilot test was conducted in a comparable school to refine ambiguous items and assess instrument performance. Reliability for the quantitative measures was determined using Cronbach's alpha, with coefficients of 0.7 or higher accepted as satisfactory. For the qualitative tools, reliability was enhanced through repeated reviews of field notes, triangulation of data sources, and consistent coding procedures. These processes strengthened the overall trustworthiness of the study.

Ethical Considerations

Ethical standards were strictly upheld throughout the study. Permission was obtained from relevant educational authorities and school administrations before data collection commenced. All participants were informed about the purpose of the study and provided consent voluntarily. Confidentiality was ensured by anonymizing responses and securing all collected data. Participation was entirely voluntary, and individuals were assured that they could withdraw at any point without consequences. These ethical procedures safeguarded the rights, dignity, and privacy of all participants and promoted openness during the data-gathering process.

Data Analysis

Quantitative data were analyzed using both descriptive and inferential techniques. Descriptive statistics summarized students' laboratory engagement patterns, while Pearson correlation and multiple regression analyses were used to examine the strength and predictive value of laboratory time in relation to science performance. Qualitative data from interviews, focus groups, and observations were transcribed and subjected to thematic analysis, which involved coding responses, identifying recurring patterns, and interpreting how participants made sense of their laboratory experiences. The results of both strands were then integrated, enabling the researcher to cross-validate findings, compare converging insights, and produce a richer interpretation of how laboratory time influences examination outcomes.

Table 1 presents descriptive statistics summarizing students' engagement in laboratory activities and their corresponding performance in science examinations. These statistics provide an overview of the central tendencies, variability, and general patterns in students' laboratory participation, practical exposure, and contextual factors such as access to resources and teacher support. Examining these descriptive measures allows for a preliminary understanding of how laboratory experiences relate to academic outcomes.

Table 1:Descriptive Statistics of Students' Laboratory Engagement and Science Performance

Variable	**N**	**Minimum**	**Maximum**	**Mean**	SD	**Interpretation**
Weekly Laboratory Hours	200	1	6	3.45	1.12	Moderate engagement
Number of Experiments Cond'ucted	200	2	15	7.68	3.14	Moderate practical exposure
Science Exam Scores (%)	200	40	95	71.23	12.45	Average performance

Laboratory Resources Rating(1–5)	200	1	5	3.12	0.98	Fair resources
Teacher Support Rating(1–5)	200	2	5	3.87	0.83	Generally supportive

Note: N = Number of students surveyed; laboratory hours and experiments represent independent variables; exam scores are the dependent variable.

As shown in Table 1, students reported a moderate level of weekly laboratory engagement (Mean = 3.45 hours, SD = 1.12) and conducted a moderate number of experiments (Mean = 7.68, SD = 3.14) over the study period. Average performance on science examinations was **71.23%**, indicating generally satisfactory achievement among participants. Ratings for laboratory resources were **fair (Mean = 3.12, SD = 0.98)**, suggesting some limitations in available equipment and materials, whereas teacher support was generally perceived as positive (Mean = 3.87, SD = 0.83), highlighting the importance of instructional guidance in facilitating laboratory learning. These descriptive insights establish a foundation for subsequent inferential analyses examining the relationships between laboratory engagement and academic performance.

Table 2 presents the Pearson correlation coefficients examining the relationships between students' laboratory engagement—measured by weekly laboratory hours and the number of experiments conducted—and their performance on science examinations. This analysis provides insight into the strength and direction of associations among these key variables

Table 2:Correlation Between Laboratory Engagement and Science Performance

Variable	Weekly Laboratory Hours	Number of Experiments	Science Exam Scores
Weekly Laboratory Hours	1		
Number of Experiments	0.68**	1	
Science Exam Scores	0.54**	0.49**	1

Note: p < 0.01; Pearson correlation used. Results indicate a significant positive relationship between laboratory engagement and science exam performance.

As indicated in Table 2, there are significant positive correlations between all measures of laboratory engagement and science exam scores. Specifically, weekly laboratory hours were strongly correlated with the number of experiments conducted ($r = 0.68$, $p < 0.01$), suggesting that students who spent more time in the laboratory also engaged in a greater number of practical activities. Both weekly laboratory hours ($r = 0.54$, $p < 0.01$) and the number of experiments conducted ($r = 0.49$, $p < 0.01$) showed moderate positive relationships with science exam performance. These findings imply that higher levels of laboratory engagement are associated with better academic outcomes**,** supporting the hypothesis that active participation in practical work contributes to enhanced conceptual understanding and performance in science.

Table 3 presents the results of a multiple regression analysis examining the predictive effects of laboratory engagement (weekly laboratory hours and number of experiments), teacher support, and laboratory resources on students' science exam scores. This analysis assesses the relative contribution of each variable in explaining variance in academic performance, providing insight into which factors most strongly influence science achievement.

Table 3: Multiple Regression Predicting Science Exam Scores

Predictor Variables	**B**	**SE B**	**β**	t	P
Weekly Laboratory Hours	4.12	0.78	0.42	3.45	<0.001
Number of Experiments	1.85	0.65	0.21	5.28	0.005
Teacher Support	2.14	0.89	0.18	2.85	0.017
Laboratory Resources	1.03	0.77	0.09	1.34	0.183

Interpretation: Weekly laboratory hours and number of experiments significantly predict science performance; teacher support has a moderate effect, while resource availability was not statistically significant.

As shown in Table 3, weekly laboratory hours emerged as the strongest predictor of science exam scores ($\beta = 0.42$, $p < 0.001$), indicating that students who spent more time engaged in laboratory activities tended to achieve higher academic performance. The number of experiments conducted also significantly predicted exam scores ($\beta = 0.21$, $p = 0.005$), as did teacher support ($\beta = 0.18$, $p = 0.017$), highlighting the importance of instructional guidance in reinforcing practical learning. In contrast, laboratory resources did not significantly predict performance ($\beta = 0.09$, $p = 0.183$), suggesting that while adequate resources are necessary, they may not directly influence achievement when other factors like engagement and support are present. Overall, the regression results underscore the critical role of active participation and teacher support in maximizing the benefits of laboratory work for student learning outcomes.

Table 4 presents the results of a thematic analysis of qualitative data collected from students regarding their perceptions of laboratory engagement. The analysis identifies key themes, sub-themes, and illustrative quotes that provide rich, contextual insight into how students experience and interpret practical science activities. This qualitative evidence complements the quantitative findings by highlighting the factors that facilitate or hinder effective learning in laboratory settings

Table 4:Thematic Analysis of Qualitative Data (Students' Perceptions of Laboratory Engagement)

Theme	Sub-Themes	Illustrative Quotes	Interpretation
Value of Laboratory Work	Understanding Concepts	I understand better when I see the experiment myself rather than just reading in the book."	Students recognize labs as enhancing comprehension.
	Problem-Solving Skills	Experiments help me figure out solutions on my own."	Practical work develops independent problem-solving.
Time Constraints	Short/Insufficient Sessions	"Sometimes the lab is too short, and we don't finish the experiment properly."	Limited time reduces learning effectiveness.
	Rushed Schedules	Teachers hurry us to finish because of exams."	Curriculum pressure undermines deep engagement.
Resource Challenges)	Equipment and Consumables	Some apparatus is broken or missing, so we repeat experiments mentally	Poor resources affect practical engagement.
Teacher Support	Guidance and Feedback	Teachers explain carefully and guide us through the steps, which helps a lot	Teacher facilitation enhances learning in labs.
Motivation and Engagement	Increased Interest in Science	I enjoy science more when I do experiments; it makes learning fun."	Practical work boosts intrinsic motivation and engagement

As shown in Table 4, students recognize several benefits and challenges associated with laboratory work. The value of laboratory work emerged as a prominent theme, with students reporting enhanced conceptual understanding and the development of independent problem-solving skills. Time constraints**,** including short sessions and rushed schedules, were frequently cited as barriers that limit the depth of learning. Resource challenges, such as broken or missing equipment, also negatively affect practical engagement. Conversely, teacher support, characterized by guidance and feedback, was highlighted as a crucial factor that facilitates effective learning. Finally, motivation and engagement were strongly influenced by hands-on activities, with students expressing increased interest and enjoyment in science when actively participating in experiments. These qualitative insights underscore the importance of sufficient laboratory time, instructional support, and adequate resources in promoting meaningful and engaging science learning experiences.

Summary of Key Findings

The study revealed that active engagement in laboratory activities is strongly associated with improved science performance. Students who spent more time in the laboratory and conducted a greater number of experiments achieved higher exam scores, highlighting the critical role of hands-on participation in learning. Teacher support emerged as another significant factor, with guidance and feedback enhancing the effectiveness of practical work. Interestingly, while access to laboratory resources is important, the amount of time students actively spent on experiments had a more pronounced impact on performance than resource availability alone. Descriptive analyses indicated moderate levels of laboratory engagement and satisfactory exam outcomes, suggesting potential for further improvement. Qualitative insights corroborated these findings, with students reporting that laboratory work enhanced their conceptual understanding, problem-solving abilities, motivation, and enjoyment of science, though time constraints and limited resources sometimes hindered deeper engagement. Overall, the integrated results underscore that extended, well-supported laboratory experiences not only strengthen academic achievement but also foster cognitive and socio-emotional development, providing a compelling case for prioritizing time, teacher facilitation, and meaningful practical exposure in science education.

Discussion

The findings of this study underscore the pivotal role of *active laboratory engagement* in enhancing students' academic performance in science. Quantitative results indicated that both weekly laboratory hours and the number of experiments conducted were positively associated with science exam scores, with weekly laboratory hours emerging as the strongest predictor. These results align with Carroll's (1963) model of school learning, which emphasizes that time-on-task is a critical determinant of learning outcomes. Similarly, Kolb's (1984) Experiential Learning Theory frames practical engagement as a cyclical process where concrete experience, reflective observation, and active experimentation reinforce conceptual understanding, supporting the observed relationship between laboratory time and academic performance.

The study also highlighted the significance of *teacher support* as a predictor of student achievement. Qualitative insights revealed that students value guidance and feedback during experiments, which facilitates comprehension and skill development. This is consistent with the findings of Kim and Tan (2011), who emphasized that pedagogical expertise and supportive instructional practices maximize the effectiveness of practical work. Vygotsky's (1978) socio-cultural theory further explains this phenomenon, suggesting that social interaction and guided support within the zone of proximal development enhance learning outcomes. In this context, teacher facilitation appears to mediate the impact of laboratory engagement on performance, bridging hands-on experience with deeper conceptual understanding.

While laboratory resources were rated as fair, they did not significantly predict performance in the regression analysis. This finding suggests that *engagement and support may outweigh mere resource availability* when it comes to improving academic outcomes, echoing the argument by Hofstein and Mamlok-Naaman (2007) that the quality and structure of practical activities are often more important than the quantity or sophistication of equipment. However, qualitative data revealed that inadequate or broken resources can limit the depth of engagement, indicating that resources still play a role in shaping students' experiences even if they do not directly predict performance.

Time constraints emerged as a recurrent challenge, with students reporting rushed schedules and short laboratory sessions. This finding resonates with Abrahams and Millar (2008), who emphasized that practical work achieves its greatest impact when students have sufficient time to manipulate materials, reflect on observations, and relate findings to theoretical expectations. Extended laboratory time allows students to revisit procedures, correct misconceptions, and consolidate learning, fostering both individual cognitive restructuring (Piaget, 1970) and socially mediated knowledge development (Vygotsky, 1978).

Qualitative data further illustrated that laboratory work enhances *motivation, problem-solving skills, and intrinsic interest in science*, corroborating previous studies linking practical engagement with positive affective and cognitive outcomes (Moon, 2013; Bandura, 1997). Students' reports of increased enjoyment and confidence in science reinforce the notion that practical experiences cultivate self-efficacy, which has been shown to correlate strongly with academic achievement.

Overall, the integrated findings demonstrate that *extended, well-supported laboratory experiences* are crucial for meaningful science learning. Active participation, guided by competent teachers and supplemented by adequate time and resources, promotes conceptual understanding, skill development, motivation, and academic performance. These results have clear implications for curriculum design, suggesting that schools should prioritize sufficient laboratory time, structured practical activities, and teacher facilitation to maximize learning outcomes in science education.

Delimitations and limitations

This study was deliberately delimited to science students and teachers in one Ghanaian educational district, focusing on the relationship between laboratory time and basic education science exam performance, with teacher support and resources as moderators, while excluding broader factors like socioeconomic status or prior achievement; the convergent mixed-methods design emphasized correlational analysis using questionnaires, exam scores, interviews, and observations over one term for feasibility. Limitations include the cross-sectional design precluding causality, self-reported Likert-scale biases despite reliable Cronbach's $\alpha \geq 0.70$, restricted generalizability from the single-district sample, and unmeasured confounders like student motivation, suggesting future longitudinal studies with diverse samples and objective measures.

Conclusion and recommendations

conclusions

This study concludes that extended time spent on laboratory activities significantly enhances students' performance in science examinations, reinforcing the critical role of practical engagement in deepening conceptual understanding and scientific skills. Teacher support further strengthens this relationship, while the availability of laboratory resources showed less impact, highlighting the importance of instructional quality and active student participation. These findings underscore the need for education systems, especially in resource-limited settings, to prioritize sufficient laboratory time and effective teacher facilitation to improve science learning outcomes.

Recommendations

- Educational authorities should increase the allocation of curriculum time dedicated to practical laboratory sessions to enhance student engagement.
- Policymakers and school administrators are encouraged to prioritize ongoing professional development for science teachers, focusing on effective laboratory instruction techniques.
- Schools ought to develop and enforce well-structured laboratory procedures to maximize hands-on learning opportunities, even when resources are limited.
- Researchers should pursue longitudinal and experimental studies that investigate the long-term effects of laboratory interventions on student science outcomes in various educational settings.

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