



Impact of Laboratory Infrastructure and Utilization on Academic Performance of STEM Fields Students in Cross River State Tertiary Institutions

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Abstract

This study examined the contribution of laboratory infrastructure and utilization on students' academic performance in STEM in some State Tertiary Institutions in Cross River State, Nigeria. The study adopted a correlational research design and was conducted in four tertiary institutions: University of Cross River State, Cross River State College of Education, Federal College of Education, Obudu, and University of Education and Entrepreneurship, Akamkpa. The population comprised 7,050 students, from which a sample of 378 students was determined using the Taro Yamane formula. Data were collected using structured instruments measuring laboratory infrastructure, laboratory utilization and academic performance. Data were analysed using mean, standard deviation, Pearson Product-Moment Correlation and multiple regression analysis at the 0.05 level of significance. The major findings showed that the level of laboratory infrastructure was moderate ($M = 2.63$, $SD = 0.95$), while laboratory utilization was also moderate ($M = 2.92$, $SD = 0.95$). Laboratory infrastructure had a positive and statistically significant relationship with academic performance, $r(376) = .46$, $p < .001$, while laboratory utilization also had a positive and statistically significant relationship with academic performance, $r(376) = .52$, $p < .001$. The correlation between laboratory infrastructure and laboratory utilization was also positive and substantial ($r = .58$, $p < .01$). Multiple regression analysis revealed that laboratory infrastructure and laboratory utilization jointly explained 35% of the variance in academic performance ($R^2 = .35$), and the overall regression model was statistically significant, $F(2, 375) = 108.82$, $p < .001$. Laboratory utilization made a stronger unique contribution to academic performance ($\beta = .39$, $p < .001$) than laboratory infrastructure ($\beta = .25$, $p < .001$). The fitted regression model was $AP = 28.41 + 0.31LI + 0.48LU$. It was concluded that laboratory infrastructure and its effective utilization are critical factors related to students' academic performance in STEM. The study further recommends increase investment on laboratory infrastructure, consumable supply, equipment maintenance; adequate and constant electrical power supply; and direct students' engagement on the operation/utilization of Science laboratories to facilitate learning.

Keywords: Laboratory infrastructure, utilization, academic performance, students of STEM, Tertiary Institution, Cross River State.

Introduction

Science, Technology, Engineering, and Mathematics (STEM) education hold a pivotal position in developing human capacity, technological ability, and innovative competence. The modern economy requires, in ever-increasing measure, graduates who can progress beyond the mere recollection of theoretical knowledge, to the application of principles of science, manipulation of technologies, identification and resolution of problems and, creation of evidence-based solutions. Thus, the quality of STEM education must not be seen simply as a matter of classroom instruction, but

crucially also, as a reflection of the contexts in which students learn and apply practical knowledge.

Laboratory and workshop activities are central to the delivery of quality STEM education and training as they offer opportunities for learners to translate abstract ideas into observable, measurable, design-able and implementable practical activities. Research continues to demonstrate that the provision of practical work is a critical component of successful science and STEM learning, even though the educational effectiveness of practical work is heavily contingent on the design

and delivery of such activities (Oliveira & Bonito, 2023).

Tertiary STEM educational engagement is often strongly dependent on laboratory based learning, for example students in engineering learn through a range of machines, equipment and systems; in Biology & Chemistry, it relies on access to experiment facilities, specimens and reagents while in Physics, equipment for experimentation and measurement instruments are needed. The Mathematics and Computer students also interact increasingly with a Computational and Technological learning environment in which their concepts relate directly to real world problems. Thus, laboratory plays role as intermediary stage between general knowledge and professional and specialized knowledge. A review by Oliveira and Bonito (2023) highlights the importance of active engagement and constructive practice as core component of laboratory education leading to students' conceptual, procedural skills and general educational development.

The effectiveness of a laboratory component of STEM education is thus intrinsically tied to the availability of supporting infrastructure. This laboratory component entails physical setup, furniture, instruments, equipment, utilities (power, etc.), safety apparatuses, consumables, and other resources necessary for practical Science Education. These resources constitute the material condition upon which practical learning among learners hinge. When inadequate, obsolete, ill-maintained or simply inaccessible facilities are put in place, the ability of the institution to offer learning-outcomes-oriented practical education becomes correspondingly limited. Such situation poses a grave concern, especially in resource-limited educational environments whereby the existence of a school laboratory does not presuppose their readiness or sufficiency to meet modern, innovative learning outcome goals of STEM education.

In Nigeria, the concerns of infrastructure shortfalls in laboratory-based STEM education can be seen in several ways. For example, Abidoye and Adedeji (2022) found that student learning outcomes challenges were predicted and contingent upon inadequate laboratory facility access and utilization of facilities in Kwara State. Similarly, Ofeimu and Asemhe (2022) in their examination of teachers' pedagogical process and student-level of performance in Biology, Chemistry and Physics identified laboratory resource adequacy and availability as predictor variables of student learning outcomes. This implies that laboratories should be treated not merely as decorative or ornamental

furniture to institutions of learning, but as instructional resources, whose adequacy and use may impact directly on the academic achievement of students.

More specifically, Abbey-Kalio (2024) reported the significant association between laboratory resource availability, utilization and accessibility on Chemistry students' academic achievement, with accessibility as strongest predictor. Akinnawonu and Yonlonfoun (2026) argued that laboratory-facility provision and utilization jointly contribute significantly to students' academic achievement in Chemistry. More specifically utilization had strong and equal significant compared to provision (both significant in regression model). This study suggests that the role of investment in the higher education will depend on not just what institution has, but use and that student should have reasonable opportunity to engage with the laboratory infrastructure and equipment/facilities provided. Utilization (how often and extensively the provided facilities are used for instructions) is another distinct but related dimension that affects and enhances the quality of practical work provided by laboratory and thus leads to student academic performance.

Utilization of laboratory is the degree or level at which the laboratory is being put to use by student for instructions, lab session, experimental work and the specific part of the equipment which is used/accessed by student(s), extent of supervision to student, availability of other materials, and extent that the provided practical sessions have been carried out for conceptual and problem solving experiences. Therefore this study aims to investigate the impact of the laboratory infrastructure and laboratory utilization on the academic performance of STEM students in four State Tertiary Institution of Cross River State, namely University of Cross River State, (UNIROSS), Cross River State College of Education, Akamkpa, Federal College of Education, Obudu (FCE Obudu), and University of Education and Entrepreneurship, Akamkpa (UEEA). The study cover students from different discipline such as; Civil Engineering, Mechanical engineering, Electrical and Electronic Engineering, Wood Work Engineering, Automobile Technology Education, Building Technology Education, Electrical and Electronic technology education, Metal Work Technology Education, Woodwork Technology Education, Computer Science /Computer Education, Biology, Chemistry, Physics and Mathematics programme which provide a good spectrum of what exist beyond a particular discipline (Akinnawonu & Yonlonfoun, 2026). A collection of these dimensions

across a diversity of STEM subjects and in various higher educational institution, established findings to support effective higher education and laboratory management practices that can ultimately contribute to the improvement of practical STEM learning in Nigeria.

Statement of the Problem

The extent to which students in the STEM programs acquire the necessary competencies depends not only on the quality of the instructional delivery of the theoretical content, but also on the opportunities they have to engage in practical experience through the functionality of laboratories, workshops and specialized facilities. Practical learning makes it possible to relate theoretical concepts to the concrete experience of observation, experimentation, measurement, modeling and problem-solving. However, it is observed that the educational value of practical work largely depends on the conditions in which it is carried out and on the extent to which it concerns in the student's learning process (Oliveira & Bonito, 2023). In spite of the importance of practicality learning, concern is voiced about the availability of and the access to well-functioning laboratory facilities.

Although, practical learning is critical, the existence of and the proper use of laboratories in educational institutions can be identified as one of the major issues. For the laboratories to exist does not ensure that students enjoy access to serviceable laboratory equipment, consumables, a safe electricity supply, safety measures and the maximum amount of personal involvement in practical activities; on the contrary, it could lead to students gaining a great deal of theoretical knowledge without the relevant practical skills in some STEM subjects. This can be an extremely alarming problem for tertiary institutions running STEM courses for the reason that they aim to graduate students who can apply subject knowledge to address real life scientific and technological issues (scientific, technical, and engineering). Issues which are equally pressing in Nigeria where students in Tertiary institutions should have a responsibility for producing the scientific and technical workforce that are essential to the progress of technological achievement and the society for its socioeconomic growth.

However, until now there is little research on the synergy between the presence of laboratory equipment, the utilization of laboratories and the academic performance among various STEM subjects in tertiary institutions, with research mainly focusing on individual Science subject or school

level laboratory facilities only. There is a considerable lack of any empirical evidence indicating whether the availability of laboratory equipment in tertiary level Science and Technology Education is intrinsically related to the academic performance gained by the students on the course concerned.

Thus, there is a lack of knowledge regarding whether the quality of the laboratory and the level of utilization of such equipment has impact on student's academic achievements in tertiary STEM programmes in particular and in general. Furthermore, there is a confusing equivalence in much discourse when issues of availability of laboratories and utilization of laboratory equipment and infrastructure are addressed: Availability does not imply quality or extent of use. An institution may, and does, have the facilities without providing students with any meaningful access or practice opportunities.

An institution with few resources can develop an education with excellent practice if laboratories and their equipment are functionally operated, well maintained and used extensively in teaching practice. In recent years, research has started to document this distinction between supply and utilization for effective teaching-learning processes, and there is growing evidence from several studies in Nigeria showing a stronger impact of use of laboratory infrastructure and equipment compared to simple physical availability on students' achievement (Akinawonu & Yonlonfoun, 2026). How much this pattern holds across a wide range of disciplines is an open empirical question. This question is particularly relevant in the State of Cross River whose students in Engineering and Technology programs, Natural Sciences, Mathematics, Computer Science, Technology Education rely on laboratory and workshop spaces to acquire and practice the skills required in those disciplines.

The problem addressed by this study, therefore, is the limited empirical understanding of whether the adequacy of laboratory infrastructure and its actual utilization are significantly related to the academic performance of STEM students in tertiary institutions. Without such evidence, institutional decisions concerning laboratory investment may focus predominantly on the provision of facilities without sufficient attention to their functionality, accessibility, maintenance and actual educational utilization. The present study consequently examined laboratory infrastructure and laboratory utilization and determined their individual and joint relationships with academic

performance among STEM students in four tertiary institutions in Cross River State, Nigeria.

Aim and Objectives of the Study

The general objective of the study was to examine the impact of laboratory infrastructure, laboratory utilization and academic performance of STEM students in selected tertiary institutions in Cross River State.

Specifically, the study sought to:

- i. assess the level of adequacy of laboratory infrastructure available to STEM students in the selected tertiary institutions in Cross River State.
- ii. determine the extent of utilization of laboratory infrastructure among STEM students in the selected tertiary institutions in Cross River State.
- iii. examine the relationship between laboratory infrastructure and academic performance of STEM students in the selected tertiary institutions in Cross River State.
- iv. determine the relationship between laboratory utilization and academic performance of STEM students in the selected tertiary institutions in Cross River State.

Research Questions

The following research questions guided the study:

- i. What is the level of adequacy of laboratory infrastructure available to STEM students in the selected tertiary institutions in Cross River State?
- ii. To what extent is laboratory infrastructure utilized by STEM students in the selected tertiary institutions in Cross River State?
- iii. What relationship exists between laboratory infrastructure and academic performance of STEM students in the selected tertiary institutions in Cross River State?
- iv. What relationship exists between laboratory utilization and academic performance of STEM students in the selected tertiary institutions in Cross River State?

Research Hypotheses

The following null hypotheses were tested at 0.05 level of significance:

- i. Laboratory infrastructure and laboratory utilization do not

significantly predict the academic performance of STEM students in the selected tertiary institutions in Cross River State.

- ii. There is no significant difference in the predictive contribution of laboratory infrastructure and laboratory utilization to the academic performance of STEM students in the selected tertiary institutions in Cross River State.

Literature Review

Conceptual Review

Laboratory Infrastructure in STEM Education

The notion of a laboratory infrastructure refer to physical and material facilities provided in Science, Technology, Engineering and Mathematics (STEM) Education as basis for practical teaching and learning. In the context of this study, Laboratory Infrastructure goes beyond the physical provision of a laboratory building. This includes functionality of laboratory furniture, instruments, equipment, electricity, ventilation system, safety measures and supplies, workspace and other laboratory required resources to make practical work meaningful. This definition is imperative because it a laboratory can exist but yet it remains inadequate educationally; If, there is absence of or defect or obsolete or inaccessibility of the necessary facilities and equipment that should be found in a laboratory.

The necessity of laboratories in teaching STEM is because of nature of STEM Education; it require a different context of teaching and learning than that of other disciplines in the sense that its students requires opportunities to make their own discoveries of phenomenon; practice of practical skills. The notion of a laboratory infrastructure goes hand- in- hand with teaching and learning facilities for which is used for teaching and learning STEM. Thus a lack of Laboratory Infrastructure in the teaching and learning would cause inconsistency between theoretical teachings and practices application by the students. Oliveira and Bonito (2023) in their review of practical work in science education show that practical activity occupy an important position in school science education, which connects student with the phenomenon and promotes practical and conceptual learning.

Oliveira and Bonito (2023) also noticed the limitations in practice. They found out that laboratory learning cannot be assumed to take place based solely on the use of practical activity. A good laboratory infrastructure comprises adequacy, functionality and accessibility. Adequacy is related to the availability of the quality and quantity of a

particular facilities or material/items for a number or category of student. Functionality relates to the actual state of a particular facilities, materials or items to provide certain service. This involves workability and ability to meet requirement. Accessibility is the extent to which a school student could get to the facilities which the school has for learning/training during the training. This concept is of much important in the Higher Institution that are known for large students' population and sometimes specialized laboratories.

Recent study in Nigeria have provide more evidence on these, thus adequacy and utilization were found to be lowest among the students as far as lab-oratory items in public school in Edo North Senatorial District and, also these are found to predict the outcome of students at learning Chemistry, Physics and Biology (Ofeimu and Asemhe 2022). Likewise, a similar study among some Nigeria undergraduate found that availability of, accessibility of and use of laboratory resource had a significant effect on academic achievement of Chemistry students and accesibility was the most potent variable among laboratory resource (Abbey-Kalio 2024). From these studies, laboratory infra-structure may then be seen to be an educational resource whose value lies in ability to actualize learning. This implies that money institution spends on labs in STEM Education can only be measured by the extent to which these facilities contribute to student's performance and these should go beyond the acquisition of items and buildings alone but should embrace their up keep, use, replacement of old materials etc and electricity of the laboratory.

Laboratory Utilization and Practical Engagement

Laboratory utilization is defined as the extent of use of the available laboratory facilities, equipment and resources for teaching and learning purposes. This includes the frequency with which labs practical sessions are held, how accessible the facilities are, opportunities that students have for working with the laboratory equipment or facilities, the incorporation of practical activities into classroom teachings, and supervising students engaged in laboratory work. Therefore, utilization is the conversion of the physical infrastructure of laboratories to a practical learning environment. The differentiation between provision and utilization has critical implication.

Availability of resources such as equipment doesn't necessarily means its effective use which can be limited by insufficient, poorly used laboratory schedule or limited student access time. Conversely

well-planned utilization is crucial, regardless of whether resources are adequate or limited. Active participation in experiments in practical works has gained significant research attention. The literature suggests that the utility of laboratory work for knowledge acquisition, practical skill development, and overall academic achievement is dependent on the pedagogical conceptualization and management of practical activities. Thus, measuring laboratory utilization, the frequency of laboratory session alone might not be the correct indicator for measuring student's utilization of their labs. Students' active engagement and its nature in laboratory work are also equally important (Oliveira and Bonito 2023). Cheung and Sonkqayi (2025) conducted a research on the association between practical-work Frequency and clarity of Instruction with student achievement in three Science cognitive domains among 3,265 students taking Trends in International Mathematics and Science Study (TIMSS 2019). Importantly the study's operationalization distinguished three different outcomes related to knowledge: knowing, applying and reasoning, instead of conceptualizing them into an undifferentiated measure of Science performance.

Their finding offer empirical support for the idea that laboratory practice has the potential to explain variations across different cognitive outcomes in science. Similar trends have been observed in Nigeria where Abbey-Kalio (2024) revealed a correlation between the lab availability, accessibility and utilization and Chemistry students' Academic Achievement. Similarly Akinlawon and Yonlonfoun (2026) observed significant joint and relative contributions between provision of and Utilization of Chemistry laboratories to students' Academic Achievement in Ogun State Nigeria. The similarities in findings emphasized the point that the educational question about laboratories availability should extend to actual utilization by students.

Academic Performance in STEM Education

Academic performance indicates the extent to which students meet intended learning outcomes when assessed. Specifically, within STEM education, the term Academic performance refers to how well the students grasp concepts, apply concepts to new situation, can solve problems, reason analytically and, where appropriate, demonstrate skill in an appropriate operation. Although the amount that students memorize during an examination is frequently taken as a measure of their performance in the disciplines, whereas the discipline needs to be understood in much broader terms than simple memorization.

The ability for students to relate statements to an observable empirical reality is central to understanding the role of practical education in students' learning; an educational opportunity for students to test a theoretical proposition and establish cause and effect links. Such links could in many cases be difficult or impossible to draw otherwise from lecturing alone. Empirical evidence supporting this contention comes from Cheung and Sonkqayi (2525), who discovered that laboratory-related experiences and the intelligibility of teaching predicted achievement in different aspects of cognitive learning in Biology, Science and Technology. Research in Nigeria also supports this view, and the findings it revealed is however not entirely coherent. Again, Ofeimu and Asemhe (2022) discovered that laboratories equipment adequacy and utilization was predictive of students learning outcomes in Physics, Chemistry and Biology. Similarly, Abbey-Kalio (2024) identified significant correlation between laboratory resources related variables and students' academic achievement in Chemistry in Osun State.

In contrast, an investigation in Calabar was conducted by Neji and Nuoha (2015) and found that facilities in the Science laboratories have not be adequately utilized, and its use did not affect significantly on variance of the academic performance. Such disparity in research findings is informative. It suggest that the relationship between laboratory resources and the students' Academic performance cannot be assumed to be constant across all disciplines, and research results should therefore not necessarily be generalized and used to justify policy decisions in a particular academic context such as the tertiary institution level for Nigeria.

Theoretical Perspective

This research was founded on the Constructivist Learning theory (Piaget, 1973; Vygotsky, 1978). This theory states that learners construct knowledge through the process of experiencing and engaging in learning experiences using direct hands-on manipulation of concrete learning materials (Piaget, 1973; Vygotsky, 1978). In the context of Science, Technology, Engineering and Mathematics (STEM) education, laboratory acts as an important learning environment in which students perform various experiences through concrete manipulation of learning objects/activities which in turn contribute to students learning and academic achievement. Therefore, adequate laboratory infrastructure and appropriate laboratory

utilization cannot be overemphasized for constructivist learning to take place.

Learning according to this constructivist perspective can be viewed as the process where students construct meaning through experience and are not simply receptacles for transmitted information; knowledge is constructed rather than received as they engage in explorations of problems, phenomena, evidence, and social contexts. The argument that Laboratory learning is inherently compatible with the constructivist framework is based on the idea that practical activity directly exposes students to phenomena, and provides the opportunities for students to seek explanation and justification, formulate tentative hypotheses, collect evidence, and revise their hypotheses or explanations. In well-planned, adequately resourced laboratory environments, students are involved not just in "receiving scientific knowledge, but in scientific ways of exploring and applying that knowledge" (Reece & Collins, 2014).

From the context of this study, constructivist theory is highly relevant in explaining the relationship between laboratory infrastructure and usage. The construction is dependent on the adequate resources in the laboratory that acts as the environment wherein students learn better via engagement or application whereas utilization reflects the usage in the learning process. So, although the infrastructure can be adequate but if utilized inappropriately, constructivist learning might be limited compared to where laboratory infrastructure resources are average. The laboratory could therefore be adequately utilized to favor the constructivist nature of learning through direct material manipulation, explanation seek, exploration and validation. Ofeimu and Asemhe (2022) made a conscious attempt at investigating the adequacy and use of laboratory equipment within constructivist theory; and their findings revealed that laboratory resources predicted learning performance indicate the usefulness of laboratory activities for the learning of constructivism.

Constructivist Learning Perspective

Empirical Review

Laboratory Infrastructure and Students' Academic Performance

Research indicates generally that a higher resource availability correlates with student success in laboratory environments, but to varying degrees of magnitude and consistency. In Nigeria, Abidoye et al. (2022) sought out evidence as it related to the relationship between the presence of laboratory

facilities and students' performance in Upper Basic Schools, in the Kwara State. Their study sought specifically to discover the relationship between availability of laboratory facilities and academic performance among Basic Science teachers, it lends evidence toward a relationship between laboratory facilities availability and students' academic performance. Ofeimu and Asemhe (2022) provide more compelling evidence using the predictive abilities of appropriateness of laboratory equipment and usage in relating them to students' success in their laboratory experiment work in the Edo North Senatorial District. The study used 320 learning centers and a sample of 1,320 senior secondary students; students learning outcome predictor tested through multiple regression statistics showed that appropriates and appropriateness of equipment/utilization were found in low quantity, usage and appropriate access predict strongly to student's Science performance; Chemistry, Physics, and Biology.

Furthermore, to strengthen more evidence of the relationship between students' success in Science and the availability/accessibility/utilization of laboratory resources, Abbey-Kalio (2024) sought assessed the exact relationship specifically within the Chemistry courses students taking Chemistry as a learning discipline in Rivers State. Abbey-Kalio's study adopted the Pearson correlational analysis through correlating access, availability, and utilization. This analysis showed a definite and significant correlation among each variable, but found that access has the strongest correlation with academic performance. These sources combined bring forth some clear information that laboratories and the use of their resources are significant factors in academic achievement of students, however a majority of these studies focus on the secondary education sector, and a more focused examination on individual Science disciplines-such as Chemistry. The current study moves beyond this limitation and explore students performing well among disciplines of engineering, the Natural Sciences, Mathematics, Computer Science, and Technology Education at the tertiary level.

Laboratory Utilization and Students' Academic Performance

Empirical literature suggests utilization even more important than provision of laboratory facilities. According to Neji and Nuoha (2015), in a study of Chemistry students in Calabar it was revealed that laboratories were not being properly utilized and utilization was not a significant

predictor of variability in academic achievement. The significance here is that providing laboratories is not a sufficient measure of whether they have made an impact on learning outcomes. However, Ofeimu and Asemhe (2022) found both the provision and utilization of laboratories to be important predictors of learning outcomes in Chemistry, Physics, and Biology, and Abbey-Kalio (2024) has also found significant associations between the utilization of laboratories and Chemistry students' academic attainment.

The findings from the recent study by Akinlawon and Yonlonfoun (2026) is particularly informative about the relationship between the provision and utilization of laboratories and Chemistry students' academic achievement, suggesting a significant relative and joint contribution of laboratory provision and utilization. The relevance of the study to the current one is because of how it deals with provision and utilization separately, not assuming one represents the other. Similar supporting international evidence can be showed in the study of Cheung and Sonkqayi (2025), the study analyzed the TIMSS 2019 dataset from 3265 students in Hong Kong to find associations between the frequency of practical-work and student achievement within knowledge, application and reasoning Science, the relevant of the study supports the hypothesis of utilization's importance with an achievement link.

Practical Work and STEM Learning

Oliveira and Bonito (2023) systematically reviewed literature to identify ways in which practical work can bring advantages for the learning of Science. Their identified advantages include practical skills, understanding of scientific concepts, and engagement with science. However, they also documented disadvantages and criticisms of practical work. Of particular relevance to the current research, these results indicate that the benefits and set-backs of laboratory work are not inherent.

The way in which laboratory facilities or infrastructure impacts on student achievement is mediated by how it is used (e.g., what students and teachers do), the learning aims of the practical work and the specific instructions/teaching strategies employed. Cheung and Sonkqayi (2025) similarly provided evidence that shows how often other instructional conditions functions. Their work found that frequency of practical work combined with the clarity of instructional conditions impacted on students' performance in higher-order levels of Bloom's taxonomy. Laboratory utilization should be

considered within the context of other instructions teachers use to teach.

Synthesis of the Literature and Research Gap

Based on the articles reviewed, four general conclusions were drawn. Firstly, laboratory facilities are vital physical resources which form the basis for hands-on learning in STEM related fields. Secondly, laboratory resources are useful for teaching purposes to the degree to which they are accessible, utilizable and used. Thirdly, while a number of studies relate practical engagement to enhanced learning and academic performance; the empirical evidence does not perfectly align across studies, suggesting that there are factors beyond laboratory resources which translate to performance.

Regardless of these contributions, significant gaps remain in the literature on the topic. There seems to have been a much interest by Nigerian studies in the use of laboratory facilities in secondary schools, with detailed consideration given to single subject disciplines namely Chemistry, Biology and Physics. Studies involving more than one subject generally tend to focus on secondary schooling. For example, a clear focused on laboratory practices with Chemistry students in public secondary schools, not tertiary-level students in a range of STEM courses. Furthermore Ofeimu and Asemhe (2022) were concerned with use of facilities by secondary students; while Abbey-Kalio (2024) researched use of laboratories by secondary-level Chemistry students.

Another gap pertains to a wider range of STEM subjects included in research frameworks. Research has failed to empirically include engineering, technology education, natural sciences, Mathematics and Computer Science together, even though infrastructure and practicality demands are

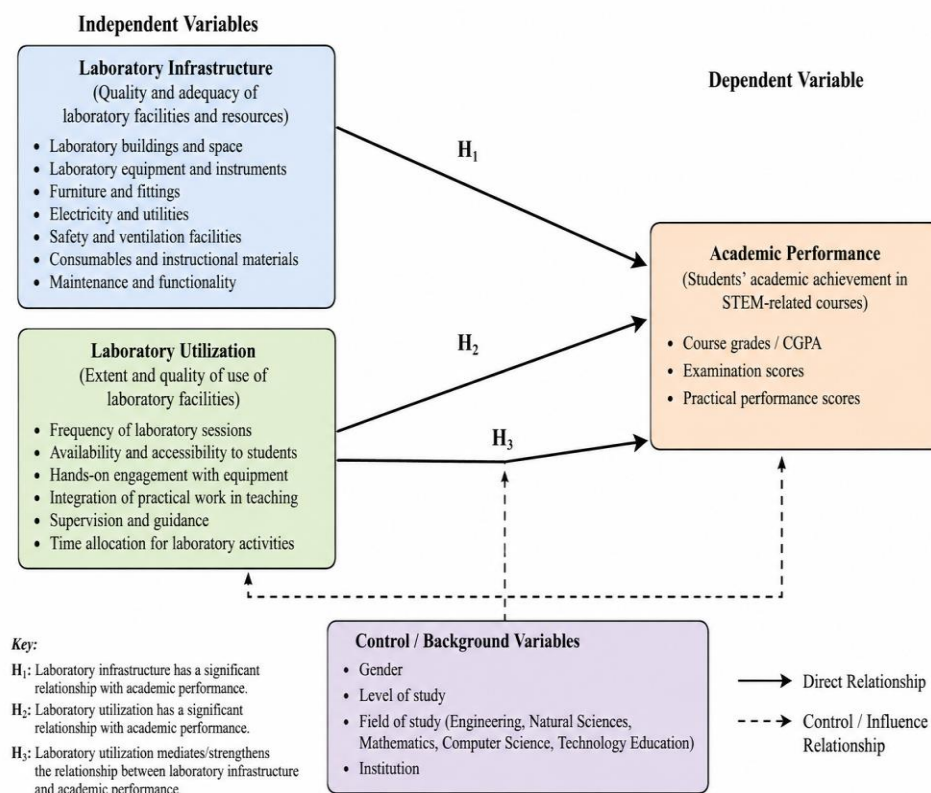
different in all these disciplines. As such the lessons learnt from China or individual science disciplines fail to represent a generalizable learning environment from a broader range of STEM student population.

A third gap is found in simultaneously analyzing infrastructure provision and use. While most recent work started distinguishing these two constructs, there have been few studies that have actually considered how infrastructure and utilization of labs can predict together the performance of tertiary students in the state. However Akinnawonu and Yonlonfoun (2026) recent findings on using provision separately is insightful but only consider it at secondary-school level and specifically Chemistry in Ogun state.

Fourthly, consideration has not yet been given to laboratory use and infrastructure in the context of tertiary institutions in Cross River State. Existing research review offered very little insight on laboratory environments where students are learning in the state's tertiary institutions in STEM courses. However tertiary students have expectations that are more advanced, as they need to develop higher levels of practical, technical, analytical and problem-solving skills.

The problem that this study set out to answer that of laboratory infrastructure, utilization and their effect on students' performance in STEM discipline among the tertiary students in Cross River State by taking into consideration four tertiary institutions. The study differs from the existing ones in three ways: it shifted the focus from secondary school to tertiary education, looked at STEM subjects as a collective instead of individual Science subjects, and analyzed infrastructure alongside laboratory utilization in a simultaneous regression model.

Fig.1 Conceptual Framework of the study



Conceptual Synthesis

The literature reviewed suggests a logical relationship among the three principal constructs of the study. Laboratory infrastructure represents the resources and physical conditions available for practical learning. Laboratory utilization represents the extent to which those resources are accessed and deployed in instructional activities. Academic performance represents the learning outcome associated with students' educational experiences.

The conceptual logic can therefore be expressed as: Laboratory Infrastructure → Laboratory Utilization → Academic Performance

with laboratory infrastructure also having a potential direct association with academic performance:

Laboratory Infrastructure → Academic Performance

This framework does not imply a deterministic causal pathway. Rather, it provides an empirical basis for examining whether better laboratory conditions and greater utilization are associated with better academic outcomes. Other variables—including instructional quality, students' prior knowledge, motivation, lecturer competence, curriculum and institutional conditions; may also influence academic performance.

The literature consequently supports investigating laboratory infrastructure and utilization as complementary dimensions rather than

treating them as interchangeable indicators. A central proposition emerging from the review is that the educational value of laboratory investment is likely to depend on the extent to which infrastructure is converted into meaningful student engagement. The present study tests this proposition within a multidisciplinary tertiary STEM context in Cross River State.

Methodology

Research Design

The study adopted a descriptive correlational research design. The design was considered appropriate because the study examined the existing state of laboratory infrastructure and its utilization and determined the relationships between these variables and the academic performance of STEM students without manipulating any of the variables or assigning respondents to experimental and control groups. Descriptive and correlational approaches are appropriate for describing naturally occurring conditions and examining relationships among measurable variables without experimental manipulation. The descriptive component of the design enabled the study to determine the level of adequacy of laboratory infrastructure and the extent of laboratory utilization in the selected tertiary institutions.

The correlational component enabled the study to determine the strength and direction of the relationships between laboratory infrastructure, laboratory utilization and students' academic performance. The independent variables in the study were laboratory infrastructure and laboratory utilization, while academic performance of STEM students constituted the dependent variable.

The design was represented as follows:

X_1 ————— Y

X_2 ————— Y

$X_1 + X_2$ ————— Y

Where:

X_1 = Laboratory Infrastructure;

X_2 = Laboratory Utilization; and

Y = Academic Performance of STEM Students.

Pearson Product-Moment Correlation was used to determine the relationships between the study variables, while multiple regression analysis was used to determine the combined predictive contribution of laboratory infrastructure and laboratory utilization to students' academic performance.

The design was considered suitable for the study because the laboratory conditions and patterns of utilization existed naturally within the institutions and were examined as they occurred, rather than being experimentally manipulated.

Area of the Study

The study was conducted in Cross River State, Nigeria, in the South-South geopolitical zone of the country. The state provided an appropriate setting for the study because of the presence of tertiary institutions offering diverse programmes in Science, Technology, Engineering and Mathematics (STEM).

The study specifically covered four tertiary institutions, namely University of Cross River State (UNICROSS), Cross River College of Education, Akamkpa, Federal College of Education, Obudu (FCE Obudu), and University of Education and Entrepreneurship (UEE), Akamkpa.

The four institutions represented different categories of tertiary educational institutions and offered a broad range of STEM-related programmes.

Their inclusion provided an appropriate basis for examining the availability, adequacy and utilization of laboratory infrastructure across different institutional and programme contexts. The University of Cross River State provided programmes in Engineering and the Physical Sciences, while Cross River State College of Education, Federal College of Education, Obudu and University of Education and Entrepreneurship, Akamkpa provided Science Education and Technology Education programmes in addition to other STEM-related disciplines. The diversity of programmes across the four institutions made the study area suitable for examining laboratory infrastructure and utilization in relation to students' academic performance.

Site of the Study

The study was conducted in STEM-related Departments, laboratories, workshops and other practical learning facilities within the three selected tertiary institutions.

At the University of Cross River State, the study covered students in Civil Engineering, Electrical/Electronic Engineering, Mechanical Engineering, Wood Products Engineering, Biology, Chemistry, Physics and Mathematics.

Civil Engineering involved areas relating to the design, construction and maintenance of physical infrastructure; Electrical/Electronic Engineering covered electrical systems, power, electronics and telecommunications; Mechanical Engineering involved the design, analysis, manufacturing and maintenance of mechanical systems; while Wood Products Engineering focused on wood Science, processing and timber technology applications. The study also covered students in Biology, Chemistry, Physics and Mathematics.

At the Cross River State College of Education, Akamkpa, Federal College of Education, Obudu, and University of Education and Entrepreneurship, Akamkpa, the study covered students in Automobile Technology Education, Building Technology Education, Electrical/Electronic Technology Education, Metal Work Technology Education, Woodwork Technology Education, and Computer Science/Education combinations, Biology Education, Chemistry Education, Physics Education and Mathematics Education. These programme areas were covered because they involved laboratory, workshop, practical or technology-supported learning activities and were therefore directly relevant to the investigation of laboratory infrastructure and utilization.

The study's focus on laboratory sites was also consistent with the original research framework, which identified laboratories and STEM Departments as the specific locations for assessing equipment adequacy, usage practices and laboratory management.

Population of the Study

The population of the study comprised 7,050 undergraduate students enrolled in the identified STEM-related programmes in the three selected tertiary institutions. The University of Cross River State had the largest population, comprising 5,500 students from 100 to 500 level. The Cross River College of Education had a STEM population of 293 from 200 to 300 level. Federal College of Education, Obudu had a population of 650 students from 100 to 300 level, while University of Education and Entrepreneurship, Akamkpa (being a new University) had a total population of 607 students from 100 to 200 level. Thus, the population of 7,050 represented the undergraduate students enrolled in

the STEM-related programmes covered by the study across the four selected tertiary institutions. The population distribution is presented in Table 3.1.

Sample Size

A sample of 378 students was used for the study. The sample size was determined from the total population of 7,050 students using the Taro Yamane sample size determination formula at a 0.05 level of precision.

The proportional distribution resulted in 295 respondents from the University of Cross River State, 35 respondents from Federal College of Education, Obudu, 32 from University of Education and Entrepreneurship, Akamkpa and 15 respondents from the Cross River State College of Education, Akamkpa. This approach ensured that the contribution of each institution to the sample corresponded approximately to its proportion of the study population. The proportionate sample and sample distribution is presented in Table 3.1.

Table 3.1: Population and Sample Distribution of Students by Institution

Institution	STEM Related Programmes Covered	Population	Sample Proportionate Distribution	The Sample
University of Cross River State, Calabar.	Civil Engineering, Electrical/Electronics Engineering, Mechanical Engineering, Wood Products Engineering, Biology, Chemistry, Physics and Mathematics	5,500	77.96%	295
University of Education and Entrepreneurship, Akamkpa	Automobile Technology Education, Building Technology Education, Electrical/Electronic Technology Education, Metal Work Technology Education, Woodwork Technology Education, Computer Science/Education, Biology Education Chemistry Education, Physics Education and Mathematics Education	607	8.61%	33
Federal College of Education, Obudu	Automobile Technology Education, Building Technology Education, Electrical/Electronic Technology Education, Metal Work Technology Education, Woodwork Technology Education, Computer Science/Education, Biology Education Chemistry Education, Physics Education and Mathematics Education	50	9.22%	35

Cross River State College of Education, Akmkpa	Automobile Technology Education, Building Technology Education, Electrical/Electronic Technology Education, Metal Work Technology Education, Woodwork Technology Education, Computer Science/Education, Biology Education Chemistry Education, Physics Education and Mathematics Education	293	4.82%	15
	Total	7,050	100	378

Sampling Technique

A multistage sampling procedure was used in selecting the respondents.

At the first stage, the four tertiary institutions were purposively selected because they offered STEM-related programmes and had laboratory, workshop or practical facilities relevant to the objectives of the study.

At the second stage, the identified STEM-related programmes were grouped according to their respective disciplines and programme areas. The programme groups included Engineering, Physical Sciences, Mathematics, Computer science and Technology Education.

At the third stage, proportionate allocation was used to determine the number of respondents selected from each institution based on its contribution to the total population of 7,050 students.

At the final stage, students were selected from the identified programmes using a simple random sampling procedure. This gave eligible students within the identified sampling frames an opportunity to participate in the study.

The multistage procedure was appropriate because the study population was distributed across three institutions and several STEM disciplines. It also facilitated adequate institutional representation while maintaining the predetermined sample size of 378 students.

Instrumentation

Data for the study was collected using three principal instruments:

- Laboratory Infrastructure and Utilization Questionnaire (LIUQ);
- Laboratory Infrastructure Observation Checklist (LIOC); and
- Academic Performance Record Extraction Schedule (APRES).

Laboratory Infrastructure and Utilization Questionnaire (LIUQ)

The Laboratory Infrastructure and Utilization Questionnaire (LIUQ) was designed to collect the data from the student respondents regarding the availability and usage of the laboratory facilities at their own programme. The questionnaires consisted of parts that relate to the main variables being investigated by the study: Part A was aimed at securing certain demographic profile of the respondents like institution, program and course of study and level.

Part B was meant to determine the variables relating to laboratory infrastructure. The statements involved items on the availability, suitability, functionality, and accessibility of the laboratory facilities, equipment, instruments, consumables, furniture, electrical supply and safety measures.

Part C was designed to examine the laboratory utilization variables of the study. The statements involve item on frequency and regularity of laboratory work, accessibility of laboratory facilities to students, availability of equipment during practical work session, students' supervision during practical work session, and participation of students in laboratory work session and utilization of laboratory activities in the teaching/learning processes.

All the questions were based on structured Likert type scale in order for the variables to be converted into quantitative data.

Laboratory Infrastructure Observation Checklist (LIOC)

The Laboratory Infrastructure Observation Checklist (LIOC) was used to obtain direct information on the physical and functional condition of laboratory and workshop facilities in the selected institutions.

The checklist covered such areas as:

- Availability of laboratory/workshop space
- Adequacy of equipment
- Availability of relevant instruments

- iv. Availability of consumables
- v. Functionality of equipment
- vi. Adequacy of furniture
- vii. Electricity supply
- viii. safety facilities
- ix. Ventilation and lighting
- x. Maintenance condition
- xi. Accessibility of facilities and
- xii. General physical condition of the laboratory or workshop.

The observation checklist provided an objective complement to the questionnaire responses by enabling the researcher to directly assess the condition and availability of laboratory facilities. The use of an observation checklist was consistent with the original methodology, which specified direct observation of laboratory facilities, equipment and consumables as one of the data collection methods.

Academic Performance Record Extraction Schedule (APRES)

The Academic Performance Record Extraction Schedule (APRES) was used to obtain students' academic performance information from available institutional academic records. The schedule was used to record the relevant academic performance measure adopted for the study. Where applicable, information relating to students' academic results in relevant STEM courses or other officially recognized academic performance indicators was extracted from institutional records. The use of institutional academic records reduced reliance on students' subjective estimation of their academic performance and was measured through document analysis of official academic results, including GPA and course grades, as a source of academic performance information.

Validity of the Instruments

The instruments were subjected to expert validation to establish their content validity and appropriateness for the study. The Laboratory Infrastructure and Utilization Questionnaire, Laboratory Infrastructure Observation Checklist and Academic Performance Record Extraction Schedule were presented to experts in Measurement and Evaluation, STEM Education and relevant science and technology disciplines.

The experts examined the instruments with respect to the relevance of the items to the study objectives, adequacy of coverage of the study variables, clarity of language, appropriateness of the response options and suitability of the instruments

for the target respondents. The observations and recommendations of the experts were used to revise the instruments before their administration. The validation process ensured that the instruments adequately represented the constructs of laboratory infrastructure, laboratory utilization and academic performance examined in the study. This was consistent with the original proposal's provision for expert validation of the research instruments.

Reliability of the Instruments

A pilot study was conducted using respondents from University of Calabar whose characteristics is similar to those of the institutions included in the main study but which was not included in the final sample. The pilot study was conducted to assess the clarity of the questionnaire items, identify ambiguous statements and establish the internal consistency of the instrument. Cronbach's alpha coefficient was used to determine the reliability of the questionnaire scales. The reliability coefficients were determined for the major dimensions measuring laboratory infrastructure and laboratory utilization and gave an overall reliability of 0.82 which indicates that the instruments were reliable.

The observation checklist was also reviewed for consistency in the application of its indicators. Where observations involved more than one research personnel, the observers were guided by the same observation criteria to promote consistency in recording laboratory conditions.

Procedure for Data Collection

The researcher first sought and was granted permission by the management of the four selected institutions, Heads of respective Departments to administer research tools, visit the relevant labs/workshops and collect academic data. Where research assistants participated, they were sensitized in regard to the aims of the research, methodology, questionnaire, observation guidelines, ethically and proper use and retrieval of completed questionnaire. A sample of 378 student subjects from the 4 institutions were selected to complete the Laboratory Infrastructure and utilization questionnaire was administered and collected by the researcher who closely monitored the entire process in order to avoid or reduce loss of tools and minimize incomplete returns.

The researcher visited pertinent labs and workshops and collected data using the Laboratory Infrastructure Observation Checklist focusing on access, adequacy and condition of facilities, equipment and consumables. Data for academic

performance was obtained by completing the Academic performance record extraction Schedule form corresponding institutions subject to their approval.

After data collection, the questionnaires, observation schedule were reviewed for completion. The collected data were then subjected to coding, entry and analysis using the Statistical Packages for the Social Sciences (SPSS) software package.

Ethical Considerations

The study also followed basic ethical research principles required when working with human subjects

- i. The research proposal was submitted to the relevant authorities of the institutions and the participating departments and written approval to carry out the research was obtained. The participants were informed of the nature and purpose of the study before being asked to participate in the study on voluntary ground.
- ii. The study ensured all information provided by respondents shall be kept confidential. The names of the respondents, were not compulsory, and the information provided were used only for research purposes.
- iii. Special care was taken when using information about academic performance obtained from the institutions' records. This data collected was meant to be used for the research study only and kept under confidentiality. The researcher had also assured the participants that the

students' academic performance shall only be used for the study and the purpose shall not be compromised in any way as a result of their participation in the study.

Method of Data Analysis

The data obtained were classified, coded and analyzed using SPSS for Social Sciences. Descriptive statistical methods, as well as inferential statistical methods, were employed.

Descriptive Statistics

Frequency counts, percentages, Means and Standard Deviations were employed to summarize the characteristics of respondents as well as to present the adequacy of laboratory infrastructure, laboratory usage, and academic performance, respectively. The descriptive results below indicate the general laboratory situation in the four educational institutions.

Pearson Product-Moment Correlation

The PPMC was used to calculate the direction and strength of relationships that exist among the variables in the study. These relationships include; Laboratory Infrastructure with Students Academic Performance, Laboratory Utilization with Students Academic Performance and Laboratory Infrastructure with Laboratory Utilization. The coefficients that emanate from this analysis served as an indication as to how they vary with one another.

Multiple Regression Analysis

Multiple Regression analysis was utilized in an effort to determine how laboratory infrastructure and laboratory utilization combine to predict students' academic performance.

Results

Research Question One

- i. What is the level of adequacy of laboratory infrastructure available to STEM students in the selected tertiary institutions in Cross River State?

This research question was analyzed with descriptive statistics (mean and standard deviation) and the results is as presented in table 2.

Table 2
Mean and Standard Deviation of Laboratory Infrastructure Adequacy

S/N	Laboratory Infrastructure Indicator	Mean	SD	Decision
1	Adequacy of laboratory/workshop space	2.84	0.91	Moderate
2	Availability of relevant equipment	2.71	0.96	Moderate
3	Availability of laboratory instruments	2.68	0.94	Moderate
4	Availability of consumable materials	2.39	1.02	Low
5	Adequacy of electrical power supply	2.31	1.05	Low

6	Adequacy of laboratory furniture	2.76	0.89	Moderate
7	Availability of safety equipment	2.43	1.01	Low
8	Adequacy of ventilation	3.01	0.87	Moderate
9	Maintenance of laboratory equipment	2.28	1.03	Low
10	Accessibility of laboratory facilities	2.87	0.90	Moderate
Grand Mean		2.63	0.95	Moderate

Table 2 indicates that the overall level of laboratory infrastructure adequacy was moderate, with a grand mean of 2.63 and standard deviation of 0.95. Ventilation recorded the highest mean score ($M = 3.01$, $SD = 0.87$), followed by accessibility of laboratory facilities ($M = 2.87$, $SD = 0.90$) and laboratory/workshop space ($M = 2.84$, $SD = 0.91$). The lowest mean scores were recorded for maintenance of laboratory equipment ($M = 2.28$, SD

$= 1.03$), electrical power supply ($M = 2.31$, $SD = 1.05$), and availability of consumables ($M = 2.39$, $SD = 1.02$).

The result suggests that laboratory infrastructure available to STEM students was moderately adequate, although important deficiencies existed particularly in equipment maintenance, power supply, consumables and safety facilities.

Research Question two

- ii. To what extent is laboratory infrastructure utilized by STEM students in the selected tertiary institutions in Cross River State?

In like manner, research question two was analyzed with descriptive statistics (mean and standard deviation) and the results is as presented in table 3.

Table 3
Mean and Standard Deviation of Laboratory Utilization

S/N	Laboratory Utilization Indicator	Mean	SD	Decision
1	Frequency of practical laboratory sessions	2.69	1.02	Moderate
2	Students' access to laboratory facilities	2.94	0.95	Moderate
3	Regular use of laboratory equipment	2.86	0.98	Moderate
4	Students' participation in practical activities	3.12	0.88	High
5	Availability of equipment during practical sessions	3.18	0.91	High
6	Adequacy of laboratory supervision	3.05	0.90	High
7	Frequency of hands-on activities	2.88	0.97	Moderate
8	Integration of practical activities into teaching	3.16	0.89	High
9	Opportunity to operate laboratory equipment	2.57	1.06	Moderate
10	Regularity of laboratory-based assignments	2.74	0.99	Moderate
Grand Mean		2.92	0.95	Moderate

The results in Table 3 indicate a moderate level of laboratory utilization, with a grand mean of 2.92 and standard deviation of 0.95. Students reported relatively high levels of practical participation ($M = 3.12$), integration of practical activities into teaching ($M = 3.16$), availability of equipment during of practical sessions ($M = 3.18$), and laboratory supervision ($M = 3.05$). However, students' opportunity to personally operate laboratory equipment recorded a comparatively

lower mean of 2.57. This finding suggest that although practical activities occurred, students do not always have sufficient individual hands-on access to equipment.

The findings indicate that laboratory infrastructure was utilized to a moderate extent, with evidence of practical activities and supervision but comparatively limited opportunities for students to independently operate laboratory equipment.

Research Question Three

- iii. What relationship exists between laboratory infrastructure and academic performance of STEM students in the selected tertiary institutions in Cross River State?

Pearson Product-Moment Correlation (PPMC) was used to determine the strength and direction of the relationships between the study variables and the result was presented in table 4.

Table 4

Pearson Product-Moment Correlation between Laboratory Infrastructure and Academic Performance

Variables	N	R	p-value	Decision
Laboratory Infrastructure	378	0.46	< .001	Significant
Academic Performance	378			

Table 4 shows a positive, moderate and statistically significant relationship between laboratory infrastructure and students' academic performance, $r(376) = .46$, $p < .001$. This indicates that students who reported better laboratory infrastructure tended, on average, to record higher academic performance. Because $r = .46$, the

relationship is positive and moderate. The statistical significance indicates that the observed relationship is unlikely to have occurred by sampling variation alone under the null hypothesis. There was a positive and statistically significant relationship between laboratory infrastructure and academic performance of STEM students.

Research Question Four

- iv. What relationship exists between laboratory utilization and academic performance of STEM students in the selected tertiary institutions in Cross River State?

Again, Pearson Product-Moment Correlation (PPMC) was used to determine the strength and direction of the relationships between the study variables and the result was presented in table 5.

Table 5

Pearson Product-Moment Correlation between Laboratory Utilization and Academic Performance

Variables	N	r	p-value	Decision
Laboratory Utilization	378	0.52	< .001	Significant
Academic Performance	378			

Table 5 indicates a positive, moderately strong and statistically significant relationship between laboratory utilization and students' academic performance, $r(376) = .52$, $p < .001$. The result suggests that higher levels of laboratory utilization were associated with higher academic

performance among STEM students. The correlation is somewhat stronger than that between infrastructure and academic performance suggesting that there is a positive and statistically significant relationship between laboratory utilization and academic performance of STEM students.

Hypothesis one

- i. Laboratory infrastructure and laboratory utilization do not significantly predict the academic performance of STEM students in the selected tertiary institutions in Cross River State.

Multiple regression was adopted for the analysis and the result presented in tables 6, 7 and 8.

Table 6

Intercorrelations among the Study Variables

Variables	1	2	3
1. Laboratory Infrastructure	1.00	.58**	.46**
2. Laboratory Utilization	.58**	1.00	.52**
3. Academic Performance	.46**	.52**	1.00



The table shows that infrastructure is positively related to utilization; infrastructure is positively related to academic performance; and utilization is positively related to academic

performance. The correlation of .58 between infrastructure and utilization means that there exist a multicollinearity between the variables.

Table 7

Model Summary for Laboratory Infrastructure and Utilization Predicting Academic Performance

Model	R	R ²	Adjusted R ²	Std. Error of Estimate
1	.59	.35	.35	6.42

The model produced a multiple correlation coefficient of $R = .59$ and an R^2 of .35. This means that laboratory infrastructure and laboratory utilization jointly accounted for approximately 35% of the variance in students' academic performance. The remaining 65% of the variance was attributable

to other factors not included in the model, random variation and measurement error. For the multiple regression, R^2 represents the proportion of variation in the dependent variable explained collectively by the predictors.

Table 8

ANOVA for Multiple Regression Model Predicting Academic Performance

Model	Sum of Squares	df	Mean Square	F	p
Regression	8,965.40	2	4,482.70	108.82	< .001
Residual	15,450.60	375	41.20		
Total	24,416.00	377			

The regression model was statistically significant, $F(2, 375) = 108.82$, $p < .001$. This indicates that laboratory infrastructure and laboratory utilization, considered jointly, significantly predicted students' academic

performance. In other words, the two predictors collectively provided statistically significant explanatory information about variations in academic performance.

Hypothesis two

- There is no significant difference in the predictive contribution of laboratory infrastructure and laboratory utilization to the academic performance of STEM students in the selected tertiary institutions in Cross River State.

Here, multiple regression was adopted for the analysis and the result presented in tables 10.

Table 10

Multiple Regression Coefficients for Predicting Academic Performance

Predictor	B	SE B	Beta (β)	t	p
Constant	28.41	2.84	—	10.00	< .001
Laboratory Infrastructure	0.31	0.07	.25	4.43	< .001
Laboratory Utilization	0.48	0.07	.39	6.87	< .001

The results show that laboratory infrastructure significantly predicted academic performance, $B = 0.31$, $\beta = .25$, $t = 4.43$, $p < .001$. Similarly, laboratory utilization significantly predicted academic performance, $B = 0.48$, $\beta = .39$, $t = 6.87$, $p < .001$. Because the standardized beta coefficient for laboratory utilization ($\beta = .39$) is larger than that for laboratory infrastructure ($\beta =$

.25), laboratory utilization made the stronger unique contribution to the prediction of academic performance in this illustrative model.

Regression Equation

$$AP = 28.41 + 0.31LI + 0.48LU \quad \dots \text{Equation (1)}$$

Where;

LI = Laboratory infrastructure and LU = Laboratory Utilization

Table 9 the regression equation $AP = 28.41 + 0.31LI + 0.48LU$ means that when laboratory infrastructure and utilization scores are zero, the predicted academic performance is 28.41. Holding laboratory utilization constant, a one-unit increase in laboratory infrastructure is associated with a 0.31-unit increase in predicted academic performance. Holding laboratory infrastructure constant, a one-unit increase in laboratory utilization is associated with a 0.48-unit increase in predicted academic performance.

Discussion of Findings

The current investigation shows that there is a consistent relationship between the laboratory environment and students' learning outcomes in STEM Programmes offered by the four tertiary institutions studied. On average, the ratings of the infrastructure of laboratories were at a moderate level ($M=2.63$), whereas utilization was also at a moderate level ($M=2.92$). More important, laboratory infrastructure and laboratory utilization were found to have a significant positive relationship with academic performance, and it is utilization which displays a greater bivariate correlation ($r=.52$) than laboratory infrastructure ($r=.46$). On further analysis of regression of laboratory infrastructure and utilization, these two combined contributed 35% variation in academic performance of students in these institutions, with utilization contributing more in this regards ($\beta=.39$) than infrastructure ($\beta=.25$).

In short, an inference was derived from the two variables that laboratory contributes to students' learning not only through availability of material and equipment but much through accessibility and utility of equipment by learners. The moderately reasonable values of laboratory infrastructure suggest a base provision of practical scientific, Technology, Engineering, and Mathematics Education, but not one sufficient to be termed complete. Practical laboratory classroom; lighting, ventilation and accessibility appear quite favourable when contrasted with maintenance issues regarding equipment, consumables; electricity and safety. The foregoing are remarkable in that they suggest the effectiveness of an applied teaching program depends upon the functioning chain; most importantly, material space should be available, safe, operational, and well-resourced with facilities. A break down in any chain results in limitation of conversion of classroom teaching into practical activities.

This contention is in tandem with that of Oliveira and Bonito (2023) who have recently conducted a study using systemic review showing the educational value of practical work relies strongly on effective implementation conditions and not just occurrence of activity. The findings align with that of Ofeimu and Asemhe (2022) that, laboratory infrastructure availability and lab utilization were strong predictor of students' academic outcome in Chemistry, Physics and Biology, Abidoye et al. (2022) and Abuo, Etorti, and Agada (2025) which highlighted the importance of facilities availability for students in learning Science. Thus the present findings that effective learning in applied education depends on facilities availability and functionality is reinforced.

Additionally, the present finding considered students from different STEM Departments. A moderate utilization is equally important to be discussed as the finding shows laboratory teaching involves the conducting of actual lab session by students but not to a large extent using instruments, measuring and controlling parameters of experiment and analyzing results of experimentation. Practical instruction carried out using demonstrations, involves students observing without any hands-on activity, thereby limiting its benefits.

The same notion is emphasized by Oliveira and Bonito (2023) that for lab activity to give the pedagogical purpose intended, it needs to facilitate the student-object interaction. As previously observed, that utilization had a higher correlate than infrastructure to academic performance of the students might be a stronger indication of value and impact that the research ascertained and achieved as it means that the infrastructure is less important compared to actual practice. The present finding aligns closely with similar result obtained from recent Nigerian context regarding the relative contributions of laboratory infrastructure and utilization to students' academic performance ($\beta = 0.398$ and $\beta = .526$) which show utilization contributed more than provision, Akinnawonu & Yonlonfoun, 2026). The moderate correlation of laboratory infrastructure and students' academic performance ($r=.46$, $p < .001$) suggests that availability and good facility can facilitate student engagement and promote students learning. It supports argument that practice in a conducive and good laboratory environment offer opportunities for students to encounter, observed, measurement and experiment with phenomena and concept of study (Cheung and Sonkqayi, 2023) and Etorti, (2026).

As such, practical activities could potentially foster the development of different skill

which includes reasoning, observation, measurement and problem solving, this makes it one of the indispensable activities in Science learning in schools, where students acquire conceptual, procedural and psychomotor skills and knowledge in Science subject. Therefore, lab utilization had a somewhat greater correlation than the lab infrastructure with academic outcomes of students ($r = .52$ $p < .001$). This reinforces previous arguments that the learning effectiveness is determined more by the frequency and the active learning experience a students have during laboratory lesson.

When a laboratory is properly equipped but if not utilized by students, if it's inaccessible to students, or, if laboratory activities are primarily for demonstrations, its educational impact on students will be meager. But if the frequency of utilization is high in a planned and methodical way it should have impact on students' learning outcome. Finding has also shown practical impact of laboratory facilities at an applicable level that should translate into learning outcomes (Akinawonu and Yonlonfoun, 2026); this also shows that there is an interdependency between infrastructure and utilization as this will have effect in whatever learning process occurs in the STEM institutions.

The result means that students had access to lab which helped their learning, but there was still room for utilization to improve learning to a greater extend due to lack of sufficient engagement. The relatively high correlation between the laboratory infrastructure and laboratory utilization ($r=.58$) lends support to the interpretation of the regression findings that improvements in the former could facilitate improvements in the latter. However, the relationship is not a perfect one, which means that the availability of good laboratory facilities in itself does not guarantee their full utilization. Institutional arrangements, teaching strategies employed by lecturers, the volume of student's enrollment, availability of consumable materials, and the level of maintenance, adequate funding and electrical provision / power infrastructure also contribute to effective utilization of these facilities.

The multiple regression result is arguably the most convincing result of this study, as the regression model for laboratory infrastructure and utilization combined predicts and explained a substantial amount of the total variance in academic performance ($r= .35$, $p< .001$). This suggests that laboratory inputs can play an important role in the academic climate of STEM students in tertiary institutions. However, the amount of unexplained variance($r= .65$) suggests that other factors including: learning resources, lecturer quality and

instructional practices, student aptitude , motivation and interest, as well as assessment policies play some role in the determination of student's academic outcomes. The present finding also corroborate with the result of Etorti (2026) that students' academic performance in Science depends on external factors or stimuli in additions to laboratory practices.

A major contribution of the study is therefore the empirical delineation of the distinction between provision of resources and use of resources, with the data demonstrating an association, rather than interchangeability. We argue that provision represents the potential of laboratories for facilitating learning, and utilization is the degree to which such potential is realized within student experiences. The superior contribution of utilization to the explanatory power of the regression equation may signify that it is the ability to make provision work, which matters most for institutional effectiveness.

Conclusion

The study investigated the impact of laboratory infrastructure and laboratory utilization on academic performance of students in the STEM related courses from four tertiary institutions in Cross River State, Nigeria. The result shows that from the analytical framework employed, Laboratory infrastructure and laboratory utilization both are important dimensions of the student's learning outcomes Science, Engineering Technology and allied-disciplines learning environment. The study's result shows that facilities provided do not have the same educational value at varying levels of availability without the opportunities for students to meaningfully utilize laboratory equipment/facilities and materials for learning.

Laboratory infrastructure was found to be moderately adequate and so was laboratory utilization moderate. This implies there are resources for laboratory teaching and learning activities, however these facilities were not fully utilized to optimize their educational value, thus creating room for a gap between the presence of the facilities and the value intended to be added to teaching and learning as suggested by existing literature that practical activities contribute to students learning effectively when it is thoughtfully design, provision of resources and implementation is such ways as actively involving learners in their experiences, Oliveira and Bonito (2023). Laboratory infrastructure and its utilization showed significant positive relationship to the students' academic performance in their STEM courses. Also,

utilization was significantly greater contributor to performance in STEM courses than infrastructure, thus, suggesting that there is something more to the equipment being available. It depends more on factors like the accessibility, number of visits, quality of supervision, hands-on exposure by student and the frequency at which student carry out experiments.

In conclusion, the study found that to develop effective STEM education in tertiary institutions there should be a paradigm shift from the simple availability of facilities to how these facilities are functioning properly, accessibility by student, and utilization by student in performing laboratory activities and how useful these activities are when students perform it with effective instructional. In addition, effort should be geared to develop the relevant mechanism for maintenance and effective distribution of materials and equipment to make functioning practical classrooms possible and also, provision of adequate service in the lab with electricity and security to support teaching and learning activities in their relevant areas.

Recommendations

Based on the findings of the study, the following recommendations are made:

- i. Tertiary institutions must give the provision and improvement of laboratory infrastructure a high priority. Care should be taken particularly in ensuring that adequate laboratory equipment, materials, consumables and facility equipment (power supply, ventilation, safety facilities etc.) needed to deliver STEM subject practical work effectively.
- ii. It is equally important that laboratories are actively used as they are made available. Institutions should schedule adequate numbers of practical course opportunities to ensure that laboratories are used throughout each working day, instead of allowing facilities and equipment to lie idle.
- iii. Student access to equipment to allow "hands on" experience should be maximized. Practical lessons should be designed to permit students to carry out experiments (as opposed to just observing demonstrations), to use equipment, collect and interpret experimental data, and to solve scientific problems.

- iv. Institutional preventive-maintenance programs should address laboratory equipment. Laboratories should maintain accurate inventories, preventive maintenance schedules, and documented functional states for major equipment within laboratories and workshops.
- v. Governments and institutional leaders must further invest in laboratory consumables. A lack of materials, consumables, and reagents undermines the educational potential of "high-tech" laboratory equipment.
- vi. Dependable electricity access and alternative power sources for laboratories must be ensured. This should be emphasized for electrical sciences, computer engineering, and various other Science and technical programs where laboratory operations rely heavily on electrical and digital equipment.
- vii. Professional development for laboratory instructors and technicians should be strengthened. This should include training in the effective and safe use and maintenance of laboratory equipment, as well as training in laboratory pedagogies and relevant new STEM technologies.

These suggestions align with established findings regarding practical work: the effectiveness of laboratory components relies heavily on their successful implementation rather than mere participation frequency (Oliveira & Bonito, 2023).

Limitations of the study

The findings of the study should be interpreted in the light of certain limitations.

- i. First, four tertiary institutions in Cross River State were chosen to provide study participants. The selected institutions encompassed a wide array of STEM degree courses and yet results from these institutions can't be expected to perfectly reflect the status of every tertiary institution in Cross River State, or Nigeria as a whole; especially those with different laboratory and funding structures.
- ii. Second, the students themselves played a primary role in evaluating the level and usage of laboratory infrastructure elements. Individual self-reports of

- infrastructure have strengths, in capturing students' perceptions of the adequacy of the facilities; however, such reports are also influenced by cognitive limitations (memory and judgment bias) and may reflect not the actual state but students' own perceptions thereof. The state of a facility as recorded by student responses therefore might not always perfectly correlate with institution-defined facility status.
- iii. Third, the cross-sectional nature of the study allowed for identification of correlations, not causal relationships. Although, clear associations exist between laboratory infrastructure, its usage and academic success, it does not allow for the assumption that enhanced infrastructure leads necessarily to enhanced learning outcomes, or that improved facility usage leads necessarily to better learning outcomes
 - iv. Fourth, academic performance is influenced by several variables beyond laboratory conditions. Factors such as students' prior academic ability, lecturer competence, teaching methods, motivation, class size, curriculum structure, assessment practices and students' socioeconomic circumstances were not comprehensively incorporated into the present model. The unexplained proportion of variance in the regression model reinforces the likelihood that other relevant determinants of academic performance exist.
 - v. Differences among disciplines could have also affected the observed results since; laboratory needs of Civil Engineering; Electrical and Electronics Engineering; Mechanical Engineering, Chemistry, Biology, Physics, Mathematics; Computer Science; and Technology Education programmes were not the same. Thus, a single aggregate estimate might not represent the infrastructural and usage needs of different disciplines.

Contribution to knowledge

The study makes several contributions to knowledge.

Firstly, it produces an empirical evidence about the linkages between laboratory infrastructure

and its actual utilization and students' academic performance in the Nigerian tertiary STEM programmes. There has been considerable work on practical work in Science Education, but limited evidence about physical adequacy and actual educational use of laboratory facilities across a range of STEM disciplines in the Nigerian University sector simultaneously. Secondly, it produces a conceptual contribution in the form of the clear differentiation of the two concepts, laboratory infrastructure and laboratory utilization.

The availability of facilities and the educational use of those facilities are theorized as distinct though related constructs, as owning laboratory facilities does not by the very fact mean students will engage with it meaningfully during practical work.

Thirdly, it produces evidence about the findings that, it might be the utilization rather than the provision of facilities which is more important from an educational point of view. The greater predictor ability of laboratory utilization in our regression models indicates that institution policies might need to focus more on efficient maintenance and optimum use, rather than on simply investing in acquiring new facilities.

Fourthly, it produces a quantitative explanatory model that describes the relationship between laboratory infrastructure, laboratory utilization and student academic performance. This provides a conceptual framework for understanding how comprehensively factors related to use of laboratory facilities influence students' outcomes, and is available for future empirical testing, revision and elaboration.

Fifthly, it produces information with practical implications for tertiary institutions and for STEM policy decision making. The evidence suggests that investment in laboratory facilities is not just about buildings and the purchase of equipment; it also involves maintenance costs, the provision of consumables, utilities such as electricity, technical staffing, student access, and ensuring productive and meaningful usage.

Sixthly, it adds to an increasingly popular and growing body of knowledge that, the productivity of practical teaching and learning in STEM education hinges on the quality of practice students actually encounter; which is compatible with the meta-analysis of Oliveira and Bonito (2023) concluding that the educational value of practical work relies on the quality of its implementation rather than its quantity alone.

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