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Assessing Learners' Understanding of Microbiology Applications in Multidisciplinary Biological Science Degree

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ABSTRACT

This study investigates the comprehension of microbiological concepts among students and identifies areas for improvement in microbiology education. The participants comprised 56 second-year learners (17 males, 39 females) studying microbiology as part of their BSc Biology program at a university in South Africa's Eastern Cape. A survey was conducted to assess respondents' accuracy in answering ten questions covering various aspects of microbiology, including definitions, classifications, historical figures, and applications in different disciplines. The results of the survey on microbiology knowledge revealed that respondents performed best in identifying Antonie van Leeuwenhoek, with an accuracy rate of 85.7%. Conversely, they performed worst in accurately identifying the reasons to study microbiology, with only 10.7% of responses being accurate. The results reveal varying levels of accuracy, with notable strengths in historical knowledge and identification of infectious diseases. However, deficiencies are observed in taxonomical classifications and understanding of interdisciplinary applications. Strategies for addressing these gaps through targeted educational interventions, curriculum development, and innovative pedagogical approaches are discussed. Overall, this study underlines the importance of ongoing efforts to enhance microbiology education and prepare students for the complexities of the field.

KEYWORDS

BSc Biology; biology education; curriculum; curriculum development; microbiology

INTRODUCTION

Microbiology stands as a cornerstone in the realm of biological sciences, offering a profound understanding of the microscopic world that surrounds us. It also serves as the cornerstone of biological sciences education. From unravelling the mysteries of infectious diseases to harnessing the power of microbial organisms for biotechnological advancements, the field of microbiology encompasses a diverse array of disciplines and applications (Gautam, 2023). In the context of higher education, a comprehensive grasp of microbiological concepts is essential for students pursuing degrees in biological sciences, providing them with a solid foundation for further exploration and specialization. Understanding microbiology holds particular significance for students pursuing a Bachelor of Science (BSc) in Biology, as it forms an integral component of their academic and professional development. Microbiology's direct relevance to numerous career paths aligns closely with the diverse interests and aspirations of BSc Biology students. Whether they intend to specialize in healthcare, pharmaceuticals, agriculture, environmental science, or biotechnology, a solid understanding of microbiology is indispensable (Fagunwa & Olanbiwoninu, 2020). Through the evaluation of learners' comprehension of microbiology, educators ensure that BSc Biology students acquire the requisite knowledge and skills to navigate these career paths effectively. Proficiency in microbiology not only equips students with the scientific principles necessary for addressing current challenges but also prepares them for emerging issues in these dynamic fields (Fahnert, 2016).

Several studies have highlighted persistent educational gaps in microbiology training, ranging from insufficient integration of laboratory skills and real-world applications to superficial coverage of core concepts (Brownell et al., 2014; Fahnert, 2016; Marbach-Ad et al., 2019). These deficiencies can hinder students' critical thinking, conceptual understanding, and preparedness for multidisciplinary scientific challenges. Theoretical frameworks such as constructivism offer valuable insights into these challenges. Constructivist learning theory posits that learners actively construct knowledge through experience and reflection, emphasizing the importance of meaningful engagement with content rather than rote memorization (Piaget, 1970; Vygotsky, 1978). This perspective showcases the need for microbiology instruction that is inquiry-based, contextual, and student-centred. Yet, many undergraduate programmes continue to rely heavily on didactic teaching approaches that do not foster deep learning or conceptual change.

Moreover, by fostering critical thinking, problem-solving abilities, and interdisciplinary perspectives, proficiency in microbiology cultivates the essential attributes needed for success in scientific careers (Osman et al., 2013). BSc Biology graduates, ultimately, this research seeks to contribute to the enhancement of biological sciences education by promoting a deeper understanding of microbiology and its pivotal role in addressing global challenges. By equipping learners with a solid foundation in microbiological principles and applications, we venture to empower the next generation of scientists to tackle emerging issues in health, agriculture, and environmental sustainability with confidence and proficiency. The main aim of this study is to evaluating learners understanding of microbiology applications in general biological science degree.

Research Objectives

- To determine learners' basic and current knowledge on microbiology
- To assess learners' recognition of microbiology's relevance within various biological disciplines related to their degree
- To examine learners' understanding of how microbiology integrates with other fields of biology such as zoology, botany, and entomology
- To identify gap in knowledge and understanding of microbiology

LITERATURE REVIEW

Microbiology's Role in Education and Global Stewardship

Microbiology, at its core, invites us to explore a world invisible to the naked eye but fundamental to all life forms. This field has radically transformed the way we understand disease, health, ecosystems, and even our own identities as human beings (Schneider, 2024; Timmis et al., 2024). Microorganisms were once seen solely as agents of decay or illness, but today they are recognized as critical partners in sustaining life (Melby et al., 2025). They digest our food, enrich our soils, cycle nutrients, and even influence our mental health through the gut-brain axis. Wills (2022) note that microbiology has played a transformative role in revealing these connections, shifting the narrative from fear of germs to appreciation of microbial ecosystems. This shift is particularly important for students who are beginning their journey in biological sciences—it encourages them to view microorganisms not as mere lab subjects, but as complex, essential contributors to life.

What makes microbiology so engaging especially for undergraduate students is how it blends mystery with relevance. The awe of discovering a previously unknown microbe under the microscope is matched by the realization that such discoveries could lead to life-saving antibiotics or sustainable farming techniques (Wilson & Ho, 2023). Timmis et al. (2024) highlight how this dual role—curiosity-driven exploration and practical application—makes microbiology uniquely positioned within biological education. For students, learning microbiology often becomes the first encounter with research that directly addresses global challenges. It's a discipline that helps them see the connection between microscopic processes and macroscopic realities. This perspective nurtures not just scientific literacy, but also a sense of global citizenship and responsibility, preparing them to become not only scientists but stewards of both human and environmental health.

The Role of Microbiology in Higher Education

In the context of higher education, especially within a Bachelor of Science (BSc) in Biology program, microbiology is not just another subject—it's a gateway. It introduces students to the complexity and interconnectedness of life at the microscopic level. Gautam (2023) notes that microbiology plays a pivotal role in equipping students with foundational knowledge across multiple branches of biology, such as genetics, molecular biology, and environmental sciences. For many, their first microscope session—peering into a drop of pond water teeming with life—sparks the realization that biology is as much about the invisible as it is about the visible. This revelation often becomes a turning point, transforming abstract textbook knowledge into tangible curiosity.

More importantly, the way microbiology is taught today has evolved to reflect the changing landscape of science education. Gone are the days of purely theoretical lectures and “cookbook” lab exercises (Fahnert, 2017). Increasingly, universities are embracing inquiry-based, student-centred learning. In Australia, for instance, large-scale programs such as the Authentic Large-scale Undergraduate Research Experience (ALURE) at the University of Queensland have introduced real research into microbiology classrooms (Auchincloss et al., 2014; Kappler et al., 2017). These initiatives engage students in original investigations—such as analyzing soil microbes for novel antibiotic compounds or profiling local microbiomes—giving them a genuine taste of scientific discovery. Such experiences have been shown to boost student engagement, confidence, and critical thinking (Osman et al., 2013). For BSc Biology students, this shift transforms microbiology from a passive learning subject into an active exploration, preparing them not only for postgraduate studies but also for meaningful careers in research, healthcare, agriculture, and beyond.

For many students, the microbiology classroom and lab become transformative spaces—where science becomes tactile and curiosity takes shape. The experience of growing bacterial colonies or using a microscope to observe the life within a single drop of water often leaves a lasting impression. These hands-on engagements allow students to move beyond rote memorization into authentic exploration. Students begin to ask deeper questions: *Why do microbes behave differently in different environments? How can we use them to solve environmental problems? Can microbes be allies in medicine rather than threats?* This inquiry-driven learning fosters a deeper connection to the discipline. It also brings a sense of relevance—what they learn in class today could contribute to developing a life-saving vaccine or a soil-enriching biofertilizer tomorrow. In this way, microbiology doesn’t just inform students; it inspires them.

Moreover, the early integration of microbiology into the undergraduate curriculum sets a strong tone for lifelong scientific engagement. As students’ progress through their degree, they draw on microbiological knowledge repeatedly—in physiology, biochemistry, biotechnology, and environmental biology (Buthelezi & Mpuangnan, 2024; Fahnert, 2017). Even for those who do not specialize in microbiology, its influence persists throughout their academic journey. It helps them build interdisciplinary bridges and fosters a mindset that is holistic rather than fragmented. By framing microbiology as a foundational and integrative science, universities empower students with the confidence and competence to navigate and contribute meaningfully to a variety of scientific and societal domains.

Microbiology as a Career Catalyst

Microbiology is more than an academic requirement—it's a career catalyst that opens doors to diverse and evolving professional pathways. Its relevance spans healthcare, pharmaceuticals, agriculture, environmental conservation, biotechnology, food safety, and public health (Goel et al., 2024). For BSc Biology students, this broad applicability allows them to align their academic experiences with their personal interests and career aspirations. As noted by Fagunwa & Olanbiwoninu (2020), a foundational knowledge of microbiology is indispensable for those entering roles such as medical laboratory technologists, environmental scientists, microbial ecologists, or biotechnologists. In this regard, microbiology acts as both a compass and a toolbox: it points learners toward a wide range of career opportunities while equipping them with practical and analytical skills essential in the workforce.

What further strengthens microbiology's impact is its alignment with global and local priorities. The increasing burden of antimicrobial resistance, emerging zoonotic diseases, food security challenges, and the need for sustainable agriculture are all areas where microbiologists are urgently needed (Zhang et al., 2024). BSc Biology graduates who have been exposed to applied microbiology are better positioned to respond to these challenges with innovation and evidence-based strategies. Proficiency in microbiology also increases employability, as employers in both public and private sectors often seek candidates who can apply microbiological techniques in clinical diagnostics, industrial fermentation, environmental monitoring, or genetic engineering (Akinsemolu et al., 2023). This relevance to real-world problems makes the discipline not only intellectually stimulating but also socially impactful.

Moreover, microbiology fosters transferable skills that are highly valued across disciplines. Students trained in microbiology learn to think critically, analyze complex data, manage laboratory protocols, and communicate scientific findings clearly. These competencies are just as important in policy development and science communication as they are in research laboratories. For instance, a graduate who may not pursue a bench science role can leverage their microbiology background in science journalism, regulatory affairs, or public health advocacy. Microbiology nurtures both scientific rigor and curiosity—two essential ingredients for lifelong learning and adaptability. This flexibility ensures that students are not confined to narrow job titles but instead prepared for dynamic, interdisciplinary careers.

Finally, exposure to microbiology can be transformative at the personal level. Students often report that learning about the microscopic world enhances their awareness of issues like hygiene, disease prevention, and environmental stewardship in daily life. This personal empowerment is often the seed from which deeper civic engagement or scientific leadership grows. Whether working in a remote clinic, developing vaccines, restoring polluted ecosystems, or shaping biosafety policies, graduates who understand microbiology carry with them a critical awareness of how small organisms influence large-scale outcomes. Through this lens, microbiology becomes more than a career—it becomes a lifelong lens for understanding and improving the world.

Cultivating Scientific Thinking and Real-World Skills

One of the most valuable contributions of microbiology education lies in its ability to develop students' scientific thinking. Rather than simply memorizing facts about microbes, students are encouraged to ask questions, generate hypotheses, design experiments, analyze data, and draw evidence-based conclusions. This scientific process, embedded in microbiology training, fosters a mindset that goes beyond the classroom—it promotes curiosity, critical analysis, and logical reasoning. According to Fahnert (2016), this approach nurtures independent learners who are capable of making informed decisions and solving problems systematically. In today’s information-rich but often misleading world, these are crucial life skills, not just academic outcomes. Microbiology, with its hands-on experiments and data interpretation, thus serves as a training ground for broader intellectual development.

Moreover, microbiology uniquely prepares students with real-world technical skills that are directly applicable to research, industry, and public health contexts. Through practical lab work—such as culturing bacteria, performing antimicrobial susceptibility tests, DNA extraction, microscopy, or environmental sampling—students learn techniques used in clinical and industrial microbiology laboratories (Buthelezi & Mpuangnan, 2024). These practical competencies are increasingly valued by employers, especially in settings like diagnostic labs, pharmaceutical manufacturing, agricultural biotechnology, and water quality testing (Ezemba et al., 2025). In addition, students often work in teams, manage lab notebooks, interpret ambiguous results, and present findings—mirroring the dynamics of professional scientific environments. This combination of technical proficiency and experiential learning bridges the gap between theory and application. It also boosts student confidence, enhances employability, and reinforces the value of microbiology education as a foundation for both scientific and societal contributions.

Assessing Understanding to Enhance Learning

To ensure microbiology education is effective, educators must regularly assess students' understanding—not as a punitive measure, but as a tool for growth. Thoughtful assessment helps identify gaps, refine teaching strategies, and support student learning in meaningful ways (Zhai, 2021). Whether through lab reports, case-based learning, or project-based assessments, evaluations can reveal how students apply microbiological concepts to real-life scenarios. As Fahnert (2016) argues, effective teaching in microbiology must evolve alongside global scientific trends and student needs. In doing so, we ensure that learners are not just absorbing facts, but developing a deep, functional understanding of the subject.

Assessment in microbiology education serves a dual purpose: it not only evaluates students’ grasp of complex concepts but also plays a critical role in reinforcing and deepening their learning. Traditional assessments, such as written exams and quizzes, provide a snapshot of students’ theoretical knowledge. However, to truly capture the depth of understanding required in microbiology, educators are increasingly adopting diverse assessment strategies. These include practical exams, lab reports, research projects, and reflective assignments that encourage students to apply concepts in real-world contexts. According to Osman et al. (2013), such formative assessments promote active learning by encouraging students to integrate theory with practice, fostering higher-order thinking skills such as analysis, synthesis, and evaluation. Effective assessment design thus becomes an essential pedagogical tool that drives continuous learning, identifies gaps in knowledge, and informs targeted instructional interventions.

Beyond measuring academic achievement, assessment in microbiology also nurtures essential scientific competencies such as critical thinking, problem-solving, and communication (Timmis et al., 2024). For instance, practical assessments that require students to interpret experimental data or troubleshoot unexpected results mimic real-life scientific challenges, helping students develop resilience and adaptability. Peer assessments and group projects foster collaboration and the exchange of diverse perspectives, preparing students for multidisciplinary teamwork in their future careers. Furthermore, integrating technology—such as virtual labs, online quizzes with instant feedback, and interactive simulations—enhances engagement and provides immediate insights into student performance (Alam, 2023). By using varied and dynamic assessment methods, educators can create a more inclusive and supportive learning environment that motivates students to take ownership of their learning journey and builds a solid foundation for lifelong scientific inquiry.

Empowering Students to Address Global Challenges

Microbiology is not confined to labs and textbooks—it plays a key role in solving some of the world's most pressing challenges. From climate change to food security, antimicrobial resistance to pandemic preparedness, microbial science is central to global sustainability (Timmis et al., 2024). Educators who teach microbiology are not just imparting knowledge—they are nurturing future scientists, innovators, and problem-solvers. When students understand how soil microbes can improve crop yields or how gut bacteria influence health, they begin to see themselves as part of the solution. Fagunwa & Olanbiwoninu (2020) emphasize that microbiology education must instill not only knowledge, but also a sense of responsibility and possibility.

Microbiology education plays a pivotal role in preparing students to confront some of the most pressing global challenges of our time. Infectious diseases, antimicrobial resistance, food security, environmental degradation, and climate change are complex problems deeply intertwined with microbial processes (Zhang et al., 2024). By understanding microbiology, students gain insight into the underlying mechanisms that drive these issues—such as how pathogens evolve resistance to drugs or how soil microbes contribute to sustainable agriculture. This scientific knowledge empowers students to think critically about solutions that are grounded in evidence and innovation. As Fagunwa & Olanbiwoninu (2020) note, equipping biology graduates with strong microbiological foundations enhances their ability to develop interventions that are not only effective but also sustainable and socially responsible.

Moreover, microbiology education fosters a global and interdisciplinary perspective that is essential for addressing challenges that transcend borders. Students learn to appreciate the interconnectedness of human health, ecosystems, and microbial diversity (Timmis et al., 2024). This awareness cultivates a sense of responsibility and urgency, motivating students to engage in research, policymaking, and community outreach aimed at improving public health and environmental sustainability. Through projects, internships, and collaborations, students experience firsthand how microbiological applications from developing vaccines to bioremediation techniques can have tangible impacts on communities worldwide (Zhang et al., 2024). Ultimately, by empowering students with knowledge, skills, and ethical grounding, microbiology education helps nurture a generation of scientists and citizens ready to lead and innovate in the face of global challenges.

Conclusion: Reimagining Microbiology Education for the Future

In sum, microbiology is more than a requirement for a biology degree, it is a transformative discipline that shapes how students view the world and their place in it. By emphasizing its applications, fostering scientific curiosity, and assessing understanding in meaningful ways, we can elevate the impact of microbiology education. This literature review supports the core aim of this study: to evaluate learners' comprehension of microbiology within the context of a general biological sciences degree. Ultimately, by strengthening microbiology education, we empower students to meet the demands of modern science and contribute solutions to the ever-evolving challenges of health, agriculture, and the environment.

RESEARCH METHOD

Participants

The target group consisted of second-year learners who was enrolled for microbiology course under Bachelor of Science (BSc) programs in Biology in the eastern cape of South African university. A total of 56 learners (17 male and 39 female) completed the survey between the 09th and 25th of September 2023. Participation was voluntary, and learners had the option to decline.

Research Design

This study employed a cross-sectional survey design, which involved collecting data at a single point in time to assess the current level of microbiology understanding among second-year BSc students. The cross-sectional approach is widely used in educational research for its ability to provide a snapshot of participants' knowledge, attitudes, or behaviours without requiring long-term follow-up (Creswell & Creswell, 2018; Levin, 2006). A deductive research approach was applied, as the study was grounded in established microbiological educational frameworks and aimed to test specific assumptions about learners' comprehension based on standardized content taught in Bachelor of Science programmes (Bryman, 2016). A mono-method quantitative strategy was used, utilizing a structured self-administered questionnaire distributed online via Google Forms. Quantitative research allows for objective measurement and statistical analysis of variables, making it particularly suited for evaluating educational outcomes (Cohen, Manion, & Morrison, 2018). The questionnaire was designed to align with the curriculum content, microbiology textbooks, and national educational standards. It included ten closed-ended questions categorized on an accuracy scale: *Accurate*, *partially accurate*, and *inaccurate*. This format allowed for uniform grading and facilitated straightforward quantitative analysis of student performance. The survey research method was selected for its cost-effectiveness and ability to reach a relatively large sample quickly and efficiently (Dillman, Smyth, & Christian, 2014). Given the geographic and logistical constraints of the study setting—a university in the Eastern Cape, South Africa—this approach enabled broad data collection with minimal resource expenditure.

A structured questionnaire was designed by the research team to assess learners' understanding of microbiology, with content validity confirmed through expert review and a Cronbach's alpha coefficient of 0.82 indicating good internal consistency. The questions were designed based on course syllabi, textbooks, and educational standards in microbiology. The learners were invited via Google Form questionnaire link and submit it promptly, within one week. The learners have the option to decline participation in the study. The first section consists of the declaration and demographic data, followed by questions around learners understanding of microbiology applications in general biological science. This study follows a positivist paradigm, since it aims to empirically assess learners' understanding of microbiology using a structured questionnaire. Positivism relies on observable and measurable facts, rejecting metaphysical explanations. It has significantly influenced various fields, including physics, mathematics, and accounting, where quantitative methods dominate research practices (Wati, 2024). Conversely, critiques of the positivist paradigm highlight its limitations, particularly in social sciences where human experiences and subjective interpretations are essential. Furthermore, it employs quantitative research methods, such as statistical analysis, to derive conclusions from data (Castrillo, 2024). Positivism posits that science is the only valid form of knowledge, emphasizing the need for empirical verification (Wati, 2024). In disciplines within natural sciences, positivism aids in understanding natural phenomena through empirical data collection (Castrillo, 2024). The study assumes that knowledge can be measured quantitatively through responses based on predetermined course syllabi and educational standards. To enhance content validity, the questionnaire items were reviewed by two microbiology lecturers and one curriculum specialist, who assessed the relevance, clarity, and alignment of the questions with key learning outcomes (Haynes et al., 1995). It consisted of two sections:

Demographic Information & Consent Declaration, Microbiology Knowledge Assessment

Data Collection Process

To collect the data, a Google Forms link was shared with the learners through their university emails and class WhatsApp group. The questionnaire started with a brief introduction and a consent section, which students had to agree to before continuing. They were given one week—from 9 to 15 September 2023 to complete the form at their own pace. A reminder message was sent halfway through the week to encourage more responses. All responses were automatically recorded online, and access to the data was limited to the research team to ensure privacy.

Data Analysis

Following data collection via Google Forms, responses were exported to IBM SPSS Statistics (Version 28) for analysis. The dataset was first cleaned to remove any incomplete entries, and variables were coded according to predefined categories (*Accurate*, *Partially Accurate*, *Inaccurate*). Descriptive statistics, including frequencies and percentages, were generated to summarize learner responses to each question. These outputs allowed for a clear understanding of trends in microbiology knowledge across different topic areas. Tables were then formatted for reporting purposes and cross-checked for consistency with the raw data.

Ethical Considerations

Participation was voluntary, and students had the option to decline without consequences. Data was collected anonymously to protect participants' identities, and informed consent was obtained before participation. The study adhered to ethical research guidelines to ensure confidentiality and integrity.

FINDINGS

The investigation probed the depth of knowledge among participants regarding fundamental concepts within microbiology, spanning historical, taxonomical, and practical dimensions. The analysis of responses (shown in Table 1) to individual questions provided insights into the accuracy and comprehensiveness of respondents' understanding across a spectrum of microbiological topics. In elucidating the conceptual framework of microbiology, respondents displayed varying degrees of proficiency. Notably, 59% demonstrated accurate comprehension, whereas 30% exhibited partial accuracy and 11% conveyed misconceptions. This nuanced distribution highlights the necessity for targeted educational interventions to ensure a comprehensive grasp of microbiological fundamentals. Furthermore, inquiry into the major classifications of microbiology revealed a notable divergence in respondent proficiency levels. While 44.6% provided accurate taxonomical classifications, a considerable portion, comprising 42.9%, misidentified or demonstrated partial accuracy, highlighting potential gaps in foundational knowledge within this domain.

Conversely, the examination of historical figures within microbiology yielded more promising results, with 85.7% accurately identifying Antonie van Leeuwenhoek. This robust demonstration of historical acumen indicates a commendable familiarity with seminal figures and their contributions to the field. Exploration into the identification of infectious diseases beyond HIV and TB unveiled a relatively high level of proficiency among respondents, as 73.2% provided accurate designations. This suggests a commendable awareness of prevalent infectious agents, albeit with discernible areas for improvement. The analysis of microbiology's interdisciplinary applications elicited nuanced responses, revealing variegated levels of comprehension across different domains. While 60.7% accurately delineated microbiological applications in zoology, a mere 32.1% demonstrated similar proficiency in the context of entomology. Similarly, in botany, 55.4% accurately portrayed microbiological applications, signifying varied levels of interdisciplinary integration within the respondents' understanding. Moreover, the examination of penicillin's origin emphasized a moderate level of proficiency, with 51.8% accurately attributing its source. However, a substantial proportion, constituting 44.6%, exhibited inaccuracies, indicative of potential areas for focused educational intervention. Collectively, these findings elucidate both strengths and deficiencies within respondents' comprehension of microbiological concepts. While certain areas, such as historical figures and infectious disease identification, showcased commendable proficiency, others, including taxonomical classification and interdisciplinary applications, revealed opportunities for targeted educational interventions to enhance conceptual clarity and interdisciplinary integration within the realm of microbiology education. While respondents demonstrated solid knowledge in core areas—such as microbiology history (85.7% accurate) and infectious disease identification (73.2%), their grasp of interdisciplinary applications varied widely. Understanding of microbiology's role in zoology (60.7%) and botany (55.4%) was moderate, but entomology lagged significantly (32.1% accurate). This disparity is likely rooted in curriculum design: many undergraduate programmes treat microbiology as a stand-alone subject, with limited integration into other biological disciplines (Alexander et al., 2024; Vasquez, 2022). Vasquez (2022) highlighted that even culturally responsive microbiology curricula often remain confined to microbiological topics, lacking cross-disciplinary connections that contextualize the science in broader ecological systems. Similarly, Alexander et al. (2024) demonstrated that interdisciplinary CUREs (Course-Based Undergraduate Research Experiences) significantly improve students' self-efficacy and application skills by engaging them in multifaceted microbiological research that spans organismal and ecological realms

Furthermore, a recent study on entomology education revealed that virtual tools like iNaturalist can boost student interest and observational skills in insect biology, but such tools must be deliberately integrated into microbiology curricula to build transferable understanding. Without intentional links such as case studies on microbial pest control or microbial influence on pollinators students are unlikely to connect microbiological concepts to these interdisciplinary domains. According to project-based learning research, authentic, context-driven experiences are essential for reinforcing such connections (Xue et al., 2023). In summary, the observed gaps in interdisciplinary comprehension likely stem from disciplinary silos, limited exposure to contextualized learning, and insufficient pedagogical tools that bridge microbiology with fields like entomology, botany, and zoology. Addressing these issues would require curriculum redesign to include integrated learning experiences, co-taught modules with allied departments, and research-based activities that explicitly highlight the applied nature of microbiology across biological sciences. The alignment between the research objectives and survey responses is summarized in Table 2 (see appendix), which outlines how each objective was addressed through specific questions and highlights key findings related to learners' understanding of microbiology. Overall, the findings reveal a mixed level of knowledge among participants stronger in historical and basic definitions, but weaker in taxonomical understanding, interdisciplinary applications, and conceptual depth. These results highlight the need for more structured support in certain thematic areas within the microbiology curriculum to bridge observed knowledge gaps and enhance relevance across biological disciplines.

DISCUSSION

To address the identified gaps in microbiological understanding, the discussion may centre on implementing strategies such as targeted educational interventions, curriculum development, and innovative pedagogical approaches. Firstly, while active-learning strategies such as flipped classrooms and interdisciplinary projects have been shown to enhance microbiology learning globally, their implementation in South African universities faces structural barriers. Many institutions, particularly historically disadvantaged ones, struggle with inadequate lab infrastructure, overcrowded classrooms, and limited access to digital tools, constraints that can impede hands-on and collaborative pedagogies (Woldegiorgis, 2022; Chomunorwa et al., 2023). Without addressing these foundational limitations, scaling up such interventions may remain aspirational rather than actionable.

Secondly, the digital divide—accentuated by socioeconomic and geographic disparities—poses a significant impediment to equitable microbiology education. Students from rural or low-income backgrounds often lack reliable internet access, devices, and digital literacy skills, which were particularly evident during the COVID-19 shift to online learning (Tamrat & Teferra, as cited in 2022 studies; Woldegiorgis, 2022). This digital inequity likely contributes to students' limited engagement with technology-enabled learning tools, such as virtual labs or simulations, which can support understanding of interdisciplinary microbiology applications.

Lastly, linguistic and foundational educational challenges further compound student difficulties. With many entering university as first-generation learners from under-resourced schools, students often have limited prior exposure to scientific English and microbiological terminology (CHE, 2021; Du Plessis & Mestry, 2019). This barrier hinders comprehension of concept-heavy topics like interdisciplinary microbial roles in botany, zoology, or entomology. Effective reform should therefore include scaffolded learning, multilingual support, foundation modules, and localized digital resources such as simulations or case studies focused on South African microbial applications to foster academic success within the local context.

Curriculum development activities could pivot towards the integration of active learning strategies, practical laboratory experiences, and real-world applications of microbiology to augment student engagement and understanding (Aparna et al., 2020; Khan et al., 2024; Nyutu et al., 2018). By incorporating practical exercises, case studies, and interdisciplinary projects into the curriculum, educators could afford students opportunities to apply theoretical knowledge within authentic contexts (Hester et al., 2018), thereby fostering deeper comprehension and retention of key concepts as evidenced by the survey's findings. In addition, innovative pedagogical approaches, such as the implementation of flipped classrooms, problem-based learning modalities, and collaborative inquiry methodologies, represent viable avenues to engender active student engagement and nurture critical thinking skills (Angshurekha et al., 2020; Cortez et al., 2023. Nichat et al., 2023). By pivoting away from traditional lecture-centric instruction towards interactive and student-centred learning paradigms, educators could foster environments conducive to knowledge construction, problem-solving, and conceptual mastery, as implicated by the observed disparities in comprehension across various aspects of microbiology.

Moreover, the integration of technology-enabled learning platforms, virtual simulations, and multimedia resources stands to enrich student learning experiences, catering to diverse learning modalities and preferences (Saini, 2016). The assimilation of interactive digital tools and resources into the curriculum could enhance accessibility, facilitate self-directed learning, and engender heightened engagement with microbiological concepts, as corroborated by the survey's outcomes. Collectively, the adoption of targeted educational interventions, curriculum refinements, and innovative pedagogical methodologies holds promise in addressing the discerned deficiencies in microbiological understanding, empowering students to attain heightened levels of proficiency, and cultivating enduring appreciation for the multifaceted and interdisciplinary nature of the discipline. Findings from the study could inform curriculum development efforts by highlighting areas where emphasis should be placed to improve overall understanding and competency in microbiology. This could involve revising course content, incorporate active learning strategies, or integrating real-world applications to enhance engagement and comprehension. For example, Winter and his colleagues (2023) have pioneered a new hub-and-spoke biology curriculum centred on interdisciplinary laboratory practical sessions, aimed at bolstering student employability through hands-on experiences and collaboration across disciplines.

In integrating microbiological principles within interdisciplinary contexts, emphasizing the necessity for enhanced interdisciplinary collaboration and education to foster a comprehensive understanding of microbiology's applications. Interdisciplinary collaboration and education are pivotal for nurturing a comprehensive understanding of microbiology's diverse applications within contemporary scientific exploration (Garcia et al., 2022). Microbiology, as a multidimensional discipline (McDonald et al., 2023), intersects with various scientific realms, including zoology, botany, entomology, and medicine. Thus, facilitating interdisciplinary collaboration becomes indispensable in unlocking the full potential of microbiological research and its practical implications. The intricate interconnections inherent in biological systems emphasize the necessity of enhanced interdisciplinary collaboration in microbiology.

Moreover, conventional disciplinary boundaries often confine students' exposure to the interdisciplinary nature of microbiology, leading to fragmented knowledge and limited comprehension of the broader implications of microbial research. This may entail incorporating interdisciplinary coursework, facilitating collaborative research projects, and providing experiential learning opportunities that bridge theory and practice. The results could also serve as a foundation for future research undertakings aimed at exploring factors influencing knowledge acquisition in microbiology, assessing the effectiveness of educational interventions, or investigating trends in microbiology education over time. Overall, the study aims to provide meaningful insights into the current state of microbiology education, identify areas for improvement, and propose strategies for enhancing the learning experience and competency of students in this field.

CONCLUSION

In conclusion, this study provides valuable insights into the current state of microbiology education, elucidating both strengths and areas for improvement among respondents. The analysis of survey results revealed varying levels of accuracy and comprehension across different aspects of microbiological concepts, highlighting the need for targeted educational interventions and curriculum enhancements. By leveraging innovative pedagogical approaches and integrating practical experiences, educators can effectively address identified gaps and foster deeper understanding among students. Moving forward, continued efforts in curriculum development and educational innovation are crucial to cultivate a robust understanding of microbiology and prepare students for the dynamic challenges of the field. This study has several limitations, including a relatively small sample size drawn from a single university, which may limit the generalizability of the findings. Data collection relied solely on self-administered online questionnaires, which could affect response accuracy and completeness due to lack of supervision and varying internet access. Additionally, the study measured mainly declarative knowledge and did not incorporate practical or performance-based assessments. Some research objectives were addressed indirectly without applying statistical tests to explore relationships, limiting the depth of interpretation. Lastly, the cross-sectional design captures only a snapshot of learners' knowledge, without assessing changes over time. Despite these limitations, this study provides valuable baseline data on microbiology knowledge among undergraduate students and highlights critical areas for educational improvement and curriculum development.

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REFERENCES

Akinsemolu, A., Onyeaka, H., Fagunwa, O. and Adenuga, A.H., (2023). Toward a resilient future: the promise of microbial bioeconomy. *Sustainability*, *15*(9), p.7251. https://doi.org/10.3390/su15097251

Alam, A., (2023, March). Leveraging the power of 'modeling and computer simulation'for education: An exploration of its potential for improved learning outcomes and enhanced student engagement. In *2023 International Conference on Device Intelligence, Computing and Communication Technologies, (DICCT)* (pp. 445-450). IEEE. https://doi.org/10.1109/DICCT56244.2023.10110159

Angshurekha, D., Purnima, B., Atanu, C. & Uttara, B. (2020). Introducing flipped classroom to undergraduate students in microbiology. *Internal Journal of Health Research and Medico Legal Practice*, 6(1), 34-40. ISSN 2454-5139. https://doi.org/10.31741/ijhrmlp.v6.i1.2020.7

Aparna, Y., Anuradha, K., Jyothi, C., Sri Manjari, K. & Challa, A.K. (2020). Bringing real-world microbiology experiences to undergraduate students in resource-limited environments. *Frontiers in Microbiology*, *11*, 589405. https://doi.org/10.3389/fmicb.2020.589405

Auchincloss, L.C., Laursen, S.L., Branchaw, J.L., Eagan, K., Graham, M., Hanauer, D.I., Lawrie, G., McLinn, C.M., Pelaez, N., Rowland, S. and Towns, M., (2014). Assessment of course-based undergraduate research experiences: a meeting report. https://doi.org/10.1187/cbe.14-01-0004

Bryman, A. (2016). *Social research methods* (5th ed.). Oxford University Press. ISBN: 978-0-19-9689453

Buthelezi, P.Z. and Mpuangnan, K., (2024). The Impact of integrating the history of science into life science teaching of viruses on students' comprehension of microbiology concepts. *International Journal of Innovative Technology and Interdisciplinary Sciences*, *7*(1), pp.1-14. https://doi.org/10.15157/IJITIS.2024.7.1.1-14

Castrillo, C. J. H. (2024). Paradigma Positivista. Boletín Científico de Las Ciencias Económico Administrativas Del ICEA, 12(24), 29–32. https://doi.org/10.29057/icea.v12i24.12660

Chemin, M. (n.d.). *VitalStats: Public higher education 2019*. Council on Higher Education.

Chomunorwa, S., & Mugobo, V. V. (2023). Digital transformation and post-COVID-19 education in South Africa: A review of literature. *South African Computer Journal, 35*(1), 91–100. https://hdl.handle.net/10520/ejc-comp_v35_n1_a8

Cohen, L., Manion, L., & Morrison, K. (2018). *Research methods in education* (8th ed.). Routledge. https://doi.org/10.4324/9780203224342

Cortez, C.P., Osenar-Rosqueta, A.M.F. & Prudente, M.S., (2023). Cooperative-flipped classroom under online modality: Enhancing students' mathematics achievement and critical thinking attitude. *International Journal of Educational Research*, 120, 102213. https://doi.org/10.1016/j.ijer.2023.102213

Creswell, J. W., & Creswell, J. D. (2018). *Research design: Qualitative, quantitative, and mixed methods approaches* (5th ed.). SAGE Publications. ISBN: 978-1-50-6386706

Dillman, D. A., Smyth, J. D., & Christian, L. M. (2014). *Internet, phone, mail, and mixed-mode surveys: The tailored design method* (4th ed.). Wiley. ISBN: 978-1-118-92130-2

Du Plessis, P., & Mestry, R. (2019). Teacher training for diverse classrooms in South Africa. *Educational Research for Social Change, 8*(2), 136–150. https://doi.org/10.17159/2221-4070/2019/v8i1a2

Echavez Jr, A., Yncierto, C., Obiasada, R., Dayag, M., Alcazar, R. & Kilag, O.K. (2024). Advancing Literacy and Numeracy: Exploring Trends and Strategies for Elementary School Students. *International Multidisciplinary Journal of Research for Innovation, Sustainability, and Excellence* (IMJRISE), *1*(2), 144-150. https://orcid.org/0009-0002-0350-0601

Ezemba, C.C., Adams, P.Y., Okoye, P.C., Ezemba, A.S., Ajeh, J.E., Osuala, O.J., Mbah, O.M. and Iyiola, O.O., (2025). Methods and Strategies of Teaching Microbiology in Nigerian Higher Institutions: Problems and Remedies. *Scientia. Technology, Science and Society*, *2*(2), pp.3-26. https://doi.org/10.59324/stss.2025.2(2).01

Fagunwa, O.E. & Olanbiwoninu, A.A. (2020). Accelerating the sustainable development goals through microbiology: some efforts and opportunities. *Access microbiology*, 2(5). https://doi.org/10.1099/acmi.0.000112

Fahnert, B. (2016). Edging into the future: education in microbiology and beyond. *FEMS Microbiology Letters*, *363*(7), fnw048. https://doi.org/10.1093/femsle/fnw048

Fahnert, B., (2017). Keeping education fresh—not just in microbiology. *FEMS Microbiology Letters*, *364*(21), p.fnx209. https://doi.org/10.1093/femsle/fnx209

Gautam, J. (2023). Fundamental Of Microbiology. Academic Guru Publishing House. ISBN:978-9391039989

Goel, N., Choudhary, P., Pattanaik, L., Padhi, S.K., & Chaudhary, P. (2024). Exploring the Potential of Microbial Biomolecules in Advancing Human Health and Environmental Sustainability. In *Industrial Microbiology and Biotechnology: An Insight into Current Trends* (pp. 515–566). Singapore: Springer Nature Singapore. https://doi.org/10.1007/978-981-97-1912-9_22

Hester, S.D., Nadler, M., Katcher, J., Elfring, L.K., Dykstra, E., Rezende, L.F. & Bolger, M.S. (2018). Authentic Inquiry through Modeling in Biology (AIM-Bio): An introductory laboratory curriculum that increases undergraduates' scientific agency and skills. *CBE—Life Sciences Education*, *17*(4), ar63. https://doi.org/10.1187/cbe.18-06-0090

Kappler, U., Rowland, S.L. and Pedwell, R.K., (2017). A unique large-scale undergraduate research experience in molecular systems biology for non-mathematics majors. *Biochemistry and Molecular Biology Education*, *45*(3), pp.235-248. https://doi.org/10.1002/bmb.21033

Khan, F.M.A., Majid, H., Rehman, J., Zeeshan, M., Moiz, B., Jafri, L. & Khan, A.H. (2024). Advancing Medical Laboratory Practice in Pakistan: Insights from a Focus Group Study on Technologists' Training Needs. 24, 938. https://doi.org/10.1186/s12909-024-05836-x

Knight, D.L. (2023). Exploring Biochemical Literacy (Doctoral dissertation, University of Surrey). University of Surrey, Guildford, Surrey, UK

Levin, K. A. (2006). Study design III: Cross-sectional studies. *Evidence-Based Dentistry, 7*(1), 24–25. https://doi.org/10.1038/sj.ebd.6400375

Madhavan, M. & Mustafa, S. (2023). Systems biology–the transformative approach to integrate sciences across disciplines: Systems Biology: Integrating Biological Sciences. *Physical Sciences Reviews*, *8*(9), 2523-2545. https://doi.org/10.1515/psr-2021-0102

Makumane, M., & Pelser, T. (2022). Mobile learning as a mediator in science education in rural South African universities. *South African Journal of Higher Education, 36*(2), 142–158. https://doi.org/10.20853/39-2-5884

Marbach-Ad, G., Briken, V., Frauwirth, K., Gao, L. Y., Hutcheson, S. W., Joseph, S. W., Mosser, D., Parent, B., Shields, P., Song, W., Stein, D. C., & Yuan, R. (2019). A model for incorporating inquiry-based laboratory experiences into undergraduate microbiology. *Journal of Microbiology & Biology Education, 20*(1), 1–9. https://doi.org/10.1128/jmbe.v20i1.1740

McDonald, M.D., Owusu-Ansah, C., Ellenbogen, J.B., Malone, Z.D., Ricketts, M.P., Frolking, S.E., Ernakovich, J.G., Ibba, M., Bagby, S.C., & Weissman, J.L. (2023). What is microbial dormancy?. *Trends in Microbiology*. 32(2). https://doi.org/10.1016/j.tim.2023.08.006

Melby, Melissa K., Eglee Zent, Sheryl Ariste, Rimmon Shoukat, and Mark Nichter (2025). "“The Littlest Creatures that Live Inside Us”: Public understandings influencing microbiome-related behaviors." *Social Science & Medicine* 376 (2025): 117864. https://doi.org/10.1016/j.socscimed.2025.117864

Nichat, A., Gajbe, U., Bankar, N.J., Singh, B.R., Badge, A.K. & Badge, A. (2023). Flipped classrooms in medical education: improving learning outcomes and engaging students in critical thinking skills. *Cureus*, 15(11). https://doi.org/10.7759/cureus.48199

Nyutu, E.N., Cobern, W.W. & Pleasants, B.A. (2018). Student engagement in direct instruction, undergraduate microbiology laboratories. *Journal of Biological Education*. *53*(3), 250-264. https://doi.org/10.1080/00219266.2018.1469535

Osman, K., Hiong, L.C. & Vebrianto, R. (2013). 21st century biology: an interdisciplinary approach of biology, technology, engineering and mathematics education. Pr*ocedia-Social & Behavioral Sciences*, 102, 188-194. https://doi.org/10.1016/j.sbspro.2013.10.732

Piaget, J. (1970). *Science of education and the psychology of the child*. Orion Press. ISBN: 978-0670621729

Ramolobe, K. S., Malatji, M., & Mavuso, S. (2024). An evaluation of venue capacity constraints on teaching and learning in higher education. *Transformation in Higher Education, 9*, a328. https://doi.org/10.4102/the.v9i0.328

Saini, A.K. (2016). Technology enabled learning & multimedia: a revolutionary approach in teaching and learning process. *International Journal of Research in Social Sciences*, 6(3), 653-666. ISSN: 2249-2496

Schneider, T. (2024). The microbiome function in a host organism: A medical puzzle or an essential ecological environment?. *Biological Theory*, *19*(1), 44-55. https://doi.org/10.1007/s13752-023-00434-4

Timmis, K., Hallsworth, J.E., McGenity, T.J., Armstrong, R., Colom, M.F., Karahan, Z.C., Chavarría, M., Bernal, P., Boyd, E.S., Ramos, J.L. and Kaltenpoth, M., 2024. A concept for international societally relevant microbiology education and microbiology knowledge promulgation in society. *Microbial Biotechnology*, *17*(5), p.e14456. https://doi.org/10.1111/1751-7915.14456

Torruellas Garcia, J., López-Moreno, K., Côté, V. & Crump, K. (2022). Creating an Interdisciplinary Curriculum within the Undergraduate Arts and Sciences through Agar Art. *Journal of Microbiology & Biology Education*, *23*(1), e00160-21. https://doi.org/10.1128/jmbe.00160-21

Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*. Harvard University Press. ISSN: 2249-2496

Wati, R. (2024). Analyzing and Viewing the Development of Construction of the Philosophical View of Positivism. *Journal of World Science*. https://doi.org/10.58344/jws.v3i8.689

Wills, M. A. (2022). *Ruptures: Life Without Germs in the Microbiome Era*. University of California, Davis. https://escholarship.org/uc/item/7fm588p1

Wilson, B.A. and Ho, B.T., 2023. *Revenge of the Microbes: How Bacterial Resistance is Undermining the Antibiotic Miracle*. John Wiley & Sons. ISBN: 978-1683673804

Winter, G., Ketheesan, N. & Andronicos, N.M. (2023). A new hub-and-spoke biology curriculum designed around interdisciplinary laboratory practical sessions to enhance student employability. *Microbiology Australia*. *44*(3) 131-135. https://doi.org/10.1071/MA23039

Zhai, X., 2021. Practices and theories: How can machine learning assist in innovative assessment practices in science education. *Journal of Science Education and Technology*, *30*(2), pp.139-149. https://doi.org/10.1007/s10956-021-09901-8

Zhang, T., Nickerson, R., Zhang, W., Peng, X., Shang, Y., Zhou, Y., Luo, Q., Wen, G. and Cheng, Z., 2024. The impacts of animal agriculture on One Health—Bacterial zoonosis, antimicrobial resistance, and beyond. *One Health*, p.100748. https://doi.org/10.1016/j.onehlt.2024.100748

APPENDIX

Table 2.

Alignment of research objectives with survey items, key findings, and analytical approach

Research Objective	Survey Questions/Indicators	Summary of Findings	How It Was Addressed
1. To determine learners' basic and current knowledge of microbiology	Q1: What is microbiology? Q2: Major classifications Q3: Antonie van Leeuwenhoek Q8: Source of penicillin	Moderate understanding observed: 59% defined microbiology correctly; 85.7% identified Leeuwenhoek; 44.6% answered classifications accurately.	Addressed through descriptive analysis of foundational microbiology concepts with accuracy percentages.
2. To assess learners' recognition of microbiology's relevance within various biological disciplines related to their degree	Indirectly inferred from Q5–Q7 on microbiology's applications in zoology, entomology, and botany	Learners showed varied recognition: 60.7% accurate in zoology, 55.4% in botany, and 32.1% in entomology, reflecting differing levels of perceived relevance across disciplines.	Addressed by analyzing accuracy of responses on microbiology's relevance in related biological fields as an indicator of recognition.
3. To examine learners' understanding of how microbiology integrates with other fields of biology such as zoology, botany, and entomology	Q5: Use in zoology Q6: Use in entomology Q7: Use in botany	Varied understanding was evident; stronger grasp in zoology and botany applications compared to entomology.	Addressed descriptively by evaluating learners' explanations of microbiology's interdisciplinary integration without inferential statistics.
4. To identify gaps in knowledge and understanding of microbiology	Q4: Infectious diseases Q9: Reasons to study microbiology Q10: Fields in microbiology	Significant gaps found, particularly low accuracy in reasons for studying microbiology (10.7%) and knowledge of microbiology fields (34%).	Addressed by highlighting the proportions of incorrect and partially correct answers to pinpoint knowledge gaps.

Table 1: Summary of Microbiology Knowledge Assessment Results

Questions	**Category**	**Number of Responses**	**Percentage**
1. What is microbiology?	Accurate	33	59%
	Partially Accurate	17	30%
	Inaccurate	8	11%
2. What are the major classifications of microbiology?	Accurate	25	44.6%
	Partially Accurate	7	12.5%
	Inaccurate	24	42.9%
3. Who is Antonie van Leeuwenhoek?	Accurate	48	85.7%
	Partially Accurate	2	3.6%
	Inaccurate	6	10.7%
4. Name an infectious disease besides HIV and TB?	Accurate	41	73.2%
	Partially Accurate	10	17.9%
	Inaccurate	5	8.9%
5. How can you use microbiology in zoology?	Accurate	34	60.7%
	Partially Accurate	7	12.5%
	Inaccurate	18	26.8%
6. How can you use microbiology in entomology?	Accurate	18	32.1%
	Partially Accurate	3	5.4%
	Inaccurate	35	62.5%
7. How can you use microbiology in botany?	Accurate	31	55.4%
	Partially Accurate	4	7.1%
	Inaccurate	21	37.5%
8. What is penicillin medication made from?	Accurate	29	51.8%
	Partially Accurate	2	3.6%
	Inaccurate	25	44.6%
9. What are the three reasons to study microbiology?	Accurate	6	10.7%
	Partially Accurate	5	8.9%
	Inaccurate	45	80.4%
10. What are the different fields within the field of microbiology?	Accurate	19	34%