Diagnostic Analysis of Student Misconceptions on Viral and Bacterial Concepts in Introductory Biology Courses

Chinaza Gloria Diala [1], Sophia Chidera Anaba [2], Georgina Mary Adu [3], Conlethann Chiemerie Ohaekwe [4], Opeyemi Alice Ajayi [5], Tracy Obofoni Obakhena [6]

[1] *Imo State University*
Samek Road off Okigwe Owerri Rd, Owerri, Imo 23401, Nigeria

[2] *Medik Health Clinic and Diagnostics*
40, Mike Akhigbe Wy, Jabi, District 900001, Federal Capital Territory, Nigeria

[3] *Delta State University*
P.M.B. 1, Abraka, Delta State, Nigeria

[4] *Chukwuemeka Odumegwu Ojukwu University*
P. M. B. 6059 Igbariam, Anambra State, Nigeria

[5] *The Polytechnic Ibadan*
P. M. B. 22, Ibadan, Oyo State, Nigeria

[6] *Nigerian Institute for Oceanography and Marine Research*
3 Wilmot Point Road, Off Ahmadu Bello Way, Victoria Island, Lagos State, Nigeria

DOI: 10.22178/pos.122-58

LCC Subject Category: L7-991

Received 15.08.2025
Accepted 28.09.2025
Published online 30.09.2025

Corresponding Author:
Chinaza Gloria Diala

Abstract. The fundamental aspect of biology education is not only understanding the difference between viruses and bacteria, but also recognising that this knowledge is essential for everyone worldwide, as public health requires a clear distinction between the two. Even though teachers cover these topics in secondary school, students still confuse the two microorganisms, even at the university level. This study investigates how first-year students in biological sciences understand viruses and bacteria, particularly their structural characteristics, reproduction, treatment options, and roles.

Researchers surveyed 160 first-year biology and microbiology students across three universities in Imo State using a mixed-methods approach. The survey included multiple-choice questions, open-ended responses, and short case scenarios designed to probe both factual knowledge and deeper conceptual understanding. We also conducted follow-up interviews with 20 students to clarify some of their written responses and explore their reasoning in more depth.

Our findings indicate that the majority of students correctly identified viruses as non-living and bacteria as living; however, a high number still believed that antibiotics can treat viral infections. Also, many students felt that viruses are smaller versions of bacteria or that both reproduce in the same way. There were misunderstandings among students regarding the role of bacteria. Many students classified bacteria as pathogenic organisms that cause disease, forgetting that they play beneficial roles in ecosystems, human health, and the microbiome.

Early gaps, the ongoing reduction in science teaching in primary and secondary schools, and the spread of misleading information through the media and in conversation are significant causes of the misconceptions observed among students. This study emphasised the need to implement an effective teaching method for introductory biology courses at all levels, from primary to university, particularly

those focusing on theoretical understanding and addressing students' initial beliefs. To help students build a solid foundation and knowledge in advanced biology, these misunderstandings need to be addressed, as they will support decision-making in public health.

Keywords: Viruses; Bacteria; Misconceptions; Biology Education; Public Health; Student Understanding; Science Curriculum.

INTRODUCTION

Every year, thousands of students walk into their first university or polytechnic biology class with different knowledge and ideas about biology from their high school lessons. But, when it comes to viruses and bacteria, they become more confused.

Many people often refer to bacteria and viruses as germs and are usually ignorant of their differences. The most significant and common difference many memorise is that bacteria are living and viruses are not, along with examples of each. Bacteria and viruses are areas that need to be adequately studied, as they are among the leading causes of disease and death in our society today [1].

It has been documented that students generate ideas based on incomplete information. Most of the time, our prior knowledge contradicts scientific studies, reflecting a long-standing barrier to understanding, especially in microbiology [2, 3].

Research shows that students most often create vague mental pictures of bacteria and viruses as interchangeable causes of disease [4, 5]. Research by [6] reveals that specialists face challenges in microbiology, particularly in the areas of the microbiome and microbial function, indicating that misunderstandings are not limited to students alone. A comparable study conducted in 2016 by [7, 8] found that several students consider antibiotics a cure for colds and flu caused by viruses.

Bacteria and viruses, which are often classified as germs by many, differ in their structure, behaviour, and interactions with humans. Bacteria are living, single-celled organisms capable of self-reproducing and surviving in any environment; some cause disease, while others are beneficial to human and ecosystem health. Viruses are non-cellular microbes that require a host cell to survive and replicate [9–11]. Despite these differences, many students classify them as germs.

People often misuse antibiotics, listen to medical misinformation, or follow basic health guidelines. This happens mostly when they misunderstand the difference between bacteria and viruses, though this confusion is not just academic [12]. For biology students, these early misconceptions can also create a weak foundation for future courses in microbiology, immunology, or public health.

Most of these misconceptions develop from the onset. In primary and secondary schools, teachers most often use introductory knowledge textbooks to teach biology [13, 14]. Even basic knowledge is helpful for easy comprehension, but it leaves out major information. When learners are told "sickness is caused by germs" without a deep understanding of how it happens, they come up with their own reasons for it. These reasons last long even after secondary education. Societal norms contribute to this. In movies, books, and health advertisements, bacteria are categorised as invisible enemies. It is uncommon for a learner to see bacteria as relevant; this leads to the misconception that all bacteria are the same and harmful [4, 15].

There is limited focus on how students misunderstand microbes, despite researchers having addressed biology misconceptions in general [3, 16]. This study narrows in on that gap by investigating what first-year biology students get wrong about viruses and bacteria. It also explores why we should start designing more effective and impactful teaching methods that directly target those false beliefs. Measures have been put in place to try to change this standard structure. Research strategies promised changes in learners' reasoning, such as using modelling to demonstrate rapid infection processes or conducting intensive studies of a single point to detect bacteria-caused illnesses, thereby highlighting the differences. Subsequently, the success of these methods depends heavily on the teacher's awareness of learners' misunderstandings [17, 18].

Necessarily, misunderstandings are not totally wrong; they are just mental resolutions caused by incomplete knowledge; this is the reason it is difficult to remove. To dissolve them, teachers need to incorporate broader knowledge while

explaining to learners why their misconceptions are not entirely accurate and should be discarded [19, 20].

This research does not focus solely on what students do not know; it is about understanding their main points, their confusions, and how educators can respond to them. If students are expected to engage with the biological world, they will encounter misconceptions and other issues.

METHODS

This study was conducted across three public higher education institutions in southeastern Nigeria, each offering a first-year biology course.

One hundred and sixty students who had completed at least 6 weeks of basic biology and had covered introductory microbiology topics, including teaching about viruses and bacteria, were questioned.
The research used both qualitative and quantitative methods.

The quantitative method included a structured survey with 20 questions: 10 multiple-choice, five yes/no, and five short-answer. Questions were structured to evaluate basic knowledge (e.g., Antibiotic drugs can cure a viral illness).

The qualitative features include further interviews with 30 randomly selected students. These structured interviews lasted 15–30 minutes and allowed students to explain their reasoning for specific answers, how they acquired knowledge about microorganisms, and what they did not understand.

Questionnaires were administered during lecture periods under the supervision of biology tutors. Participation was not mandatory, and all students signed an informed consent form. Interviews were conducted in a quiet study space on campus and recorded with the participants' consent. The researchers blurred the responses during the written record and review.

Numerical (quantitative) data were sorted using introductory statistical methods to calculate the number of correct and incorrect responses, as well as frequent mistakes. Non-numerical data (qualitative) were sorted categorically, with the program designed to address persistent misunderstandings, their causes, and students' analysis.

The researchers did not seek ethical approval for this study because they did not collect any sensitive information or data, and they offered all participants the option to withdraw from the study at any time.

RESULTS AND DISCUSSION

Of the 160 students who participated in this study, only 38% answered more than 75% of the microbiology questions correctly. The most common misunderstanding we noticed and recorded included:

46% believed viruses were just a smaller form of bacteria; 54% agreed that antibiotics can be used to treat both bacterial and viral diseases, or were unsure; 60% believed that bacteria cause disease and have no beneficial role. In comparison, 41% misunderstood how vaccines work, believing that vaccines kill all the virus in the body.

Table 1 – Student Performance and Common Misconceptions (n = 160)

Category	Details, %
Students scoring >75% on microbiology questions	38
Believed viruses are smaller forms of bacteria	46
Believed or were unsure that antibiotics treat viral infections	54
Believed bacteria only cause disease and have no beneficial role	60
Misunderstood vaccine function (e.g., "vaccines kill all viruses")	41

The student's answers to the short-answer question included statements such as "viruses grow and divide like bacteria" and "you can take antibiotics when you have the flu to kill the virus." Based on the students' response, they knew the terminology but lacked insight into biological processes.

Table 2 – Examples of Misconceptions from Student Short Responses

Student Statement	Misconception Identified
Viruses grow and divide like bacteria.	The belief that viruses reproduce like living cells
You can take antibiotics when you have the flu to kill the virus	Misunderstanding of antibiotic use

Student Statement	Misconception Identified
Vaccines kill all the virus in the body	Misunderstanding of how vaccines work

The researchers gained more insight during the interview session with the students. The majority of students accepted that they had "never thought about how viruses work" or "just assumed antibiotics can be used to cure every sickness." In contrast, others admitted that their secondary school biology teachers—or their primary sources of information—were the media. A few students said they thought of bacteria and viruses as "basically the same" because "they're both invisible and dangerous."

Table 3 – Thematic Insights from Student Interviews

Theme	Student Reflections
Lack of conceptual understanding	I never think about how viruses work.
Assumptions about antibiotics	I just assumed antibiotics could cure every illness.
Source of information	Media and secondary school biology classes are commonly cited.
Confusion between microbes	Some students saw bacteria and viruses as basically the same because they're both invisible and dangerous.
Impact of lab exposure	Students who had taken recent microbiology labs gave more accurate responses and described bacteria as observable through experiments.
Role of teaching method	Students taught through case studies or experiments showed fewer misunderstandings than those taught via lectures/textbooks.

Students who had recently taken microbiology lab courses were more accurate in their responses. They described bacteria growing on agar plates or being stained under a microscope, which helped them conceptualise bacteria as living, observable organisms, unlike viruses.

Teachers clearly linked students' understanding to how they taught the theories. Students who learned through case studies or hands-on experiments had fewer misunderstandings than those who relied solely on lectures and textbook reading.

The findings of this study reveal a significant gap in understanding the basics of microbiology, even among biology majors. Misunderstandings about viruses and bacteria are common and are not simply due to ignorance but are often deliberate responses to deeper issues in how biology is taught and learned [21, 22].

One key observation is that students find it challenging to understand the unseen nature of microbes [23]. Because viruses and bacteria cannot be seen with the naked eye, they depend on mental shortcuts and vague ideas that have long been accepted. These shortcuts usually make sense from a student's point of view: if both viruses and bacteria cause illness and require hospital care, then they must have the same characteristics; this shows how logical reasoning, when based on incomplete knowledge, can lead to recurring misunderstandings.

Another factor is how teachers introduce these concepts. Many students, in their first encounter with microbes, encountered them through school diagrams or simplified definitions. In those early studies, viruses and bacteria were often presented together under the title "Germs", with little emphasis on their structural and functional differences. If later teachings do not correct those first impressions, students will find it difficult to change [24].

The media also plays a significant role. News stories, advertisements, and even cartoons often portray microbes as a single, dangerous entity. When antibiotics are advertised as "Fighting germs" without distinction, it strengthens the idea that all microorganisms are harmful and treated the same way. These external messages can unintentionally weaken classroom instruction [15, 25].

What's encouraging, though, is that students who had practical lab experiences or were taught using practical situations, such as outbreak investigations or microbiome discussions, had a better understanding of the differences [26]. He suggests that when students see how microbiology relates to health, medicine, and day-to-day life, their experience becomes more refined and more dedicated.

Conclusively, the fact that so many misunderstandings came from students already in the field of biology suggests that we need to revisit how microbiology is introduced in the first year. It's not enough to teach meanings; students need

chances to research, question, and challenge the knowledge and ideas they think they already have.

This study included students from only three universities in one region, limiting broader generalisation. It focused on biology majors, so results may not apply to non-science students. Researchers did not test any specific teaching interventions. In the future, they could expand the sample scope and test targeted strategies to address these misconceptions.

CONCLUSIONS

The study confirms what many educators have long presumed: First-year biology students often have significant misunderstandings about viruses and bacteria, and these misunderstandings can prevail even in university settings. The confusion doesn't stem from small details; instead, it reveals broader misunderstandings about life forms and how they are structured, reproduce, and interact with the human body.

Rectifying these mistakes isn't just about adding more facts to a lecture; it requires a broader approach that recognises where students begin and proactively engages them in rethinking and rebuilding their understanding. Activities that can help correct students' misconceptions include inquiry-based activities, discussions about the events, and lab experiences with microorganisms.

A platform should be provided where first-year students can ask questions, perform trial-and-error, and learn from their mistakes in biology education. Students are more likely to correct their misconceptions and develop an accurate understanding of biology when they are encouraged to test their assumptions and see how scientific ideas fit into the world around them.

We're in an era where we can't allow misunderstandings about these foundations of microbial activity to go unresolved, given their importance for understanding pandemics and preventing the misuse of antibiotics. We need to resolve these misunderstandings and lay the groundwork to build a scientifically informed, capable generation of biologists on matters concerning viruses and bacteria.

And we can begin by paying attention to students, guiding them to understand, and recognising how things differ.

REFERENCES

1. Barro, P. (2020). 'Deeply worrying': 92% of Australians don't know the difference between viral and bacterial infections. *The Conversation Media Group Ltd*. doi: 10.64628/aa.wsyq5ngyj

2. Pickett, S. B., Nielson, C., Marshall, H., Tanner, K. D., & Coley, J. D. (2022). Effects of Reading Interventions on Student Understanding of and Misconceptions about Antibiotic Resistance. *Journal of Microbiology and Biology Education, 23*(1). doi: 10.1128/jmbe.00220-21

3. Simard, C. (2021). Microorganism education: misconceptions and obstacles. *Journal of Biological Education, 57*(2), 308–316. doi: 10.1080/00219266.2021.1909636

4. Lane, A. R., Momsen, J. L., & Wiltbank-Chau, L. B. (2025). Positive microbiology: addressing students' knowledge gaps regarding the benefits of microorganisms. *Journal of Microbiology and Biology Education*. doi: 10.1128/jmbe.00045-25

5. Bracko, M., & Simon, U. K. (2022). Virus-related Knowledge in Covid-19 Times - Results from two Cross-sectional Studies in Austria and Implications for Schools. *International Journal of Biological Sciences, 18*(4), 1627–1650. doi: 10.7150/ijbs.69224

6. Berg, G., Rybakova, D., Fischer, D., Cernava, T., Vergès, M. C., Charles, T., Chen, X., Cocolin, L., Eversole, K., Corral, G. H., Kazou, M., Kinkel, L., Lange, L., Lima, N., Loy, A., Macklin, J. A., Maguin, E., Mauchline, T., McClure, R., Mitter, B., Ryan, M., Sarand, I., Smidt, H., Schelkle, B., & Schloter, M. (2020). Microbiome definition revisited: old concepts and new challenges. *Microbiome, 8*(1). doi: 10.1186/s40168-020-00875-0

7. McCullough, A. R., Parekh, S., Rathbone, J., Del Mar, C. B., & Hoffmann, T. C. (2015). A systematic review of the public's knowledge and beliefs about antibiotic resistance. *Journal of Antimicrobial Chemotherapy, 71*(1), 27–33. doi: 10.1093/jac/dkv310

8. Vallin, M., Polyzoi, M., Marrone, G., Rosales-Klintz, S., Wisell, K. T., & Lundborg, C. S. (2016). Knowledge and Attitudes towards Antibiotic Use and Resistance - A Latent Class Analysis of a Swedish Population-Based Sample. *PLoS ONE, 11*(4), e0152160. doi: 10.1371/journal.pone.0152160

9. Whitaker-Dowling, P., & Youngner, J. S. (1999). Virus-Host Cell Interactions. In *Elsevier eBooks* (pp. 1957–1961). doi: 10.1006/rwvi.1999.0343

10. Norval, M. (2012). Virus–cell interactions. In *Elsevier eBooks* (pp. 82–96). doi: 10.1016/b978-0-7020-4089-4.00022-6

11. Zhu, T., Niu, G., Zhang, Y., Chen, M., Li, C., Hao, L., & Zhang, Z. (2023). Host-mediated RNA editing in viruses. *Biology Direct, 18*(1). doi: 10.1186/s13062-023-00366-w

12. Diala, C. G., Edobor, O., Edim, P. D., Oraekwe, C. N., Okenwa, C. R., Onyema, A. M., Hammed, S. U., & Onyeaghala, C. A. (2025). Antimicrobial Resistance (AMR) in Low-Resource Settings: A molecular and public health investigation into the role of environmental reservoirs and Over-The-Counter antibiotic use in South-South Nigeria. *Path of Science, 11*(8), 5008. doi: 10.22178/pos.121-15

13. Coley, J. D., & Tanner, K. (2015). Relations between Intuitive Biological Thinking and Biological Misconceptions in Biology Majors and Nonmajors. *CBE – Life Sciences Education, 14*(1), 8. doi: 10.1187/cbe.14-06-0094

14. Leonard, M. J., Kalinowski, S. T., & Andrews, T. C. (2014). Misconceptions yesterday, today, and tomorrow. *CBE – Life Sciences Education, 13*(2), 179–186. doi: 10.1187/cbe.13-12-0244

15. Sánchez-Angulo, M. (2025). Positive microbiology in the movies. *Microbial Biotechnology, 18*(9). doi: 10.1111/1751-7915.70085

16. Briggs, A. G., Hughes, L. E., Brennan, R. E., Buchner, J., Horak, R. E. A., Amburn, D. S. K., McDonald, A. H., Primm, T. P., Smith, A. C., Stevens, A. M., Yung, S. B., & Paustian, T. D. (2017). Concept Inventory Development Reveals Common Student Misconceptions about Microbiology. *Journal of Microbiology and Biology Education, 18*(3). doi: 10.1128/jmbe.v18i3.1319

17. Kaba, H. E. J., Misailovski, M., Brähler, J., Garcia, J. a. B., Artelt, T., Raupach, T., & Scheithauer, S. (2024). Innovative teaching in infection prevention and control and infectious diseases education: testing and investigation of student perceptions. *Infection*. doi: 10.1007/s15010-024-02332-8

18. Jawad, A. K., & Okab, A. A. (2024). Teachers' Awareness About Control of Communicable Diseases at Primary Schools in Al-Swaira City. *Thi-Qar Medical Journal, 25*(1).

19. Hartelt, T., Martens, H., & Minkley, N. (2022). Teachers' ability to diagnose and deal with alternative student conceptions of evolution. *Science Education, 106*(3), 706–738. doi: 10.1002/sce.21705

20. Ogundare, A., Bello, G., Adeoye, G. A., & Sulaiman, M. M. (2024). Remediating students' misconceptions in biology: A review. *Custech International Journal of Education, 1*(2), 89–102.

21. Saputri, D. A. F., & Widyaningrum, T. (2016). Misconceptions Analysis on The Virus Chapter in Biology Textbooks for High School Students Grade X. *International Journal of Active Learning. 1*(1), 30-37

22. Novitasari, C., Ramli, M., & Karyanto, P. (2019). Content analysis of misconceptions on bacteria in the biology textbook of high school. *Journal of Physics Conference Series, 1157*, 022076. doi: 10.1088/1742-6596/1157/2/022076

23. McGenity, T. J., Gessesse, A., Hallsworth, J. E., Cela, E. G., Verheecke-Vaessen, C., Wang, F., Chavarría, M., Haggblom, M. M., Molin, S., Danchin, A., Smid, E. J., Lood, C., Cockell, C. S., Whitby, C., Liu, S., Keller, N. P., Stein, L. Y., Bordenstein, S. R., Lal, R., Keller, N. P., Stein, L. Y., Bordenstein, S. R., Lal, R., Nunes, O. C., Gram, L., Singh, B. K., Webster, N. S., Morris, C., Sivinski, S., Bindschedler, S., Junier, P., Antunes, A., Baxter, B. K., Scavone, P., & Timmis, K. (2020). Visualising the invisible: class excursions to ignite children's enthusiasm for microbes. *Microbial Biotechnology, 13*(4), 844–887. doi: 10.1111/1751-7915.13576

24. Ningtyas, L. E., & Asri, M. T. (2021). Profile of 10th Grade High school students' Misconceptions on the virus topic based on the Three-Tier Multiple Choice Diagnostic Test. *Berkala Ilmiah Pendidikan Biologi (BioEdu), 10*(3), 674–682. doi: 10.26740/bioedu.v10n3.p674-682

25. Oli, M. W. (2023). On the Path to "Positive Microbiology." *Journal of Microbiology and Biology Education, 24*(2). doi: 10.1128/jmbe.00066-23

26. Rivard, R. S., Winters, M., Lettini, S., & McEliece, M. K. (2024). A customisable series of microbiology lab activities exploring a foodborne outbreak to enhance student recruitment to a biology program. *Journal of Microbiology and Biology Education, 25*(1). doi: 10.1128/jmbe.00086-23