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Inadequate Laboratory Facilities

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ABSTRACT

Inadequate laboratory facilities is the lack of functional equipment, space, reagents, and qualified personnel to man laboratories, which is a major challenge to managing science education. It has been revealed that 78% of schools lacked basic laboratory equipment, 65% had no qualified laboratory technicians, while 90% of students had not conducted up to 5 practicals in a session. There is also significant relationship between laboratory adequacy and students' performance in WAEC practical examinations. It was found that poor funding, lack of maintenance culture, and rapid student enrollment are some of the major causes of laboratory inadequacy. The paper examines the challenges to inadequate laboratory facilities and the possible or practical solutions to them to enhance national development in Nigeria.

KEYWORDS: *Laboratory facilities, academic performance, science education, Nigeria, UNESCO, WAEC/NECO, corruption, safety hazards, Sustainable Development Goal 4 (SDG 4), capital human development, STEP-B Project.*

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INTRODUCTION

Laboratory facilities are essential components of effective science, technology, engineering, medicine, agriculture, and health education. It helps to provide students, teachers, researchers, and professionals with the environment where theoretical knowledge can be tested via observation, experimentation, measurement, analysis, and problem-solving skills. In both secondary and tertiary education, practical laboratory work helps learners to develop scientific skills that cannot be acquired adequately through classroom lectures alone, as shown in Figures 1 and 2.

Inadequate laboratory facilities refer to the lack, insufficiency, poor quality, or non-functionality of laboratory equipment or total absence of equipment, materials, reagents, space, and qualified personnel required for effective practical teaching and research – which is particularly significant in developing countries, including Nigeria [1-3], as shown in Figures 3 and 4. Science and technology education largely depends on practical work for meaningful learning to take place. The adequate provision of laboratory facilities provides the platform where students test theories, develop skills, and acquire the scientific attitudes necessary for national development [1]. The problem is said to be due to poor funding, corruption, and lack of maintenance as observed by the World Bank [4, 5], leading to poor student performance in practical examinations [4], and low skill acquisition, and safety hazards [4, 5]. A laboratory is defined as a place equipped with materials, equipment, and personnel for the conduct of scientific experiments and investigations [6].

In Nigeria, many schools are known to operate with inadequate facilities. Furthermore, reports indicate that for quality science education, the ratio of students to functional laboratory equipment should not exceed 40:1 [1]. In most public secondary schools in Nigeria one microscope may serve over 100 students, and while many reagents or chemicals are either expired or completely not available [8]. Students who are taught without laboratory exposure are known to significantly score lower than those with access to functional labs [8]. Some of the factors responsible in most developing countries are poor budgetary allocation, mismanagement of funds and the lack of

maintenance culture which have led to the decay of laboratory infrastructure [2]. In Nigeria, the Federal Ministry of Education has acknowledged that laboratories lack running water, fume cupboards, fire extinguishers, and trained laboratory technicians, which poses as safety hazards to students [9]. The WHO has also warned that improvising experiments in unsafe environments can lead to chemical burns, explosions, and other accidents [7, 9].

With the drive of Nigeria toward achieving SDG 4: Quality Education and building a knowledge-based economy, the state of science laboratories must by urgently addressed, as the investment in laboratory facilities is investment in human capital development [1], as shown in Figure 5.

HISTORY

Making use of laboratories in science dates back to the 19th century during the Industrial Revolution, which was when practical work became central to scientific training. The American and European governments invested in science education after World War ll which led to well-equipped laboratories in schools and universities. The first international standard was set in 1968 by UNESCO, recommending 1 functional laboratory per 40 students and adequate supply of reagents and trained personnel [1].

However, the developing countries inherited colonial education systems that emphasized theory over practical. In this case, at independence, many African and Asian nations lacked the capital to build and maintain science laboratories. The World Bank noted that the structural adjustment programs of the 1980s further cut education budgets, leading to decay of laboratory infrastructure across Africa [4]. In Nigeria, science education received attention after the 1969 National Curriculum Conference and the introduction of the 6-3-3-4 system in 1982. Moreover, the National Policy on Education also mandated every secondary to have laboratories for Physics, Chemistry, and Biology [9]. It was during the 1970s oil boom that several federal and state government schools were equipped with laboratories via the "Universal Primary Education" and "Science Equipment Project."

In the mid-1980s, there started to be a decline due to economic recession and poor budgetary allocation, maintenance of laboratories stopped and with reagents no longer supplied [4]. As a result of this, by the 1990s WAEC Chief Examiner's Reports cited consistently that "lack of practical exposure" is the reason for the mass failure in science subjects [6].

Some donor agencies like UNESCO, DFID, and the World Bank between 2000 and 2010 intervened via the "Science and Technology Education at Post-Basic Level (STEP-B) Project." Over 100 schools were known to receive laboratory equipment. However, sustainability of the equipment was poor because there was no plan for maintenance or the supply of consumables – most of them became obsolete within 5 years [1]. This problem has continued to persist since 2015 to date despite policy provisions. It has also been revealed that over 70% of public secondary schools in Lagos State operate with inadequate or non-functional laboratories and with the common challenges of overcrowding, lack of qualified technicians, and diversion of funds meant for science equipment. The situation became worsened during the COVID-19 pandemic as schools diverted science budgets to health and sanitation needs [8].

CAUSES OF INADEQUATE LABORATORY FACILITIES

This situation is particularly significant in developing countries due to shortages of infrastructure and resources that limit the quality of science education, healthcare and scientific research. Some of the causes of inadequate laboratory facilities include:

1. Inadequate funding: Insufficient investment is a major cause of inadequate laboratory facilities, since it needs substantial funds not only for initial construction and equipment but also for the purchase of reagents, electricity, water, maintenance, calibration, replacement parts and upgrading. Inadequate fund is seen as a major constraint on the quality of education and laboratory services.
2. Poor maintenance culture: Laboratory equipment requires regular servicing, calibration and replacement of worn-out parts/components. Most often, when equipment is purchased resources are insufficient for subsequent maintenance, leading to instruments becoming obsolete or non-functional on the long run.
3. Obsolete laboratory equipment: In this case, some institutions make use of old equipment that is no longer appropriate for modern scientific training, diagnosis or research. The obsolete equipment may produce inaccurate results, frequent breakdown, and lack spare parts – this is very common in developing countries, occupying limited space and while newer or modern equipment remains unavailable.
4. Shortage of laboratory consumables: Laboratory work requires continuous supplies of chemicals, reagents, glass ware, specimen containers, protective materials and other consumables. When not purchased regularly, practical classes

and laboratory investigations are either reduced or cancelled.

5. Inadequate infrastructure: Needed for the smooth operation of a laboratory are suitable buildings, adequate space, ventilation, water supply, electricity, drainage, storage facilities and safety installations. Across Africa, inadequate infrastructure and as well as limited access to electricity are major constraints on science laboratories and STEM education.
6. Unreliable electricity supply: Modern laboratory instruments depend on stable electricity. Frequent power interruptions can prevent experiments, damage sensitive equipment and interfere with refrigeration and other essential processes. To prevent this, laboratories would require generators, solar systems, inverters or other alternative power sources, which in itself requires additional funding. Therefore, for a functional laboratory, reliable electricity is an important technical requirement.
7. Shortage of qualified laboratory personnel: Laboratory facilities cannot function effectively without trained laboratory scientists, technologists, technicians and instructors. The shortages of qualified personnel can result in underutilization of available equipment, improper maintenance and unsafe laboratory practices. Inadequate human resources and workforce training has been identified as common challenges affecting laboratory systems in low- and middle-income countries by the World Bank.
8. Poor government planning and policy implementation: Inadequate strategic planning can lead to laboratories being constructed without sufficient consideration of equipment, staffing, recurrent funding and maintenance requirements. Effective laboratory systems require coordinated policies covering infrastructure, equipment procurement, human resources, quality assurance and financing, as shown in Figure 6. Hence, weak or poor planning can produce facilities that exit physically but cannot operate effectively.
9. Rapid growth in student enrolment: The increase in student enrolment without a corresponding expansion of laboratory facilities will result in overcrowding. This will lead to the limiting of the students to handle equipment and conduct experiments themselves. The shortage of laboratory space and equipment will reduce the effectiveness of practical science education.
10. High cost of laboratory equipment: Modern laboratory equipment can be expensive to purchase, install and maintain. Some of the advanced instruments may also require specialized technicians, imported spare parts and specific environmental conditions. Therefore, for institutions with limited budgets, these costs will make it difficult to establish and continuously upgrade laboratories.
11. Dependence on imported equipment and materials: Many developing countries depend heavily on imported laboratory instruments, chemicals, reagents and spare parts. Compounding this is foreign exchange shortages, importation costs, transportation problems and delays in procurement making the materials difficult to obtain.
12. Poor procurement practices and weak governance: Inefficient procurement, poor project management and weak institutional governance can result in laboratories receiving inappropriate, substandard or incomplete equipment. Resources may also be spent on construction without adequate provision for operation and maintenance. Poor governance, poor planning and inefficient spending have been identified as contributors to infrastructure investment gaps.
13. Inadequate training of teachers and laboratory technicians: Where laboratory equipment is available, inadequate training can prevent effective utilization. There is therefore the need for teachers and technicians to receive continuous professional development to operate modern equipment, conduct experiments, observe safety procedures and perform basic repairs. The Federal Ministry of Education in Nigeria has identified laboratory personnel training, equipment repair and refresher training as important areas that require institutional attention.
14. Weak quality assurance and safety systems: Laboratories require quality-control procedures, standard operating procedures, equipment calibration and safety systems. If these are absent or poorly implemented, institutions may be reluctant to use the equipment extensively or may experience frequent breakdowns and unreliable results. This is a major challenge to laboratory capacity in low- and middle-income countries.
15. Rural and geographic inequalities: Laboratory facilities are most often concentrated in urban and well-funded institutions, while rural and disadvantaged schools may have few or even no laboratories. Geographical inequality can bring about significant differences in students' access to

practical science education cum other infrastructure.

16. Weak institutional commitment to practical education: Laboratory development may not receive adequate attention where educational institutions lay more emphasis on theoretical teaching, examinations and classroom instruction. This can lead to a cycle in which laboratories are poorly equipped, practical activities are reduced, and students graduate with insufficient hands-on experience.
17. Corruption: Corruption is one of the major structural causes of laboratory inadequacy, especially in public schools and universities. This takes different forms such as: diversion of funds, procurement fraud, ghost projects, lack of accountability, and nepotism in staffing [1, 4, 6, 7, 10-16].

SOLUTIONS TO INADEQUATE LABORATORY FACILITIES

The problem of inadequate laboratory facilities can be addressed via:

1. Increase funding for laboratory facilities: Governments, schools, universities, hospitals and other institutions need to allocate adequate and sustainable funds specifically for laboratory construction, renovation, equipment, consumables, maintenance and safety. Laboratory development should be incorporated into annual institutional budget but not on occasional emergency funding.
2. Construction and renovation of laboratories: Dilapidated, unsafe, old and overcrowded laboratories should be renovated, and while institutions without labs should construct appropriate facilities.
3. Procure modern and appropriate equipment: Needs assessment should be made by institutions before the purchase of equipment. Priority is to be given to equipment that is appropriate for the laboratory's level of operation, affordable to maintain and supported by available technical expertise.
4. Establish preventive maintenance programmes (Maintenance culture): To this end, institutions must evolve regular schedules for servicing, calibration, inspection and repair, i. e. for effective equipment management.
5. Provision of reliable electricity/other essential utilities: There is the need for dependable electricity, water, internet connectivity and appropriate environmental conditions. There is also the need for alternative power sources such as generators, solar systems, and inverters where electricity supply is unreliable or erratic.
6. Training of laboratory personnel: Laboratory technicians, teachers, researchers and students should be given regular training in equipment handling/operation, laboratory procedures, maintenance, biosafety and emergency response, since adequate facilities without competent personnel are ineffective, as shown in Figure 7.
7. Establish proper equipment management systems: Each laboratory is to maintain an up-to-date inventory of its equipment, in addition to equipment identification, location, condition, service history, calibration dates and maintenance schedules. WHO recommends equipment registers, maintenance records, usage logs and clearly assigned responsibilities.
8. Employ qualified laboratory staff and technicians: Institutions are to recruit sufficient numbers of qualified lab personnel. Where possible, an equipment officer or laboratory manager should be given the responsibility to coordinate equipment procurement, installation, maintenance, calibration and repair.
9. Improve procurement and supply-chain management: Transparent procurement procedure should be established with the adequate maintenance of stocks of reagents, chemicals, consumables, spare parts and other essential materials. Inventory systems should monitor stock levels, expiry dates and storage conditions to prevent shortages and wastage. WHO identifies effective procurement, supply-chain and inventory management as essential to maintaining reliable laboratory services.
10. Encourage partnership (Public-Private Partnership – (PPP) and external support: Governments and institutions should collaborate with universities, research organizations, industries, development agencies, professional bodies, NGOs, alumni associations, and international organizations to obtain equipment, technical assistance, training and research support. However, donated equipment should be assessed for suitability, availability of spare parts, technical support and maintenance requirements before acceptance. WHO recommends documented procedures for accepting or rejecting donated equipment.
11. Strengthen laboratory safety: Provision of appropriate personal protective equipment, fire extinguishers, first-aid facilities, emergency showers where necessary, proper chemical

storage, waste-disposal systems and clearly displayed safety procedures. Regular safety inspections should be conducted.

12. Introduce quality management systems: Institutions should establish laboratory quality-management systems covering personnel, equipment, facilities, procedures, documentation, safety, quality control and continuous improvement.
13. Monitor and evaluate laboratory facilities: Regular laboratory assessments should identify shortages in infrastructure, equipment, staffing, consumables and safety. Management should use the findings to develop improvement plans and monitor progress. External quality and periodic inspections can also help identify weaknesses that internal management may overlook.
14. Promote local production and technical support: Where feasible, countries like Nigeria can encourage local manufacture or assembly of selected laboratory equipment and consumables. Developing local technical capacity for equipment repair and calibration can help reduce dependence on foreign technicians and also shorten equipment downtime.
15. Adopt cost-effective sustainable technologies: Institutions with limited resources should prioritize durable, energy-efficient and easy-to-maintain equipment. Shared laboratories, mobile laboratories, simulation laboratories and digital/virtual laboratory technologies can supplement conventional laboratories where resources are severely constrained. However, these alternatives are to complement rather than completely replace practical laboratory experience where hands-on-training is required [7, 17-22].

THE STEP-B PROJECT

The Step-B Project was a major intervention by the World Bank and the Federal Government of Nigeria in order to address the decay in science and technology infrastructure in Nigerian secondary schools and colleges. The project was tagged: Science and Technology Education at Post-Basic Level Project which was from 2008 to 2013. The funding was from World Bank loan of $50 million and Federal Government counterpart of $12.5 million, a grand total of $62.5 million. The implementing agencies are: 1. Federal Ministry of Education, 2. The World Bank, and 3. UNESCO as technical partner.

The project target: The project target was for: 104 Federal Unity Colleges, 1,050 State Secondary Schools, 54 Colleges of Education, 36 Polytechnics, and 12 Universities.

Goal: The goal was to improve the teaching and learning of science, technology and mathematics by upgrading facilities, training teachers, and strengthening institutional laboratories.

Key components related to laboratories of the STEP-B Project

The key components are:

1. Infrastructure upgrade: This has to do with the construction and rehabilitation of science laboratories, workshops, and ICT centers in selected schools [22].
2. Procurement of equipment: This involves the supply of physics, chemistry, biology lab equipment, computers, and technical workshop tools [22].
3. Capacity building: This is the training of 15,000+ science teachers and 2,000+ lab technicians on the use and maintenance of equipment [1].
4. Curriculum support: Provision of textbooks and development of e-learning content to complement practical work [1].

Some of the achievements attained:

1. Over 800 schools received laboratory equipment packages between 2010-2012 [22].
2. 47 Colleges of Education and Polytechnics had their science labs rehabilitated [22].
3. Introduction of "School Improvement Grants" for schools to buy reagents and consumables [22].

Challenges and the reasons why the problem persisted: However, despite the investment, several studies reported that the gains were not sustained due to:

1. Poor maintenance culture
2. Corruption and diversion
3. Lack of sustainability plan, and
4. Project ended without handover [1, 8, 22].

CONCLUSION

Inadequate laboratory facilities remain a major challenge to effective teaching, learning, research, and scientific development. The lack of functional laboratories significantly contributes to the poor performance of students in science subjects. Without hands-on practical experience, students find it difficult to comprehend abstract scientific concepts, thereby negatively affecting their academic performance in both internal and external examinations. It also creates a gap between what schools produce and what the labor market demands, causing increasing unemployment and the

dependence on imported expertise. Inadequate laboratory facilities will hinder developing countries, including Nigeria's ability to achieve SDG 4: Quality Education and to also develop indigenous technology. Inadequate laboratory facilities remain a critical challenge to effective science education in Nigeria. To address these challenges will require political will, increased funding, accountability, fighting corruption/other sharp practices, and sustainable management practices. More information on inadequate laboratory facilities can be found in books in [23-35] and the following related journals:

Lagos State Journal of Science Education

African Journal of Educational Research

International Journal of Science and Technology Education Research

Journal of Research in Curriculum and Teaching

Journal of Education and Practice

Ghana Journal of Education and Teaching

International Journal of Science Education

Prospects

Journal of Educational Management

International Business Research

African Journal of Chemical Education

Journal of microbiology & Biology Education

Discover Education

Teknologidan Kejuruan

International Journal of Open Information Technologies

Mediterranean Journal of Social Sciences

Unilag Journal of Humanities

Smart Learning Environments

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Figure 1. Laboratory



Figure 2. Laboratory
Source: https://en.wikipedia.org/wiki/Laboratory



Figure 3. Empty laboratory



Figure 4. Old abandoned laboratory



Figure 5. Human Capital Theory: Key to workforce productivity

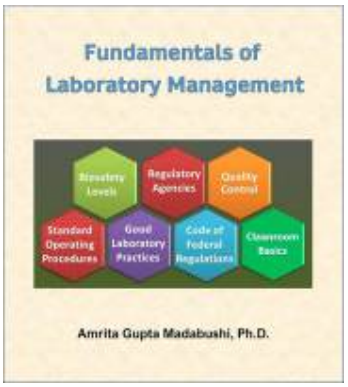


Figure 6. Fundamentals of laboratory management



Figure 7. Medical laboratory scientist

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