

Microbiology Education in Nigeria: Common Training Deficits Could Be Addressed with Modern Educational Tools[†]

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Microbiology has developed as an important field of scientific training in Nigeria over the years. It is one of the early scientific fields introduced to the country. It has contributed to the development of the scientific identity of the country, through training of personnel and applications aimed at addressing microbial diseases that present a public health concern. Recent diseases, especially of microbial origin, have however exposed the poor state of microbiology in Nigeria. Recurrent but avoidable infectious diseases such as diarrhea and cholera have led to the loss of several lives. Although the situation is complex, at least some of these shortcomings could be compensated for by enhancing the quality of training delivered to future microbiologists and related healthcare professionals and educators. An analysis of microbiology curricula in Nigerian institutions compared with those of developed countries identified several gaps. Although inadequacy in training resources, expert faculty, and funding are well recognized, it is believed that several of these training gaps could be addressed through innovative educational approaches. In this paper, I discuss how key microbiology education weaknesses in the Nigerian context could be overcome using modern, low-cost educational tools that are accessible even in the face of existing institutional challenges. Topics such as molecular cloning and PCR are discussed, together with how specific virtual classroom and related internet-based tools can be applied to teach these topics in resource-limited contexts. This paper should therefore be relevant to microbiology educators in most developing countries.

وقد ساهم في تطوير الهوية العلمية للبلاد من خلال تدريب الموظفين والتطبيقات الرامية إلى معالجة الأمراض الجرثومية التي تهم الصحة العامة غير أن الأمراض الحديثة ، لا سيما في الأصول الميكروبية ، كشفت عن سوء حالة علم الأحياء المجهرية في نيجيريا. وقد أدت الأمراض المعدية المتكررة والتي يمكن تجنبها مثل الإسهال والكوليرا إلى فقدان العديد من الأرواح. على الرغم من وجود وضع معقد ، يمكن تحسين بعض أوجه القصور هذه على الأقل من خلال تعزيز جودة التدريب المقدم إلى علماء الأحياء المجهرية في المستقبل والمتخصصين في الرعاية الصحية والمربين وحدد تحليل لمناهج علم الأحياء الدقيقة في المؤسسات النيجيرية عدة فجوات مقارنة بتلك الموجودة في البلدان المتقدمة. على الرغم من عدم كفاية تدريب الموارد ، فإن أعضاء هيئة التدريس الخبراء والتمويل معترف بهم بشكل جيد ، ويعتقد أن العديد من هذه الفجوات التدريبية يمكن معالجتها من خلال الأساليب التعليمية المبتكرة. في هذه الورقة ، ناقشت كيف يمكن تحسين الضعف الأساسي في تعليم علم الأحياء المجهرية في السياق النيجيري باستخدام أدوات تعليمية حديثة منخفضة التكلفة تكون ممكنة حتى في مواجهة التحديات المؤسسية القائمة. وتناقش مواضيع مثل الاستنساخ الجزيئي والتفاعل التسلسلي للبوليميريز مع كيفية تطبيق الفصول الافتراضية الافتراضية وأدوات الإنترنت ذات الصلة لتعليم هذه الموضوعات في سياقات محدودة الموارد. ومن ثم ، ينبغي أن تكون هذه الورقة ملائمة لمعلمي علم الأحياء الدقيقة في معظم البلدان النامية.

INTRODUCTION

Microbiology involves the study of microorganisms and their relationship with other organisms and the environment (1). The teaching of microbiology, one of the earliest scientific fields, has been in existence for millennia

(2). From the Mahavira teachings in the sixth century BCE to the Marc Terence Varro teachings in the first century BCE, microbiology education has been evolving over time (2, 3). However, the science of microbiology didn't gain much attention until Antonie van Leeuwenhoek viewed microbes under the microscope in 1676 (4). Since then, microbiology education has developed into an important subject in almost all curricula of medical and biological sciences programs, at both the undergraduate and graduate levels (1). As the nexus between basic, applied, and clinical sciences, microbiology has further made itself applicable in fields such as clinical medicine, environmental science, pharmaceutical science, molecular biology, and biotechnology (5). These applications make microbiology

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a dynamic field which develops at a fast pace. This rapid development leads to the need for constant review of the microbiology program to be in tandem with current realities (6). Although the teaching of microbiology has further developed in advanced countries, the same cannot be said about microbiology education in many developing countries, a number of which still experience infectious disease outbreaks such as Ebola and cholera, with an associated high rate of mortality. Although several factors may be responsible for this, one reason is to do with the level of microbiology training in these countries.

MICROBIOLOGY EDUCATION IN DEVELOPING COUNTRIES

Developing countries, especially sub-Saharan African countries, are still faced with the challenges of infectious tropical diseases such as HIV/AIDS, cholera, and tuberculosis, which claim millions of lives annually (7). Although progress has been made, including the massive provision of antibiotics and antiretrovirals to suppress these infections, further improving microbiology education in these countries may help protect against these diseases. However, many of these countries still have an infrastructure deficit that makes teaching and learning microbiology difficult. For example, unlike developed countries, where there is a steady supply of electricity, many developing countries have an inadequate power supply, making the use of electrical devices such as projectors and electronic blackboards difficult (8). This also limits students, for example, restricting studying in the nighttime.

Second, unlike the situation in developed countries, accessing up-to-date textbooks in many developing countries, especially sub-Saharan African countries, is difficult because libraries are usually not working at an optimal level. In some cases, lecturers and students use their personal money to procure reading materials. Finally, importing books is expensive; thus, there is a need to develop books of local relevance, and efforts are needed to keep them up to date with contemporary materials.

Another problem facing microbiology education in these same countries is poor Internet connectivity. Some departments of microbiology do not even have computers for their students' and staff's use. A reliable Internet connection greatly enhances learning and teaching in several ways. Without reliable Internet, out-of-class engagement is difficult and face-to-face learning then becomes the only platform for interaction (8). Also, the Internet provides open educational resources (9). Accessing the Internet for relevant microbiology learning materials to corroborate what is taught in class (10) enhances student understanding. It is true that with the sale of Internet data by telecom providers, there is now greater access, but students still find this expensive. In some countries, including Nigeria, universities are beginning to build internet bandwidth within their campuses, but this is also limited to a few locations (8).

The problems developing countries face regarding microbiology training are many and complex. Using Nigeria, a major player in African affairs, as a case study, the state of microbiology education and training is examined.

Microbiology education in the Nigerian context

Nigeria is Africa's biggest economy and most populous country, dubbed "the giant of Africa" (11). Occurrences in Nigeria are often used to mirror events in sub-Saharan Africa. Healthcare in Nigeria has evolved progressively over the years; however, the present state is worrisome and needs improvement. The recent outbreak of infectious diseases, such as the Ebola outbreak, and the responses of the microbiology community have further exposed the poor state of healthcare in Nigeria (12). Recurrent but avoidable infectious diseases, such as diarrhea and cholera, which continue to take lives, are evidence of the poor state of microbiology training in Nigeria.

In Nigerian institutions, basic microbiology has traditionally been taught by the faculty of science while medical or clinical microbiology unit is usually part of the college of medicine. Basic microbiology is taught as part of graduate and undergraduate programs at many universities, especially science and technology-oriented universities, while medical microbiology is taught during clinical postings. Despite advances over the years, there have been factors limiting Nigeria's potential as a global powerhouse in microbiology training. The next section attempts to provide some insight into the factors affecting the field of microbiology in Nigeria and provide solutions.

Challenges to microbiology training in Nigeria

Inadequate teaching experts. The teaching of microbiology in Nigerian institutions is limited to traditional face-to-face situations due to limited resources. Whiteboards and multimedia projectors are still commonplace. The main problem facing microbiology training in Nigeria is an inadequate supply of experts to teach future microbiologists. This results in a low lecturer-to-student ratio, leading to poor supervision of students during lectures and practical sessions (8). Graduates of microbiology can be divided into two groups: those who will leave the field of microbiology to pursue a career in non-microbiology fields, such as medicine, the banking sector, or starting a business, and those who choose to remain in the field and obtain a postgraduate degree in microbiology. Members of the first group form the bulk of microbiology graduates, and as a result of the current realities, members of the second group are not encouraged. When these individuals get the opportunity to leave Nigeria for further studies and training, they usually do not return, resulting in brain drain for the country (13). This has led to many microbiologists of Nigerian origin teaching in other countries, including the United Kingdom, the United States, Canada, the Gulf states, and other African countries.

The department of microbiology is also a service department for students in other areas of biological sciences, agricultural sciences, and veterinary sciences. This increases the workload of lecturers, often stretching them beyond the limit. This increased workload causes microbiologists to have less time and attention for self-development, in turn leading to reduced productivity (14).

Another reason for the inadequate supply of teaching experts, especially for postgraduate training, is the lack of training funds. There is no dedicated fund for microbiology training in Nigeria, although, there is the Tertiary Education Trust Fund (TETFund), which is being used to fund research and postgraduate training (8); however, it is highly competitive and there are reports of nepotism and corruption in its application processes (11). There are few lecturers with PhD degrees. However, the lack of financial resources makes training and further education difficult.

The Nigerian government doesn't prioritize spending on science, including microbiology. Over the years, while there has been a significant increase in the budget of government institutions such as the National Assembly, there has not been a similar increase in the budget of science and technology institutions, including those with microbiology departments and laboratories (15). Nigeria is a signatory to the United Nations Educational, Scientific and Cultural Organization (UNESCO) recommendation of allocating 26% of the national budget to the education sector. However, Nigeria has never abided by this recommendation (15). The proportion of the national budget allocated to the education sector in Nigeria in 2017 was 7.40% (15). Nigeria is also a member country of the Next Einstein Forum (NEF), which agreed to invest 0.7% of GDP in science and technology by 2020 and 1% by 2025 (16). However, empirical evidence has shown Nigeria isn't moving in the right direction. This reduced budget has also made it difficult for microbiology departments and institutions to perform at their optimal level.

Inadequate training infrastructure. Teaching in many Nigerian institutions tends to be abstract and imaginary because many institutions, especially government-owned training institutes, lack basic teaching equipment (17). They lack basic tools such as incubators, ovens, microscopes, and fume hoods, which are essential for microbiology teaching. Many microbiology laboratories resort to improvising during practical sessions, such as using stoves for sterilizing glassware in place of an autoclave because they have little or no budget for procuring this tool. As a result, graduates of these laboratories are not globally competitive and may not be encouraged to pursue a higher degree in the field. Universities, especially the older generations, have tools and equipment, but they are limited. During practical sessions, there is insufficient equipment for students, leading to overcrowding and loss of attention. This is coupled with the universities admitting a greater number of students than their carrying capacity and allotted admission quota,

especially for programs without regulatory bodies, such as microbiology (18).

Currently, there are no companies in Nigeria manufacturing consumables and reagents needed for practical sessions. These must be imported and are difficult to acquire, making practical sessions ineffective. Orders and quotes take a long time to be processed, and since science, like every profession, is time-dependent, this leads to reduced productivity for the tutors and lack of exposure for the students.

Outdated curricula. Many institutions use the same curriculum they have been using since the creation of the program. Lecturers may not update their teaching notes and are therefore teaching from outdated notes that do not reflect current realities (19). Likewise, many institutions do not teach microbiology topics such as molecular cloning, PCR, bioremediation, prebiotics, and probiotics because they either do not have the expertise or do not have the teaching resources. A direct comparison of microbiology curriculum content from Nigeria and the United States (as a typical developed country) identified several gaps in Nigerian curricula. For example, comparing the undergraduate microbiology curriculum of my University (Obafemi Awolowo University) and Oregon State University revealed that topics such as disease and society, the human microbiome, and emerging infectious disease and epidemics are not taught in my university, and this despite their importance in the development of the country's healthcare system. In addition, an explicit comparison of many Nigerian institutions' microbiology curricula with the ASM Curriculum Guidelines for Undergraduate Microbiology identified key topics in critical concepts, such as Information Flow and Genetics and Microbial Systems, as topics that are either not taught or need improvement in the Nigerian institutions. These topics include knowledge required for national development that needs to be acquired by future microbiologists. If Nigeria were to invest in the teaching of microbiology topics such as bioremediation, techniques to clean up contaminated areas such as the Ogoniland and other areas of the Niger Delta region could be developed, saving the country billions of Naira.

Electronic tools to the rescue?

Several interventions have been suggested to combat the factors highlighted above. However, many of them won't solve the problems of microbiology education in Nigeria overnight because they require long-term efforts. Hence, there is a need to embrace virtual classrooms and other online tools to catch up with the rest of the world. Improving training resources by adding these electronic tools to curricula will help develop microbiology education in Nigeria, especially those topics that are not being taught due to a lack of personnel or teaching tools. Several case studies from developed countries have shown that online tools can help to improve the quality of microbiology education. A report from Keyano College, Canada, revealed that the

social networking site Facebook can act as an effective tool to engage microbiology students outside of class time (20). Reports from other courses have also shown that online tools can add value to the quality of science education. For example, the Department of Anatomy at the University of Southampton incorporated the use of Twitter in teaching neuroanatomy as a form of support for medical students. The result showed that the tool facilitated communication between students and instructors, relieved anxieties, and raised the morale of the students (21). Finally, findings from Makerere University, Uganda, revealed that social networks can be used to develop social learning and a student-centered pedagogy in developing countries (22).

Some of the available websites or online tools that can be used for improving microbiology education and learning are provided in Table 1.

For emphasis, I discuss two topics in microbiology with wide applications in the healthcare system that are not taught in many Nigerian institutions due to a lack of teaching tools, and how the online tools can be used in practical terms for teaching them.

Molecular cloning. Molecular cloning is a set of methods in cellular and molecular biology used to assemble recombinant DNA molecules and direct their replication within the host organism (30). The DNA molecules, which may be a gene, are usually isolated from a prokaryotic or eukaryotic specimen (31). Following isolation, they are introduced into a host organism, usually the coliform bacteria *Escherichia coli* (31). This shows the microbiological origin of molecular cloning and the need to include it in the curricula of future microbiologists and related healthcare professionals and educators. However, this is not the case in Nigeria, where students are not taught this topic because there is neither the personnel nor the teaching tools to do so.

PCR. PCR is another technique in molecular biology, used to amplify a single copy or a few copies of a fragment of DNA across several orders of magnitude, generating thousands to millions of copies of the DNA sequence (32). PCR has deep roots in microbiology. For example, the production of the Taq polymerase enzyme used in PCR won't be possible without the scientific understanding of the thermophilic bacterium *Thermus aquaticus* and its ability to survive in high-temperature regions (33). Although some progress has been made regarding PCR use in Nigeria, especially because of its application in diagnostic medicine, widespread use has not reached microbiologists. A great deal of effort is needed to inculcate the knowledge of PCR into future microbiologists, since they form a fulcrum part of the country's healthcare system. The department of microbiology could be the main proponent of PCR training in Nigeria and take over from other departments such as biochemistry.

These two topics can be integrated into microbiology training in Nigeria using the following electronic tools.

Online science laboratories. These are makeover science laboratories that can be used for teaching microbiology practicals online (29). These virtual laboratories allow students to simulate real equipment and experiments to learn microbiology topics, including PCR and molecular cloning. They are usually open educational resources made available to students in resource-limited areas, such as Nigeria, at no cost, thus helping to bridge the gap between students from Nigeria and those of developed countries. The experiments in this laboratory can be accessed anytime, anywhere, making them available to the students at their own convenience (29). Countries such as India have used online science laboratories to improve their student knowledge of basic science by integrating them into their teaching curricula (33). This has shifted education from face-to-face-only learning to a blended learning approach.

Examples of the online science laboratory tools that can be used for teaching molecular cloning and PCR include Go-Lab Project (www.go-lab-project.eu/), PhET (<https://phet.colorado.edu/>), and Late Nite Labs. These tools allow students to simulate real experiments. For example, the online science laboratory allows learners to simulate the process involved in PCR methods, such as the initialization, denaturation, annealing, and elongation steps. It also teaches learners the importance of components and reagents such as primers, DNA polymerase, and buffer solutions needed to set up a PCR experiment. Using online science laboratories to teach microbiology in Nigeria will help to bridge the knowledge gap and allow the students to learn basic topics in microbiology that are unavailable due to limited resources.

Short videos. These tools provide visual microbiology lectures and practicals that students can watch at their own convenience. The videos provide some foundational knowledge that students can build on to enhance learning (10). The Khan Academy (www.khanacademy.org) has developed a series of short videos that can be used for teaching microbiology topics, including molecular cloning and PCR (27). At the end of the videos are short quizzes that can be used to evaluate the students' level of understanding of the topics. Integrating the videos in teaching these topics can help improve the performance of students and enhance microbiology education in Nigeria (10). The video-sharing website YouTube (www.youtube.com) also has channels with short videos dedicated to teaching microbiology topics such as molecular cloning and PCR that are not readily taught in Nigerian institutions. YouTube channels such as Edward Kerschen channel, iMedicalSchool channel and Armando Hasudungan's medical channel have developed learning materials on microbiology topics, including molecular cloning and PCR (28). Both students and tutors of microbiology in Nigeria will find these channels useful.

Many of these educational resources are free and open, with no restrictions on their use. The inclusion of these tools in the learning materials will help students to further develop their knowledge of microbiology to become

TABLE I.

Summary of online tools that can be used for microbiology education development in Africa and their functions.

| Online tools | Examples of the online tools for microbiology training | Functions | Reference |
|------------------------------------|--|---|-----------|
| Massive open online courses (MOOC) | Coursera (https://www.coursera.org/) and edx (https://www.edx.org/) | They are an open-access online course which contains microbiology lectures, reading material, problem sets, discussion boards, and other content. | 23 |
| Web games | e-bug (http://www.e-bug.eu/) | They are free educational games and animations for students and teachers covering the major topics of microbiology | 24 |
| Online repositories | Multimedia Educational Resource for Learning and Online Teaching and the MIT open courseware consortium | They contain information about microbiology-related open source tools needed for the development of curricula and teaching of microbiology at all levels | 25 |
| Question website | Pathology questions (http://pathquestions.com/cgi-bin/q.fpl) | They allow users to test their knowledge in medical microbiology using published questions | 10 |
| Social media communities | Listserv: ClinMicroNet; DivFNet; DivKNet Blogs: microBEnet Blog (http://www.microbe.net/) Podcasts: (This Week in Virology [TwiV]); (This Week in Parasitology [TwiP]) | They are electronic tools used for creating online communities for sharing personal messages, ideas, and information associated with microbiology learning. | 10, 26 |
| Short Videos | Khan Academy and YouTube channels | These tools provide visual microbiology lectures and practical's which students can watch at their own convenience | 27, 28 |
| Online science laboratory | Go-Lab Project (http://www.go-lab-project.eu/), PhET (https://phet.colorado.edu/) and Late Nite Labs | They are makeover science laboratory that can be used for teaching microbiology practicals in an online form. | 29 |

globally competitive. To solve the problem of the high cost of procuring computers together with electricity problems, the Raspberry Pi foundation (www.raspberrypi.org/) has created credit card-sized computers that can be used for many of the functions of a normal PC, especially in areas where there is a limited supply of electricity and Internet connectivity (35). Many of these tools can also be accessed using a mobile phone if a computer is not available. These point to the flexible and easy approach these online tools add to learning. The input of online tools in training materials may be the foundation for starting an online microbiology degree in Nigeria and other developing countries. This online degree could serve as a strong foundation for admission into a variety of graduate studies and professional careers in pharmaceutical companies, research organizations, universities, and agricultural institutions. Nigerian institutions can learn from the success story of universities in developed countries, such as the University of Florida, which have used online curricula to engage minorities in science and technology, including microbiology (10).

It is pertinent to conclude that online tools such as short videos also have their disadvantages, such as lack of emotional impact and an inability to aid in mastering basic skills, such as micropipetting (10). However, the integration of these useful

tools will improve teaching and assessment of microbiology by tutors, promote collaboration among students, promote virtual mobility, and facilitate real-time monitoring of students' performance (1). Finally, these tools will also encourage critical thinking among students of microbiology and initiate their quest for excellence in their training (1).

CONCLUSION

There is a need to develop synergy between all the stakeholders involved in microbiology education in Nigeria. The government should encourage microbiologists who are abroad to come back home to reverse the brain drain in the country. It is important to emphasize that the suggested online approaches would work best in areas with reliable online access and, for this reason, may be suitable only for certain regions and larger centers. Nigerian universities must therefore be adequately provided with internet facilities. An enormous revolution is happening in the teaching of microbiology in developed countries; developing countries, especially Nigeria, must not be left behind. There is an important need for microbiology instructors to incorporate electronic tools in the teaching of microbiology and transition from the classical way of

teaching microbiology to modern microbiology education. Finally, there is a growing need to teach the new generation of microbiologists in the developing world the importance of electronic tools in microbiology education.

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