www.unibulletin.com
UNIVERSITEPARK BULTEN | BULLETIN
ISSN 2147-351X | e-ISSN 2564-8039

UNIVERSITEPARK bülten bulletin

RESEARCH ARTICLE

Laboratory Technology: A "Neglected" but Unique Interdisciplinary Tool helping to Enhance Scientific Research and Development in Academic and Research Institutions in Africa

Albert Koomson · Jonathan Ntow · Prosper Dordunu
Emmanuel Birikorang · Douglas Tetteh Ayitey

Received *August 6, 2021*
Accepted *October 3, 2021*
Published Online *December 21, 2021*

CORRESPONDENCE
Albert Koomson
albert.koomson@ucc.edu.gh
University of Cape Coast, Cape Coast, Ghana.

AUTHOR DETAILS
Additional information about the authors is available at the end of the article.

To cite this article: *Koomson, A., Ntow, J., Dordunu, P., Birikorang, E., Ayitey, D.T. (2021). Laboratory Technology: A "Neglected" but Unique Interdisciplinary Tool helping to Enhance Scientific Research and Development in Academic and Research Institutions in Africa. Üniversitepark Bülten, 10(2): 99-115.*

ABSTRACT

Background/purpose – Laboratory Technology has helped to enhance teaching, as well as scientific research and development worldwide. This review aims to reveal why there is "neglect" and a "disconnect" between laboratory technologists/technicians in academic and research institutions with their respective management and higher authorities regarding their roles and responsibilities, and puts forward suggestions to some of the challenges faced.

Materials/methods – The review was conducted by briefly adopting both Arksey and O'Malley's (2005) framework and the PRISMA item checklist with some modifications. Information was obtained from the Web of Science Core Collection (WoSCC), JSTOR, and the China National Knowledge Infrastructure (CNKI) bibliographic databases, as well as via Google Scholar and the Google search engine.

Results – The review highlights that the unique interdisciplinary nature of laboratory technologists/technicians' roles should be afforded greater attention according to their diverse working environments. The challenges currently faced could be addressed through the formation of national regulatory and representative bodies for efficient governance in this area, to enhance both quality and performance, to create and implement a governance framework and associated policies, to bolster capacity building and training, consolidate self-administration and enhanced awareness of the role, quality assurance, accreditation, and regulations as well as to conduct high quality research related to laboratory operations.

Conclusion – This review suggests that a salient multifaceted approach could help foster a harmonic nexus among university laboratory technologists/technicians in scientific research and development. Finally, the paper reveals that academic and research institutions both in Africa and worldwide could meet today's essential needs and champion sustainable development if laboratory staff were afforded appropriate and commensurable recognition.

Keywords – Academic, Africa, interdisciplinary, laboratory technology, scientific research.

To link to this article–https://dx.doi.org/10.22521/unibulletin.2021.102.1

1. INTRODUCTION

Laboratory Technology is an applied science-based program of academic study which trains students to acquire the diverse techniques and knowledge needed to operate within various types of laboratories in industry, academia, government, and also private research institutions (Delgado Community College, n.d.; University of Cape Coast, n.d.). Worldwide, laboratory technologists/technicians take on a wide range of roles within laboratories , depending on their area of expertise and acquired skillset (Neuvoo, 2021). The discovery and application of the profession has become a driving force in the development of national economies, as well as in research and development, and which results in time and cost savings in numerous daily activities. Laboratory technology is an embodiment of various disciplines, hence it is referred to as an interdisciplinary profession. However, embracing this relatively new developmental area has taken some time in Africa, and much later than in the western world (Full et al., 2015; Koomson et al., 2019) .

In sub-Saharan West Africa, countries such as Nigeria and Ghana have adequately developed academic curricula covering the science laboratory technology area, with programs from ranging certificate up to degree level (Accra Technical University, n.d.; Educartis, 2021; Kumasi Technical University, n.d.). Laboratory technologists/technicians work in several branches of scientific research and development such as the natural and medical sciences as well as engineering, and can be employed by companies in areas such as forensics, pharmacology, cosmetics, manufacturing, and many others. Laboratory technologists/technicians may work independently or alongside other professions in certain fields. They represent a hands-on discipline of modern-day science, relying on a skillset as vital to modern research as theoretical understanding (Dicks, 2006).

The roles of teaching and research laboratory professionals have evolved considerably over the years, from assisting with practical setup to demonstrating the use of advanced and complex scientific equipment to both students and members of research teams from various university departments. Similarly, laboratory technologists/technicians in academic institutions, industry, the non-profit sector, as well as government undertake much of the daily leg-work of science. Job titles can vary almost as much as the job descriptions, and include terms such as teaching, research and development, and service technicians (Schubert, 2018).

Most laboratory technologists/technicians directly involved in research hold either a bachelor's or master's degree, whereas as some may even hold a Ph.D. Laboratory technologist/technician positions can offer a satisfying career as a key member of a laboratory, or as a stepping stone to a Ph.D. or other job openings. Laboratory technologists and technicians are invaluable members of the research laboratory team. They are responsible for many key components of daily scientific tasks such as the organization and maintenance of laboratory tools and equipment, laboratory administration, lab safety, data recording, as well as ensuring efficiency and accuracy of scientific experiments and research (Morus, 2016; Schubert, 2018).

The behind-the-scenes contributions by laboratory staff are instrumental in the training of quality scientists at universities, which therefore also enhances the institution's research and development capability. However, it has been reported that some universities are set to lose much of this valuable resource, with 41% of technicians due to retire in the next 10 years in the UK alone (Brazil, 2018). Reduced capacity issues within this workforce could be

similar in other developed countries too, and worse still for developing or underdeveloped countries if action is not taken. It could be said that we are sitting on "tenterhooks" because there is little or no training for younger people with such skills. From a world view, some of these anomalies may be associated with recruitment and the retaining of both new and existing staff, lack of professional recognition, inadequate remuneration, and limited opportunities for career development and progression. However, laboratory technologists/technicians are leaving their jobs because they feel undervalued, marginalized, and somewhat neglected by their institutions, coupled with the aforementioned issues (Wen et al., 2020).

In this 21st century, margins have been distorting the scientific ranks, and the former distinction between laboratory staff (technologists and technicians) and researchers has been gradually eroded in both the public (e.g., education) and private sectors (Dicks, 2006). This has occurred as a result of the heightened level of hands-on expertise in laboratory pedagogy, as well as the educational level accrued by today's laboratory staff. They are no longer part of the continuum scientific workforce as simple "glassware washers," but as trained professionals, whose works form an essential element in modern-day scientific research (Bornstein-Forst, 2017).

This review seeks to highlight how laboratory technology has become a unique interdisciplinary tool, helping to enhance scientific research and development, and especially within academic and research institutions in Africa. It also aims to address the conundrum as to why there is a "neglect" and "disconnect" between technologists/technicians in academic and research institutions with their respective university management and higher authorities by way of outlining the roles of laboratory technologists/technicians, current issues, and challenges, and to put forwards recommendations.

2. METHODOLOGY

A brief review of the literature focusing on the roles of laboratory technologists/technicians, enhancing scientific research and development in academic and research institutions, and the challenges faced together with solutions and possible recommendations for amelioration was undertaken. The patterns of literature reviewed enabled in-depth content comprehension for information extraction. In this paper, the review was reported by adopting both Arksey and Malley's (2005) framework and the PRISMA item checklist (Page et al., 2020) with certain modifications to suit the purpose of this review.

2.1 Information Search and Identification

The Web of Science Core Collection (WoSCC), Journal Storage (JSTOR), and the China National Knowledge Infrastructure (CNKI) bibliographic databases were searched, plus the Google Scholar academic search engine was used conjunctively with the Google search engine in order to identify academic works published from 1999 through to June, 2021. Most of the information was obtained from the WoSCC bibliographic database, when compared to CNKI, JSTOR and Google Scholar; along with other works concerning laboratory technologists/technicians in academic and research institutions that were not formally published at that time (June, 2021). The WoSCC search returned the highest number of accessible publications in higher impact international journals, which was followed by JSTOR, Google Scholar, and CNKI respectively. The selected bibliographic databases, academic search engines and other web sources were used to generate listings of a high number of

publications and other informational materials related to this particular review. However, access to some publications in language other than English were, to some extent, exempted due to limited resources for translation. Since WoSCC, JSTOR, and CNKI could also be considered comprehensive and globally accepted databases for the purposes of academic studies and research, they were taken as the primary sources of information. The Google Scholar and Google academic search engines were not excluded; as such, the search criteria together with the exempted publications (i.e., non-English) could also constitute a limitation of this review.

2.2 Data and Information Extraction

First, publications from the WoSCC, JSTOR, and CNKI bibliographic databases, plus Google Scholar and Google search engine searches related to the purpose of the review were identified. Basic research articles, review articles, editorials, newsletters, technical reports, notes, and academic websites, etc. were all included within the scope of the review. The search queries consisted of terms considered by the current study's authors to describe how laboratory technology as a unique interdisciplinary tool is helping to enhance scientific research and development in academic and research institutions: "laboratory technology, a unique interdisciplinary tool," "university laboratory technologists/technicians," "laboratory technologists/technicians neglected," "laboratory technologists/technicians enhancing scientific research in academic or research institutions in Africa," "laboratory technologists/technicians neglected," "laboratory technologists/technicians enhancing scientific research in academic or research institutions in Africa," "laboratory technologists/technicians enhancing scientific research in academic and research institutions," "laboratory technologists/technicians enhancing development in academic and research institutions." The search queries were streamlined so as to meet the scope of the review. Differences in views were discussed by the researchers until consensus was reached in selecting the material for the review.

3. RESULTS

The original search, which was conducted in June 2021, yielded a potentially relevant 576,472 publications and informational materials in total. These initial findings from the information extraction exercise involving the aforementioned bibliographic databases and search engines, are presented in Table 1.

Table 1. General characteristics of publications/informational materials

Source	*Items retrieved*	*Items selected (assigned rank)*	*Rank*
Web of Science Core Collection (WoSCC)	134,304	15 (1)	2
Journal Storage (JSTOR)	37,113	7 (4)	4
China National Knowledge Infrastructure (CNKI)	155	4 (5)	5
Google Scholar	341,000	13 (2)	1
Google	63,900	10 (3)	3
Total	*576,472*	*49*	

Parenthesized values: final assigned ranks of eligible selected items after filtering/screening In total, 576,472 publications or informational materials were retrieved using the queries stated in Section 2.2 (Data and Information Extraction). Google Scholar retrieved the highest number, followed by WoSCC, Google, JSTOR, and CNKI with their corresponding values of 341,000, 134,304, 63,900, 37,113, and 155, respectively. In contrast, 49 eligible publications/informational materials were selected upon further relevance screening by way of deduplication to refine the search results in order meet the scope of the current review. WoSCC had the highest number of publications/informational materials followed by Google Scholar, Google, JSTOR, and CNKI with their corresponding values of 15, 13, 10, seven, and four respectively. The researchers agreed on using these 49 eligible publications/information materials (basic research articles, review articles, websites, etc.) for the current review, and then thoroughly examined each of them prior to discussing their findings.

4. DISCUSSION

4.1 Some Responsibilities of Teaching and Research Laboratory Technologists/Technicians

University laboratories play an important role in improving the quality of higher education and research. These laboratories enable students to develop their practical abilities and to cultivate their innovation ability within the university environment (Serdyukov, 2017). In order to achieve the most efficiency from of a high-level laboratory, its university should give full play to the role of its personnel, finance, and material resources. Among these resources, it may be said that laboratory technologists/technicians are the most active and significant. The role of laboratory technologists/technicians includes teaching, research, and also administrative duties. Laboratory Technologists/Technicians work mostly like lecturers or instructors, but also have certain administrative duties too. They are a group of a university's "teachers" who provide both tuition and management services concurrently (Lewis & Gospel, 2015).

In the laboratory, they are in charge of various jobs, ranging from maintaining a hygienic environment, preparing for practical classes, laboratory research, taking security precautions, the planning, installation, and maintenance of laboratory equipment, and for the organization and implementation of laboratory policies as well as total quality management systems. In brief, the role of laboratory technologists/technicians play a key role that cannot be overlooked (Yan-wen, 2015). The primary area of laboratory management is often tasked to the laboratory technologist/technicians. Laboratory construction and development cannot be separated from the basic functions of these essential laboratory staff; similarly, a laboratory cannot function effectively without the inclusion of appropriately trained and qualified technologists/technicians.

4.2 Current Situation, Plus Major Challenges Faced by Laboratory Technologists and Technicians in Africa

The current situation of laboratory technologists/technicians has, for a long time in some parts of the world, been influenced by the traditional concepts of education, with more attention paid to the theoretical over the practical when it comes to higher education, making it a serious issue for many institutions. Owing to this, laboratory technologists/technicians have not been afforded adequate attention (Wen et al., 2020), and often considered as "assistants" working in a subordinate role in the field of teaching.

Laboratory technologists/technicians play a supporting role in the fields of both teaching and research. As such, their performance is vital for a higher education institution's research and development; however, they are never considered as self-directed accomplishments. Additionally, there are no professional standards or designed competency-based assessment for laboratory technologists/technicians, especially in Ghana and other African countries. The current situation of laboratory technologists/technicians can therefore be analyzed from the aspects elaborated upon in the following subsections.

4.2.1 Lack of Professional Recognition and Inadequate Commensurable Remuneration

The absence of robust legislation or any professional associations for teaching and research laboratory technology/technicians in most countries has resulted in the underrepresented voice of the laboratory cadres at both the institutional and national level (Schneidman et al., 2014). Currently, in Sub-Saharan West Africa, only Nigeria has established an Institute of Science Laboratory Technology which serves the role of research, teaching, servicing, and industrial laboratory technologists for quite a number of fields. The Institute is the sole professional body responsible for managing and maintaining institutional and industrial laboratories throughout Nigeria (Nigerian Institute of Science Laboratory Technology, n.d.). By contrast, university laboratories and their research and industrial technologists/technicians in both Ghana and other parts of the world remain poorly funded, poorly supported, and significantly underrepresented. The profession is not afforded its due recognition and the health hazards and risks associated with the work undertaken is rarely reflected in the remuneration on offer. They lack the collective bargaining power to argue their fiscal case and for the advancement of the laboratory profession as an essential workforce in both public and private institutions.

4.2.2 Lack of Effective Training to Meet the Modern Evolving Demands of Science and Technology

Laboratory equipment and instrumentation, along with its associated software, in most modern laboratories are continuously subject to update and refinement in the never-ending drive to minimize errors and optimize efficiency. Laboratory technologists/technicians are required, therefore, to remain constantly abreast of new and updated equipment, software, and laboratory processes, revisions to curricula, and the demands of high-level scientific research projects. Unfortunately, many laboratory technologists/technicians lack the means to maintain their effective training so as to keep themselves updated with new knowledge in their field and for the improvement of their professional skills (Zengele & Alemayehu, 2016). Gradually, the gap between technologist/technicians' knowledge base and the needs of experimental teaching is becoming wider. Continuous professional development for laboratory personnel, offered through either the private or government sectors is rarely forthcoming for research, teaching, and servicing laboratory technologists/technicians in most African countries. Even where there is any, it is far less than offered to other academic or health professionals (Kasvosve et al., 2014; Kubrushko & Nazarova, 2013). Laboratory technologists/technicians are sidelined in many ways relating to their required specialized training needs. This has made them unable to readily adapt to the evolving demands of their profession such as the cutting-edge technologies related to their field, and thus they fear becoming dormant or redundant as the wider profession moves forward at pace.

4.2.3 Vast Scientific Research Workloads and Daily Tasks Faced by Limited Numbers of Laboratory Technologists/Technicians

Due to the limited number of professional laboratorians employed by most universities and research institutions, the staff can easily become overwhelmed with the tasks expected of them. They may find it difficult to schedule their working time appropriately between the demands of their scientific research and daily work. For instance, laboratory technologists/technicians perform a number of daily laboratory activities including general laboratory management and administration, implementing safety protocols, the installation and maintenance of laboratory equipment, experimental site management, and also teaching environment preparation (El-Gilany et al., 2017). Despite all these activities, it is also expected of them to undertake research such as scientific research projects, to author scientific text, and to excel at course development. They are often busy making use of their laboratory expertise in order to carry out experimental teaching and research work; however, this can all become a "herculean task" for them to maintain any balance between these pivotal academic roles. In situations where the university laboratory does not own a specific type of scientific equipment for a particular experiment, technical staff are often forced into some sort of improvisation of some recognized analytical techniques in order to deliver practical lessons (Au-Yong et al., 2014).

4.2.4 Lack of Effective Communication with Academic Hierarchy

Today, the professional laboratory technologist/technician is rarely understood, appreciated, or communicated with, and this is especially applicable in Africa when it comes to issues related to research and experimentation in the laboratory. Most are not kept updated with information and details relating to projects, research, or the procurement of laboratory consumables or equipment. Consequently, such subtle inaction can result in the procurement of laboratory consumables and equipment which end up being unusable or inoperable, and are often unsuited to the laboratory's required specifications. Similarly, due to various reasons, some university-based laboratory technologists/technicians are not permitted to impart skills to their students during experimental lessons; instead they are only allowed to prepare laboratories for practical lessons according to the set teaching syllabus. Over the years, the lecturer's sole responsibility has been lecturing, even if that was within a laboratory setting; whereas, technologists/technicians have always been responsible for the preparation, operation, and implementation of the actual experiments. There is, therefore, a significant discontinuity of practical knowledge transfer should a problem be encountered in the course of an experiment when the lecturer is solely in charge of the laboratory lessons as they may well be unfamiliar with the instrumentation, operation, or implementation of the experiment. Hence, the result can only be disruption to the effectiveness of the teaching, with communication among both cadres detrimentally affected (Wen et al., 2020).

4.2.5 Minimum Attention Given to Laboratory Quality Management and Safety Issues Related to Teaching and Research Laboratories

Total Quality Management System is an essential epitome required for the successful running of any organization. Its procedural systems, policies, and guidelines are also crucial for the management of any modern laboratory (World Health Organization, 2011). However, it is rather unfortunate that little or no attention is given to the adoption and implementation of such systems within university teaching and research laboratories, and especially in terms of quality standards such as ISO 17025 and ISO 18001.

It is worth noting here that the inability of university and research institution management teams to implement the necessary policies related to quality management systems in laboratories have resulted in a myriad of nonconformities and traceability problems relating to data generated from experiments and research. In reality, very few accidents that occur within a laboratory are particularly physical in nature, with the majority fairly benign but perhaps triggering some long-term effect from excessive exposure to certain laboratory hazards (Kapin, 1999; Taylor et al., 2008). The physical accidents may be compensable; however, non-physical bodily injuries with long-term effects such as some forms of cancer or kidney failure, etc. may not be directly compensable, especially where symptoms of such deleterious health anomalies can manifest much later and maybe even post-retirement. Similarly, data collection, processing, storage, archiving, controlling, and retrieval in most African universities' teaching and research laboratories do not comply with any universal standard. Most irregularities in this area have resulted in the loss of valuable research data, pertinent laboratory inventories, and technological transfer (Wilson, 2012). This impedes the coherency, effectiveness, and efficiency of laboratory staff performance in discharging their duties to the maximum to enhance research and teaching in laboratories.

4.3 The Way Forward, Possible Solutions, and Recommendations

4.3.1 Formation of National Regulatory and Representative Bodies for Efficient Governance, Enhancing Quality, and Performance

It is the sole responsibility of a national laboratory regulatory body to carry out its functions dutifully, principally in areas of supervision and implementation of safety and quality management systems (Homolka et al., 2019). In nations where laboratory services lack such autonomous regulatory bodies, the authorities could consider the establishment of a robust mechanism rather than incorporating these functions into some general governmental area such as an education ministry, or some industry-focused regulatory body, even if resources are readily available.

The establishment of such a body would help maintain focus on the major needs of frontline laboratory staff working in the various universities and research institutions. Being better equipped to maintain a satisfactory level of regulation, and the implementation of oversight over laboratory management and administration systems through activities such as supervising the creation of laboratory standards, standardizing and regulating the induction and inservice training of laboratory staff, would all help to enhance the overall quality of teaching and research at the institutional level (Wadhwa et al., 2012). The mandate and supervisory role of a regulatory body would eventually help university teaching and research laboratories to attain international recognition through accreditation, which will then repose confidence in the research outcomes from those laboratories. However, national representative bodies need to be properly unionized in order to represent the common interests of laboratory professionals. It is important, therefore, that such organizations have a clear mandate and adequate resources in order to adequately represent the views of all laboratory cadres at the senior policy level.

4.3.2 Creation and Implementation of Governance Framework and Policies

Over the years, national policies and strategies regarding the structure of university and research institution laboratory technologists/technicians' career path and promotional ladders have been woefully inconsistent and inadequate. For countries in which there is available information, some have shown major anomalies such as delays in the expansion of

postgraduate degree programs, ill-structured or non-standardized job descriptions, unclear career professional development pathways, revised schemes that do not address the gaps and current situation within the laboratory profession, as well as inconsistencies between salary structures and qualifications. The absence of effective retraining strategies and inadequately structured promotional opportunities in most countries has been characterized by sheer-negligence in the advocacy of career development for laboratory staff. However, the continuous and effective implementation of government policies and strategies across various sectors could positively influence the proper development of the laboratory profession.

Additionally, university management, together with other research institutions, need to update their current unionized scheme of work on a periodic basis. This will help to ensure that all cadres have distinct and complementary job descriptions, and that they are well aligned with the national requirements of their respective laboratory system. Job titles need to be clearly connected to these job descriptions, and the differences between these cadres should be clearly understood across the education and industrial workforce.

4.3.3 Capacity Building and Training

A constitutionally mandated regulatory body can develop continuing professional development for laboratory personnel working in either industrial or teaching and research laboratories, and would be evidenced through improved analytical test results produced by laboratory staff. Reports on continuing professional development have shown tremendous benefits in some countries (Abogsesa & Kaushik, 2018).

Correspondingly, improving occupational training opportunities is crucial to the maintaining of a well-qualified laboratory workforce. Notwithstanding that laboratory technologists/technicians could opt for self-improvement using their own funds, staff require consistent job-related training and prospects in order to access further academic studies to advance the quality of laboratory services on offer, and also to boost morale within this specialist workforce (Karim et al., 2012). However, both training and additional qualifications need to be intrinsically linked to career progression. Training plans should be established upon clear needs assessment, and similarly transparent criteria for the selection of laboratory technologists/technicians is badly needed. Institutions and funding agencies need to certify that inservice training models do not disproportionately upset service provision. This may be achievable through a mix of both modern and traditional workplace-based training; one such example would be mentorships, which have proven to be significantly effective and operable, predominantly when conducted in collaboration with the private sector and associated international bodies (Whittle & Malkin, 2014).

An emphasis on practical hands-on training could be properly realized if training courses such as laboratory management and administration were better aimed at maximizing the course learning outcomes. Such courses should incorporate formative assessments. Training modules from reputable institutions and organizations such as the International Organization for Standards (ISO), the National Examination Board in Occupational Health and Safety (NEBOSH), the Institute of Occupational Safety and Health (IOSH), and the Occupational Safety, Health and Environment agencies (OSHE), which support the laboratories' advancement processes toward certification and accreditation, are all encouraging in this area as they reveal the clear relationship between acquired skills and core competencies.

This area also serves as a platform for performance monitoring and the assessment of facility improvements which can result in improved working environments. The joint training of laboratory technologists/technicians and other academic staff on areas such as safety, laboratory information management systems, grantsmanship and research need to be increased, as this could also positively affect the application and use of laboratory findings by participating research scientists/lecturers as well as laboratory staff and management. This could form a vital strategy to bridge the laboratory-lecturer gap (Hofstein & Lunetta, 2004; Turpin et al., 2010).

Finally, continuing professional development standards should be set up by national regulators in order to facilitate a well-deserved enabling environment for the realization of such improved activities.

4.3.4 Consolidating Self-administration and Enhancing the Awareness of Position

In the new situation of enhancing scientific research and development within high-level universities, laboratory technologists/technicians should be considered as "talent," and that their duty should be measured as "supporting" teaching instead of "assisting" teaching (Rong, 2018). Laboratory technologists/technicians work not only independently, but also within the wider group setup; therefore, they should possess and demonstrate a teamwork spirit. Technologists/technicians must make full use of the available human, material, and financial resources of the laboratory in order to give full play to the role of the university laboratory. They should conduct experimental teaching, renew teaching models, update teaching content, and undertake scientific research efficiently using the aforementioned resources. Thus, they have to be able to effectively communicate and cooperate with all kinds of people from different roles, including enterprise personnel from collaborative projects.

In addition to scientific research projects, an experimental teaching center and practice teaching base may also be established; for example, a university enterprise collaborative project could be launched. Experimental teaching is as important as theoretical teaching in universities (Dongru et al., 2014). Laboratory technologists/technicians and lecturers each have their respective advantages; with laboratory technologists/technicians often good at practical hands-on operations, whilst lecturers may do better in theoretical teaching. If the senior laboratory technologist/technicians are permitted to lecture on experimental courses, they could offer teaching that complements that of the lecturers in terms of a practical teaching focus. The workload of the laboratory technologists/technicians could then be regarded as part of their performance. In this way, students will also benefit from the advantages of both sets of professionals; whilst laboratory technologists/technicians will be better motivated to work in their fields and also to improve their own qualities on a continuous basis (Tian et al., 2015).

4.3.5 Quality Assurance, Accreditation, and Regulation

Most university laboratories progressively perform testing for external companies in the private sector and as such are under increasing scrutiny. As such, they may be encouraged to obtain ISO accreditation and certification, or some similar standardized recognition (Grochau et al., 2010; Solis-Rouzant, 2015). Universities are considered as pioneering hubs for innovation as a byproduct of new scientific policies and developmental technologies. Innovations need to be tested within an accredited laboratory environment in order to create certified products if they are ever to be commercialized (Carayol & Matt, 2004). Many

universities have established laboratories that provide testing services to the wider private sector, and this can act as a distinct and not insignificant revenue stream for the institution (Aqidawati et al., 2019).

It is therefore imperative that both universities and research institutions obtain the necessary training, accreditation, and certification for their respective laboratories. These processes may be delayed, however, if the university management is not fully committed to financing the laboratory accreditation process, which can be hampered when the laboratory staff responsible for the general management and administration lack the following; competency-based hands-on skills, adequate ISO lead auditor courses, laboratory quality management systems, instrumentation, safety, and other professional laboratory courses. Laboratory activities and certification renewal tends to be highly regulated by its very nature, and usually monitored by a regulatory body at the national and/or international level. This is often realized through laboratory auditing and periodic international collaborative exercises, as well as from proficiency testing performed by certain select laboratories (Lüth et al., 2019; Morris & Macey, 2004). Nevertheless, upright fulfillment of the aforementioned competency skills needed in quality laboratory management enhances the quality of research findings, analyses, and test results produced from these laboratories (Outaki et al., 2019).

4.3.6 Conducting Top-Notch Research on Issues Associated with University Teaching and Research Laboratory Technologists/Technicians

With universities, research institutions, and academicians delivering professional teaching, research and industrial laboratory technologists/technicians should be involved in spearheading a considerable amount of research specific to the profession. Laboratory technologists/technicians are effectively at the frontline when it comes to the devising and implementation of appropriate policies for the laboratory technology profession. However, much more prioritized research should be conducted in the areas of laboratory management and administration, laboratory policies, safety, laboratory information management systems, laboratory informatics, procurement, and instrumentation methods, etc. Research from such institutions should not deviate from the core mandate of the laboratory profession. Therefore, greater involvement by laboratory technologists/technicians will help to identify and address the gaps leading to the current worsening retrogression of the profession. It will also help in understanding and identifying the pertinent factors influencing today's supply of and demand for laboratory professionals. Furthermore, prioritized research in defining the effect of a diverse management approach to hiring and retaining qualified university laboratory technologists/technicians, gender imbalances in the workplace, the construction of high-level laboratories, relationship between qualifications and laboratory performance, as well as the effect of workplace factors on staff retention would help to address gaps in a more systematic and appropriate manner (Yang, 2021).

5. CONCLUSION AND SUGGESTIONS

This review paper revealed that it is vital that the essential academic supporting roles and activities performed by university laboratory technologists/technicians are not further neglected. Although there were a limited number of accessible publications retrieved in accordance with the scope of this review from the various academic bibliographic databases following screening, some interesting evidence on the current issues faced by laboratory technologists/technicians within academic and research institutions was revealed.

A multifaceted approach could be used in addressing these various issues. Hence, there is a necessity for the formation of national regulatory and representative bodies for efficient governance, enhancing both quality and performance, the creation and implementation of a governance framework and appropriate policies, capacity building and training, consolidating self-administration and enhancing the awareness of position, quality assurance, accreditation and regulation, as well as conducting advanced research on issues related to laboratory cadres. This could help to improve the motivation of laboratory technologists/technicians as well as their standard of living. Such an approach would also help academic and research institutions both in Africa and elsewhere to meet the essential needs of the era and to more effectively champion sustainable development (United Nations Office on Drugs & Crime, 2015).

DECLARATIONS

Authors' Contributions Jonathan Ntow, Prosper Dordunu, Emmanuel Birikorang and Douglas Tetteh Ayitey helped with design and structure of the study, drafting, critical literature review and manuscript editing. Albert Koomson conceived of the whole idea, coordinated the study, participated in critical literature review and helped in writing the manuscript. All authors gave final approval for publication.

Conflicts of Interest The authors declare no conflict of interest.

Funding This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Ethical approval No ethical approval was sought as the article does not present any study of human or animal subjects.

Data availability Data sharing is not applicable as no new data were created or analyzed in the presented study.

Acknowledgment The authors would like to acknowledge Mr. Felix E. Agblemanyo and Ms. Grace Pinkrah Cobbold for proof reading the manuscript and discussing with us their opinions.

REFERENCES

Abogsesa, A. S., & Kaushik, G. (2018). Impact of Training and Development on Employee Performance. *International Journal of Civic Engagement and Social Change, 4*(3), 53-68. https://doi.org/10.4018/ijcesc.2017070104

Accra Technical University. (n.d.). *Science Laboratory Technology Department*. Retrieved February 1, 2021, from https://atu.edu.gh/faculty-of-applied-science/science-laboratory-technology-department/

Aqidawati, E. F., Sutopo, W., & Zakaria, R. (2019). Model to measure the readiness of university testing laboratories to fulfill ISO/IEC 17025 requirements (a case study). *Journal of Open Innovation: Technology, Market, and Complexity*, *5*(1), Article 2. https://doi.org/10.3390/joitmc5010002

Arksey, H., & Malley, L. O. (2005). scoping studies: towards a methodological framework. *International Journal of Social Research Methodology, 8*(1), 19-32. https://doi.org/10.1080/1364557032000119616

Au-Yong, C. P., Ali, A. S., & Ahmad, F. (2014). Optimising maintenance cost performance with skilled technicians. *Structural Survey, 32*(3), 238-245. https://doi.org/10.1108/SS-01-2014-0005

Bornstein-Forst, S. M. (2017). Establishing Good Laboratory Practice at Small Colleges and Universities. *Journal of Microbiology & Biology Education, 18*(1). https://doi.org/10.1128/jmbe.v18i1.1222

Brazil, R. (2018, November 27). The unsung heroes of the lab. *Chemistry World*. https://www.chemistryworld.com/careers/the-unsung-heroes-of-the-lab/3009700.article

Carayol, N., & Matt, M. (2004). Does research organization influence academic production? Laboratory level evidence from a large European university. *Research Policy*, *33*(8), 1081-1102. https://doi.org/10.1016/j.respol.2004.03.004

Delgado Community College. (n.d.). *Science Laboratory Technology (SLT)*. Retrieved January 21, 2021, from http://dcc.edu/academics/science-math/science/science-laboratory-technology/default.aspx

Dicks, L. (2006). Setting a new benchmark. *New Scientist*, *192*(2577), 60-61. https://doi.org/10.1016/s0262-4079(06)60989-5

Dongru, F., Yanming, H., Kangbiao, Q., Bing, L. W. H., & Jinfa., W. (2014). Some thinking on strengthening team construction of laboratory technician in colleges and universities. *Experimental Technology and Management*, *31*(9), 232-234. https://en.cnki.com.cn/Article_en/CJFDTotal-SYJL201409064.htm

Educartis. (2021). *Science Laboratory Technology Bachelor - University of Jos*. Retrieved February 25, 2021, from https://www.educartis.com.ng/courses/science-laboratory-technology-university-of-jos

El-Gilany, A. H., El-shaer, S., Khashaba, E., El-dakroory, S. A., & Omar, N. (2017). Knowledge, attitude, and practice (KAP) of 'teaching laboratory' technicians towards laboratory safety and waste management: a pilot interventional study. *Journal of Hospital Infection*, *96*(2), 192-194. https://doi.org/10.1016/j.jhin.2017.02.007

Full, R. J., Dudley, R., Koehl, M. A. R., Libby, T., & Schwab, C. (2015). Interdisciplinary laboratory course facilitating knowledge integration, mutualistic teaming, and original discovery. *Integrative and Comparative Biology*, *55*(5), 912-925. https://doi.org/10.1093/icb/icv095

Grochau, I. H., Ferreira, C. A., Zoppas Ferreira, J., & Schwengber ten Caten, C. (2010). Implementation of a quality management system in university test laboratories : a brief review and new proposals. *Accreditation and Quality Assurance, 15*, 681-689. https://doi.org/10.1007/s00769-010-0713-6

Hofstein, A., & Lunetta, V. N. (2004). The Laboratory in Science Education: Foundations for the Twenty-First Century. *Science Education*, *88*(1), 28-54. https://doi.org/10.1002/sce.10106

Homolka, S., Zallet, J., Albert, H., Witt, A. K., & Kranzer, K. (2019). Introduction of quality management in a National Reference Laboratory in Germany. *PLoS ONE, 14*(10), Article e0222925. https://doi.org/10.1371/journal.pone.0222925

Kapin, J. M. (1999). Beyond chemical safety— an integrated approach to laboratory safety management. *Chemical Health and Safety*, *6*(4), 20-22. https://doi.org/10.1016/s1074-9098(99)00002-7

Karim, M. R., Huda, K. N., & Khan, R. S. (2012). Significance of Training and Post Training Evaluation for Employee Effectiveness: An Empirical Study on Sainsbury's Supermarket Ltd, UK. *International Journal of Business and Management, 7*(18). https://doi.org/10.5539/ijbm.v7n18p141

Kasvosve, I., Ledikwe, J. H., Phumaphi, O., Mpofu, M., Nyangah, R., Motswaledi, M. S., Martin, R., & Semo, B.-w. (2014). Continuing professional development training needs of medical laboratory personnel in Botswana. *Human Resources for Health, 12*, Article 46. https://doi.org/10.1186/1478-4491-12-46

Koomson, A., Gaisie, E. K., Ayitey, D. T., & Antiaye, N. A. (2019). Forensic Science : A unique interdisciplinary tool helping to combat crimes in Africa , a review. *Forensic Science Society in Ghana Newsletter, 2*(1), 1-7. https://fssgh.org/2019/12/27/forensic-science-a-unique-interdisciplinary-tool-helping-to-combat-crimes-in-africa-a-review/

Kubrushko, P. F., & Nazarova, L. I. (2013). Professional development of technical university lecturers in field of innovation teaching. In *16th International Conference on Interactive Collaborative Learning* (pp. 467-469). IEEE. https://doi.org/10.1109/ICL.2013.6644627

Kumasi Technical University. (n.d.). *HND Science and Industrial Laboratory Technology.* Retrieved February 1, 2021, from http://www.kpoly.edu.gh/academics/programmes/hnd-science-and-industrial-laboratory-technology

Lewis, P. A., & Gospel, H. (2015). Technicians under the microscope: the training and skills of university laboratory and engineering workshop technicians. *Journal of Vocational Education and Training, 67*(4), 421-441. https://doi.org/10.1080/13636820.2015.1076502

Lüth, P., Frost, K., Kurth, L., Malow, M., Michael-Schulz, H., Schmidt, M., Schulte, P., Uhlig,S., & Zakel, S. (2019). CEQAT-DGHS interlaboratory test programme for chemical safety - Need of test methods validation. *Chemical Engineering Transactions, 77*. https://doi.org/10.3303/CET1977001

Morris, A., & Macey, D. (2004). Laboratory accreditation: Proof of performance for environmental laboratories - 2001 Study. *Accreditation and Quality Assurance, 9*, 52-54. https://doi.org/10.1007/s00769-003-0736-3

Morus, I. R. (2016). Invisible Technicians, Instrument-makers and Artisans. In B. Lightman (Ed.), *A Companion to the History of Science* (pp. 97-110). Wiley. https://doi.org/10.1002/9781118620762.ch7

Neuvoo. (2021). *What does a Laboratory Technician do?* Retrieved January 21, 2021, from https://neuvoo.com/neuvooPedia/en/lab-tech/

Nigerian Institute of Science Laboratory Technology. (n.d.). *Who Are We?* Retrieved January 15, 2021, from https://nislt.gov.ng/viewcontent3.php?tab=3

Outaki, M., Gmouh, S., Bazi, F., & Kerak, E. (2019). Quality management in research: management process of the laboratories of Moroccan faculties of sciences and techniques. *Accreditation and Quality Assurance*, *24*(5), 395-404. https://doi.org/10.1007/s00769-019-01396-6

Page, M. J., Mckenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S.,…Moher, D. (2020). The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ, 2021*(372), Article 71. https://doi.org/10.1136/bmj.n71

Rong, Z. (2018). Construction and Management of University Laboratories in the Context of the Construction of High-level University. *Research and Exploration in Laboratory*, *37*(3), 278-282. https://en.cnki.com.cn/Article_en/CJFDTotal-SYSY201803072.htm

Schneidman, M., Dacombe, R. J., & Carter, J. (2014). Laboratory professionals in Africa: The backbone of quality diagnostics. *World Bank Group on Health, Nutrition, and Population*. Retrieved from http://documents.worldbank.org/curated/en/419941468010480283/pdf/927280WP0Labor00Box385377B00PUBLIC0.pdf

Schubert, C. (2018). At the front lines of science. *Nature*, *560*(7719), 517-519. http://www.nature.com/articles/d41586-018-05991-4

Serdyukov, P. (2017). Innovation in Education: What Works, What Doesn't, and What to Do about It? *Journal of Research in Innovative Teaching & Learning*, *10*(1), 4-33. https://doi.org/https://doi.org/10.1108/JRIT-10-2016-0007

Solis-Rouzant, P. (2015). Experience of Implementing ISO 15189 Accreditation at a University Laboratory. *EJIFCC*, *26*(4), 270-273. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4975363/

Taylor, J. H., Jackson, C. M., Miller, M., & Rushneck, D. R. (2008). Laboratory management in methods development. *Journal of Environmental Science and Health. Part A : Environmental Science and Engineering,* *15*(5), 393-411. https://doi.org/10.1080/10934528009374940

Tian, L., Jinrong, X., Ling, Y., Zhongyun, W., & Tao, Z. (2015). How experimental technicians playing more positive role in experimental teaching. *Experimental Technology and Management,* *6*, 143-145. http://caod.oriprobe.com/articles/45557337/How_experimental_technicians_playing_more_positive.htm

Turpin, T., Woolley, R., & Marceau, J. (2010). Scientists across the boundaries: National and global dimensions of scientific and technical human capital (STHC) and policy implications for Australia. *Asian and Pacific Migration Journal*, *19*(1), 65-86. https://doi.org/10.1177/011719681001900104

United Nations Office on Drugs & Crime. (2015). *UNODC and the Sustainable Development Goals*. Retrieved from https://www.unodc.org/documents/SDGs/UNODC-SDG_brochure_LORES.pdf

University of Cape Coast. (n.d.). *Laboratory Technology*. Retrieved January 15, 2021, from https://labtech.ucc.edu.gh/programmes/bachelor-science-laboratory-technology

Wadhwa, V., Rai, S., Thukral, T., & Chopra, M. (2012). Laboratory quality management system: Road to accreditation and beyond. *Indian Journal of Medical Microbiology*, *30*(2), 131-140. https://doi.org/10.4103/0255-0857.96647

Wen, W., Gu, P., Qiu, K., & Guo, X. (2020). The Management and Development of Laboratory Technicians in the Construction of High-level Universities. In S. Luo, H. Xue, & J. Liu (Eds.), *Proceedings of the 2020 International Conference on Social Science, Economics and Education Research (SSEER 2020)* (pp. 166-168). Atlantis Press. https://doi.org/10.2991/assehr.k.200801.041

Whittle, C., & Malkin, R. (2014). Capacity building for medical equipment technicians improves healthcare. *Journal of Clinical Engineering*, *39*(3), 142-147. https://doi.org/10.1097/JCE.0000000000000047

Wilson, L. (2012). Intangible Histories and the Invisible Technician. *University Museums and Collections Journal,* *2012*(5), 17-22. https://edoc.hu-berlin.de/bitstream/handle/18452/9369/wilson.pdf?sequence=1&isAllowed=y

World Health Organization. (2011). *Laboratory Quality Management System : Handbook*. https://www.who.int/publications/i/item/9789241548274

Yang, B. (2021). Research on the Laboratory Management Mode Based on the Optimal Allocation of Resources. *Open Access Library Journal*, *8*, Article e7119. https://doi.org/10.4236/oalib.1107119

Yan-wen, L. (2015). Team Building of Laboratory Technician under the Background of the Development of College Teachers' Professional Abilities. *Journal of Jilin Institute of Chemical Technology*, *32*(2), 44-47.

Zengele, A. G., & Alemayehu, B. (2016). The Status of Secondary School Science Laboratory Activities for Quality Education in Case of Wolaita Zone, Southern Ethiopia. *Journal of Education and Practice*, *7*(31), 1-11. https://iiste.org/Journals/index.php/JEP/article/view/34083

ABOUT THE CONTRIBUTORS

Albert Koomson, BSc. (Hons.) currently works at the USAID Fisheries and Coastal Research Laboratory in the Department of Fisheries and Aquatic Sciences, University of Cape Coast, Ghana as an Assistant Laboratory Technologist. Albert does inter and multidisciplinary research in Biomaterials, Molecular Biology, Microbiology, Laboratory Management & Administration, Laboratory Quality Management Systems, Aquatic & Environmental Toxicology, Fisheries, Forensics and Innovative (Medical) Technologies. He has peer-reviewed publications in reputable international journals and has also presented in multiple international conferences.
E-mail: albert.koomson@ucc.edu.gh
ORCID ID: https://orcid.org/0000-0002-2407-6777

Mr. Jonathan Ntow, BSc. (Hons.) a Senior Laboratory Technologist with the Department of Laboratory Technology, University of Cape Coast (Ghana). He is a young researcher with passion for problem solving research in the areas of Food Microbiology, Food Chemistry, Food Quality Management Systems, Food Risk Management Systems etc. He aspires to be an astute researcher with global impact through his present and future publications.
E-mail: jonathan.ntow@ucc.edu.gh
ORCID ID: https://orcid.org/0000-0002-8949-6684

Prosper Dordunu, MSc. currently works at the USAID Fisheries and Coastal Research Laboratory at the Department of Fisheries and Aquatic Sciences of the School of Biological Sciences, University of Cape Coast, Ghana as a Senior Laboratory Technologist. His current areas of research include; Environmental and Aquatic ecotoxicology, Laboratory Quality Management Systems, Food Quality, Bio analytics and carbon stock assessments.
E-mail: prosper.dordunu@ucc.edu.gh
ORCID ID: https://orcid.org/0000-0002-1112-5074

Emmanuel Birikorang, BSc. (Hons.) currently works at the Research Laboratory of the Department of Laboratory Technology, University of Cape Coast, Ghana as a Principal Laboratory Technician. Emmanuel does multidisciplinary research in Water Quality Analysis, Food Quality and Safety, Microbiology, QSHE in the Laboratory, Groundwater Studies. He has peer-reviewed publications in international journals of high esteem.
E-mail: ebirikorang@ucc.edu.gh
ORCID ID: https://orcid.org/0000-0001-6702-7206

Douglas Tetteh Ayitey MSc, is currently a staff at the Biomedical Engineering department of the University of Ghana as Senior Laboratory Technologist. He has industrial experience in Automation and Robotics. His research areas are power systems modeling, energy system, industrial internet of things IIoT, Internet of Medical Things (IoMT), Forensics. He has peer-reviewed publications in reputable international journals and has presented at conferences.
E-mail: dtayitey@ug.edu.gh
ORCID ID: https://orcid.org/0000-0002-2199-189X