Undergraduate Microbiology Research at the University of Benin, Nigeria: Experiences, Challenges, and Strategic Opportunities

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Abstract: Undergraduate research is a core component of Microbiology training and a crucial pathway for enhancing scientific capacity. Despite its recognised value, students in resource-limited settings often complete research projects under substantial infrastructural and institutional constraints. This study assessed the research experiences of final-year Microbiology undergraduates at a University in Southern Nigeria, using the case study to examine the opportunities and challenges inherent in the Nigerian higher education system. A cross-sectional survey was conducted among 107 of 130 final-year students using a piloted, self-administered electronic questionnaire. Key variables captured included project characteristics, supervision patterns, laboratory access, skill acquisition, confidence in research, challenges encountered, and recommendations for improvement. Quantitative data were analysed descriptively, while qualitative responses were interpreted thematically. Most students reported substantial gains in laboratory skills (91.6%), improved confidence in research design (89.7%), and generally positive supervisory experiences, with more than 94% rating supervision as good or excellent. However, recurrent systemic limitations shaped the research process. Students frequently cited erratic electricity, inadequate laboratory equipment, and high personal costs for reagents, transportation, and private laboratory analyses. Time pressure, delays in project approval, and conflicts between coursework and laboratory schedules further constrained project execution. Qualitative findings revealed a call for structured research training prior to project commencement, as well as growing enthusiasm for microbiology-driven entrepreneurship. The study highlights a paradox that while undergraduate research effectively builds skills and confidence, its full potential is undermined by infrastructure deficits and limited institutional support. Therefore, addressing these gaps requires strategic investment in laboratory capacity, improved supervisory structures, and the incorporation of entrepreneurship and innovation pathways into the curriculum, thereby engendering a new generation of graduates capable of meeting current societal demands.
Key word: Final-year; Microbiology; Nigeria; Undergraduate research; University

INTRODUCTION

Education in Nigeria is described as an instrument "par excellence" for national development, underscoring its essential role in shaping the country's future (Nigerian Educational Research and Development Council (NERDC), (2014). The policy places Universities at the centre of this mission by mandating them to develop graduates with strong technical, analytical, and problem-solving skills. Within this vision, undergraduate research serves as a practical pathway to strengthen scientific abilities, build confidence, and prepare students to make meaningful contributions to national development (NERDC, 2014). Globally, undergraduate research is widely recognised as a critical element of high-quality higher education. It provides students with opportunities to develop scientific thinking, analytical reasoning, and communication skills that are foundational to careers in science and public health (Sadler *et al*., 2010). Research participation also fosters independent inquiry, strengthens professional identity, and deepens understanding of scientific evidence and decision-making (Adebisi, 2022). In microbiology, such experiences are particularly valuable because students engage with real-world issues, such as antimicrobial resistance, (re)emerging pathogens, food safety, and environmental contamination—where investigations in the laboratory directly enhance their capacity to respond to public health challenges (ASM Task Force for Curriculum Guidelines, 2024).

Despite these benefits, the contributions of undergraduate research to capacity building vary significantly across low- and middle-income countries (LMICs). Nigeria illustrates this gap vividly. Although microbiology has a long history of teaching

in the country, persistent structural and pedagogical barriers limit research training. Aishat documents widespread deficits, including outdated curricula, limited exposure to molecular biology, and shortages of modern laboratory tools (Aishat, 2019). These constraints contrast substantially with rapid global advances in microbiology and biotechnology. Chronic underfunding of higher education compounds these challenges; Nigerian Universities frequently rely on personal contributions from staff and students to support basic research due to limited government allocations (Igiri *et al*., 2021).

Nonetheless, these constraints are not unique to Nigeria. Across Africa, Universities face financial limitations that restrict investment in laboratories, staff development, and research infrastructure (Masaiti and Teferra, 2025). Students often contend with erratic electricity, inadequate water supply, insufficient equipment, and overcrowded laboratories, all of which undermine their ability to undertake rigorous scientific work. Such challenges mirror broader inequities faced by students in LMICs, where systemic barriers shape the quality of education and limit opportunities for scientific engagement (Matthews *et al.*, 2022). In response, educators have begun exploring innovative teaching and research strategies to complement traditional laboratory training. For example, Aishat proposes that virtual laboratories and online simulations could help students practise core microbiological procedures when physical resources are scarce (Aishat, 2019). Evidence from digital pedagogy research supports the effectiveness of such tools in reinforcing conceptual and practical knowledge (Alvarez, 2021; Li *et al*., 2025).

Furthermore, the mentored research model implemented at Makerere University in Uganda has demonstrated that structured supervision can significantly enhance student learning, amidst limited laboratory resources (Matovu *et al*., 2013). Technology-enhanced microlearning represents another promising approach. In Nigeria, Instagram-based microlearning has been demonstrated to enhance student engagement and alleviate cognitive overload by providing concise, visually engaging microbiology content (Osaigbovo and Iwegim, 2018). These learner-centred strategies align with global efforts to modernise microbiology education in resource-constrained environments. More recently, Nigerian Universities, including the University of Benin, have begun linking microbiology training with entrepreneurship. The Applied Microbiology International (AMI) workshop at the University of Nigeria, Nsukka, demonstrated how undergraduate students can identify and develop biotechnology-driven business ideas, such as diagnostic services, biofertilizer production, and innovations in fermented foods (Applied Microbiology International, 2024). This reflects growing recognition of microbiology's economic potential and the role of undergraduate research in driving innovation.

Given these dynamics, a deeper understanding of undergraduate research experiences within Nigerian Universities is needed. However, evidence suggests that supportive supervision and structured research processes enhance learning (Igiri *et al*., 2021; Adebisi, 2022), a few empirical studies have examined the lived experiences of microbiology students completing their final-year projects—an essential capstone of the Bachelor of Science degree. This study addresses this gap by analysing the research experiences of final-year microbiology students at the University of Benin, Nigeria. By examining supervision patterns, laboratory access, skills gained, challenges faced, and students' recommendations, this study provides timely insights into the undergraduate research landscape in major Nigerian Universities. The findings also enable comparison with national and global best-practice models, informing strategies to strengthen microbiology education, research capacity, and innovation in Nigeria.

MATERIALS AND METHODS

Study design and population: A cross-sectional study was conducted involving final-year undergraduate microbiology students at the University of Benin, Nigeria. The study population consisted of 130 students completing their compulsory final-year project in the 2024/2025 academic session. All students were eligible to complete the exit survey after reading the study information and providing consent to participate.

Study setting: The research was conducted in the Department of Microbiology, Faculty of Life Sciences, University of Benin, a leading Federal University in Southern Nigeria. The Department trains students in diverse areas of microbiology and requires a supervised final-year research project as part of its degree requirements.

Data collection: The questionnaire (adapted from national and international best-practice models) was developed based on the literature and departmental priorities and then piloted with five Year 3 students to ensure clarity and validity. Responses were voluntary and anonymous. In brief, data were collected using a self-administered electronic questionnaire created in Google Forms. The final questionnaire collected data on demographics, project characteristics, supervision patterns, laboratory access, skill acquisition, confidence in research, challenges encountered, and recommendations for improvement. Additionally, open-ended questions captured experiential narratives for qualitative analysis. Participation was voluntary; informed consent was obtained electronically.

Data management and analysis: Quantitative data were exported to Stata 16 and managed and analysed descriptively using frequencies. Visualisations (pie charts) were generated in Google Forms. Qualitative free-text responses underwent thematic analysis guided by the Braun and Clarke six-phase framework (Braun and Clarke, 2006): Familiarisation, generating initial codes, searching for themes, reviewing themes, defining and naming themes, and producing the report. The two researchers independently coded responses and resolved disagreements through consensus.

RESULTS

Student demographics and project types

Most students were aged 20–25 (96/107, 89.7%) and female (67.3%), reflecting a predominantly young and female cohort. Undergraduate projects spanned multiple subfields of microbiology (Figure 1). One-third was Medical Microbiology (33/107, 30.8%) and one-third Environmental Microbiology (33/107, 30.8%). The remainder included Food Microbiology (20; 18.7%), Microbial Genetics (18; 16.8%) and a few in Industrial or Mycology (3; 2.9% each).

Project durations were typically short: 79.4% of students (85/107) reported spending less than 3 months on their project, and only 17.8% (19/107) reported working on their project for 3–6 months. Additionally, project work was primarily individual: 62.6% (67/107) completed individual projects, compared with 37.4% who worked in pairs or small groups.

Laboratory location

Most experiments were conducted in University facilities (Figure 2). Nearly half (48/107, 44.9%) used the department's laboratory, and another 23.4% (25/107) used laboratories of their lecturers on campus. Some students outsourced, with 16.8% (18/107) using private (typically commercial) laboratories, and 12.1% (13/107) using government laboratories (hospitals). This mix suggests a balance between relying on departmental capacity and increasing use of external partners to support student projects.

Supervision

Students reported regular engagement with supervisors. The most common pattern was weekly meetings (48/107, 44.9%). A further 32.7% (35) met their supervisor occasionally (as needed), 16.8% (18) reported bi-weekly contact, and only 3.7% (4) reported monthly meetings. Nonetheless, the perceived quality

of supervision was high overall, with 57.0% (61/107) rating it as "Excellent", 37.4% (40) rating it as "Good", and only two students rating it as "Fair" or "Poor". Thus, hands-on mentorship was generally frequent and viewed positively.

Skills and confidence

The research projects delivered broad skill gains among students (Figure 3). Nearly all students (98/107, 91.6%) reported learning new laboratory techniques. Substantial proportions also noted improvements in literature review (40.2%), scientific writing (38.3%), data analysis/interpretation (36.4%), using reference management tools (44.9%), and presentation skills (29.9%). A minority (14%) gained experience with statistical software (SPSS). Confidence in research design increased: 51.4% (55/107) felt "Confident" and 38.3% "a bit confident" in designing studies, whereas only 3.7% felt "Not confident".

Challenges encountered

A substantial number of students (41/107, 38.3%) reported significant difficulties, whereas 48.6% reported no significant challenges. The identified challenges clustered into themes, as described thus:

Infrastructure and utilities: Unreliable electricity and water supplies were frequently cited. Students described "erratic light" that caused incubators to malfunction and experiments to be delayed. Inadequate laboratory equipment was another key issue; many felt that the departmental laboratory was "below standard" or lacked essential equipment (orbital shakers, refrigerators). These constraints clearly limited the scope and quality of experimental work.

Timing and workload: Many students felt time pressure was acute. Delays in project approval, late starts, and overlap with exams left "barely any time" for experiments. Several suggested that project work should begin earlier and be formally scheduled to avoid conflicts with coursework.

Sample access and logistics: Projects requiring human or environmental samples faced hurdles. Students had difficulty obtaining consent (especially for paediatric samples), struggled with vendor access, or suffered sample contamination due to poor transportation and storage. These logistical issues were exacerbated by a suboptimal support system (university transport for fieldwork).

Financial and personal constraints: Students repeatedly reported that personal costs were burdensome. Expenses for reagents, transportation (including travel between multiple laboratory sites), and fees at private laboratories strained budgets. A few recounted personal setbacks (such as loss of data on a phone) that impeded progress when resources were already tight.

Student suggestions for improvement

In open comments (n=87 responses), students proposed multiple remedies, which fell into the following thematic priorities:

Enhanced laboratory capacity: The most frequent demand was for better-equipped laboratories and reliable utilities. Students called for "modern equipment," stable power and water, and departmental laboratories dedicated to final-year projects. Many felt that strengthening on-site facilities (rather than outsourcing) would improve quality and supervision.

Revised timing and workload: Students advocated for an earlier, clearly defined project period. Ideas included setting the project duration to one month, as in industrial training, or at least ensuring that there is no overlap between project deadlines and examinations. The respondents urged an "early start" and "adequate time" to ensure that projects are integrated into the academic calendar more effectively.

Improved supervision practices: Although supervision was generally rated as good or excellent, respondents reported occasional lapses. Some requested formal accountability measures (flagging supervisors who are unresponsive) and explicit expectations for meeting frequency and feedback.

Structured research training: Many students felt underprepared in research methods and scientific writing. The respondents recommended a pre-project

"boot camp" covering project design, data analysis, database use, reference software, and report writing. Specific activities proposed by some students included workshops on literature search, statistics, and presentation skills, to standardise the baseline competence of all final-year researchers.

Student choice and well-being: A minority of students suggested of being allowed to choose topics within their areas of interest (from an approved list) and that supervisors should show greater empathy for the stress of final-year work. These comments highlight the importance of a supportive environment for student well-being as an integral part of research training.

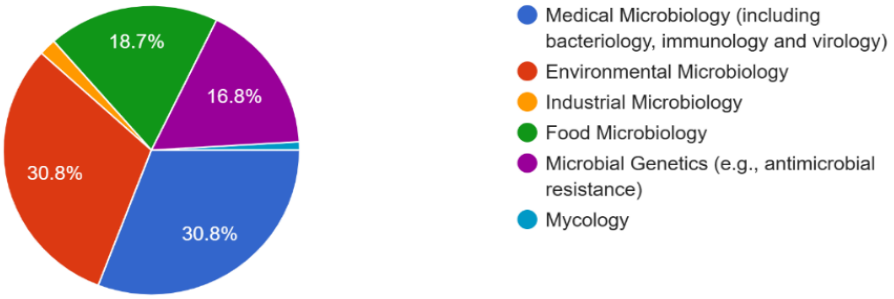

Figure 1: A pie chart of the branches of microbiology in which students conducted their projects

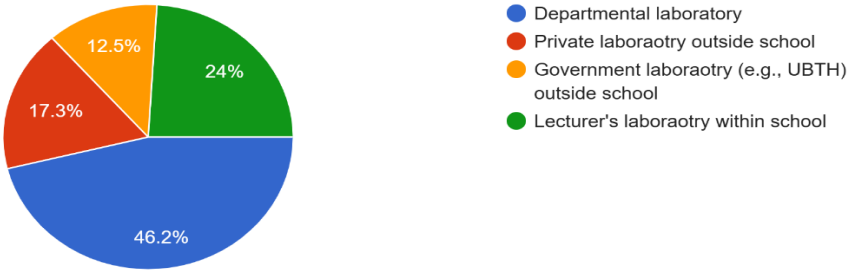

Figure 2: A pie chart of the locations where students conducted their projects

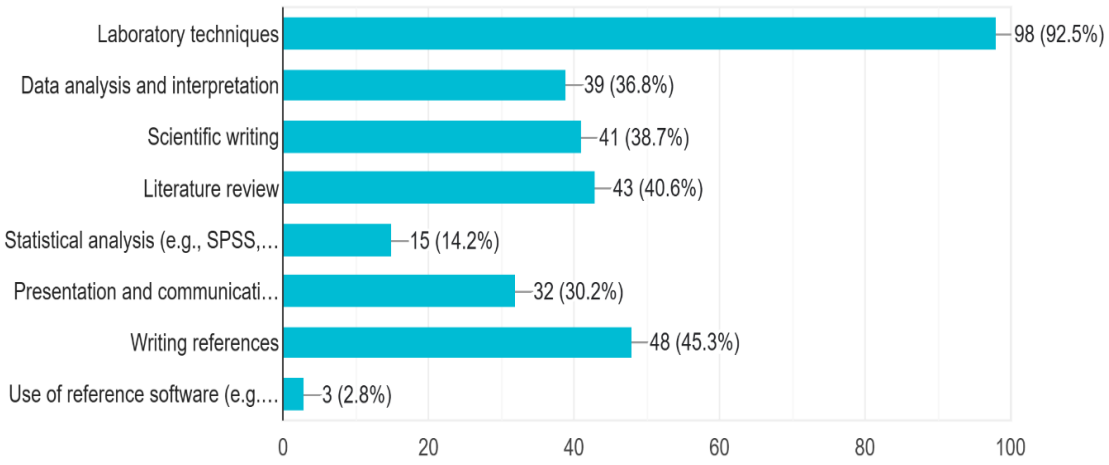

Figure 3: Students' self-reported technical skills gained during the project work

DISCUSSION

Interpretation of key findings

The findings from this study highlight a research experience that is both promising and constrained, mirroring broader trends reported across Nigerian and other LMIC academic environments. Students in the present study consistently expressed appreciation for the value of undergraduate research, particularly in strengthening laboratory competence, critical thinking, and personal confidence. These perceptions align closely with the observations of (Adebisi (2022), who underscored the importance of research participation in shaping professional identity and improving scientific reasoning among Nigerian students. The high proportion of respondents reporting gains in laboratory skills and confidence parallels the outcomes observed in Makerere University's mentored research programme, where structured supervision enhanced students' preparedness for independent inquiry despite infrastructural deficits (Matovu *et al*., 2013). However, even with these positive experiences, longstanding structural barriers remain evident. Students' reflections on inconsistent electricity, limited equipment, and high personal costs echo the challenges documented (Adebisi, 2022) and mirror the chronic funding gaps described by Igiri *et al*. (2021). The trend of self-funding research—well known among early-career academics—appears to extend to undergraduates, who often rely on private laboratories or self-purchased reagents to complete their projects. These problems are symptomatic of the wider underinvestment in research infrastructure that characterises many Nigerian universities, where government allocations to research remain inadequate and universities struggle to maintain functional laboratories (Masaiti and Teferra, 2025).

Educationally, the study reinforces the urgent need for curriculum modernisation in Nigerian microbiology programmes. Aishat (2019) identified critical gaps in laboratory capacity and curricula that fail to expose students to contemporary molecular techniques. Similar deficiencies were reported by our study participants, who highlighted the unavailability of basic reagents, limited access to equipment, and the absence of advanced technologies such as PCR platforms. These challenges constrain students' ability to undertake modern microbiological investigations, thereby limiting the competitiveness and depth of their research projects. The students' strong endorsement of a pre-project research "boot camp" underscores the value of embedding methodological training earlier in the curriculum, aligning with calls for more structured research skill development throughout the BSc programme. It is worth noting that the Department of Microbiology, in collaboration with the University Library, has initiated a mandatory three-day workshop on systematic literature search strategies and the use of digital reference management tools (Mendeley) for new final-year students.

Interestingly, supervision quality emerged as a relative strength despite the anonymity of data collection (no disclosure of personal identifiers, such as names and unique matriculation numbers). Students consistently rated their supervisors highly, reporting frequent contact and constructive engagement. This contrasts with the common narrative of insufficient mentorship in LMIC institutions, suggesting that the University benefits from a committed cadre of academic staff. Nevertheless, the request for improved responsiveness indicates that informal supervisory structures may not always meet students' expectations. The literature consistently emphasises the importance of mentorship in supporting research learning (ASM Task Force for Curriculum Guidelines, 2024). Introducing formal supervisory evaluation mechanisms could help maintain and enhance the generally positive supervisory environment currently observed.

The increasing relevance of digital pedagogies also resonates strongly with the

findings. The need to compensate for infrastructural limitations makes virtual laboratories and online simulations an attractive option. Aishat demonstrated the feasibility of using such tools to introduce molecular workflows into curricula lacking laboratory capacity (Aishat, 2019). Similarly, the Instagram-based microlearning model described by Osaigbovo and Iwegim illustrates how concise, visually rich content can reinforce key microbiology concepts and improve students' engagement. Our students' desire for better preparation and more flexible learning modalities suggests that integrating microlearning and virtual laboratories could significantly enhance the final-year project experience.

Moreover, students' entrepreneurial aspirations align with emerging innovations in Nigerian microbiology education. The Applied Microbiology International workshop, held at the University of Nigeria, Nsukka, demonstrated that students can creatively identify microbiology-based business opportunities, ranging from diagnostic testing services to biofertilizer production, and can engage successfully with innovation ecosystems through mentorship and pitch sessions (Applied Microbiology International, 2024). The enthusiasm observed among our students for practical relevance and applied research indicates that fostering entrepreneurship may serve as both a motivational driver and a viable career pathway. Interestingly, in line with the revised curricula proposed by the Nigeria National Universities Commission, the Department of Microbiology will henceforth implement Entrepreneurial Microbiology as a year three course, thereby addressing the identified gap.

Implications for research, practice, policy, and career development

The outcomes of this study have important implications across multiple domains. Firstly, the intense interest and competence expressed by students demonstrated that undergraduates represent a valuable, but underutilised asset in Nigeria's scientific enterprise. Institutionalising undergraduate research grants, supporting student-staff co-authorship, and creating more structured research mentorship programmes could strengthen the national pipeline of researchers. Secondly, digital innovation holds particular promise. Virtual laboratories, online simulations of molecular techniques, and digital microbiology modules could mitigate the impact of limited physical infrastructure. Moreover, microlearning delivered via Instagram, WhatsApp, or institutional learning platforms could support self-paced revision and reinforce practical demonstrations. Deploying these tools within a blended curriculum would acknowledge the infrastructural realities of Nigerian universities while expanding access to modern microbiology techniques. Thirdly, policy implications emerge at departmental, university, and national levels. Departments should consider adopting formal guidelines for supervision while ensuring that the well-being of both students and staff is prioritised. Universities could create internal undergraduate research funds, establish departmental "research support hubs," and systematise laboratory upgrades. At the national level, operationalising the proposed Special Research Trust Fund (Igiri *et al*., 2021) and expanding TetFund to support undergraduate research could directly enhance laboratory capacity and student experiences. However, the feasibility and sustainability of these initiatives should be objectively assessed before implementation. Lastly, career development opportunities are closely tied to these educational and structural investments. Strengthened research training, combined with exposure to entrepreneurship, could enrich the employability of microbiology graduates. Pathways linking students to postgraduate programmes, national laboratories, biotech industries, and non-governmental organisations would support long-term career trajectories and counteract the persistent problem of brain drain. Integrating modules on biotechnology entrepreneurship,

which has shown promise elsewhere in Nigeria (Applied Microbiology International, 2024), could position students to translate microbiological knowledge into commercially viable innovations.

Strengths and limitations

This study's strength lies in its comprehensive sampling of a complete graduating cohort and its mixed analytical methods, which together provide a rich, multidimensional understanding of student experiences. The high response rate and detailed qualitative submissions lend credibility and depth to the findings. However, the study is limited by its single-site design and reliance on self-reported data, which may introduce reporting biases. The qualitative analysis, although rigorous, may not capture all the nuances of individual experiences, given the manner in which data were collected—an interviewer-administered interview guide via key-informant interviews would have enhanced the granularity of the data. The variations across Nigerian Universities in laboratory infrastructure, supervision practices, and curriculum design also limit direct comparability.

Generalisability

Despite these limitations, many of the challenges identified—such as infrastructural deficits, funding limitations, and workload pressures—reflect well-documented systemic issues across Nigerian and LMIC Universities (Subair *et al*., 2012; Matthews *et al*., 2022). The study's insights are therefore likely applicable to microbiology programmes nationwide. The proposed solutions are similarly adaptable to diverse institutional contexts. Nevertheless, institutions with more advanced infrastructure or different pedagogical structures may need to tailor these recommendations to their specific environments.

CONCLUSION

The study highlights that final-year microbiology projects provide valuable technical and analytical training but are often constrained by resource limitations and scheduling conflicts. These findings are broadly consonant with reports from other Nigerian and African contexts. Therefore, addressing the identified gaps through enhanced infrastructure, innovative teaching methods, improved project management, and entrepreneurship support promises to elevate both student learning and research output. The findings of this study highlight several areas where targeted interventions could substantially enhance the undergraduate research experience. Strengthening laboratory infrastructure remains fundamental; ensuring reliable electricity and adequate equipment would reduce reliance on external laboratories and improve project feasibility. Pedagogically, adopting virtual laboratories and microlearning tools could expand access to modern techniques and reinforce conceptual understanding, thereby overcoming resource constraints. Similar emphasis should be placed on restructuring project timelines to incorporate a dedicated research period free from academic distractions and on institutionalising early topic selection to maximise available project time.

Enhancing the supervisory environment is equally important. Providing mentorship training for junior supervisors by senior colleagues (through co-supervision) and establishing confidential reporting channels for supervisory challenges would improve the quality and equity of the support provided. In parallel, the broader policy environment should be strengthened through the creation of undergraduate research grants, laboratory upgrading initiatives, and national funding mechanisms (operationalising mechanisms to integrate final project funding into the Nigerian Education Loan Fund (NELFUND)(Nigerian Education Loan Fund (NELFUND), 2025). These systemic reforms would not only improve student experiences but also contribute to the long-term development of Nigeria's scientific workforce.

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