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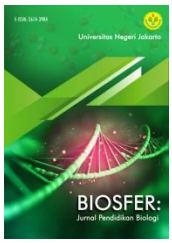

Microbiology literacy and its influence on knowledge, perceptions and community attitudes

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ABSTRACT

Microbiology literacy development shapes people's attitudes, behaviors, and perceptions toward microorganisms. This study aims to explore the relationship between microbiological literacy and people's perceptions and attitudes towards microorganisms. This study uses the Systematic Literature Review (SLR) method to analyze the relationship between microbiological literacy and public knowledge, attitudes, and perceptions of microorganisms. Data were retrieved from Scopus using relevant keywords and then filtered based on the following criteria: published between 2019–2024, in English, and open access. The analysis was conducted through four steps: coding, concept review, and summarizing key information (author, year, and core concepts). The results were synthesized to map the relationship between microbiological literacy and public perceptions. The results showed that respondents' knowledge levels varied about various health issues. Good microbiological knowledge can improve health literacy, affecting individual attitudes and perceptions of health. Regarding respondents' attitudes, it is known that respondents are interested in education and health awareness. A positive attitude toward health can encourage actions that support public health. In contrast, individuals with low microbiology knowledge orientation are more likely to cause negative perceptions and distrust of health interventions. Continuous, evidence-based education is essential to improve microbiology and health literacy and shape positive attitudes toward health interventions. Microbiology knowledge has a broad impact on daily life and the future. However, there are significant challenges in understanding microbiology. Public perception of microbes is often only associated with 'germs' and negative images. Therefore, microbiology knowledge in learning must be presented in visual arts and visual, olfactory, and tactile experiences. The more we understand the role and knowledge of microbes, the better we can make relevant decisions.

INTRODUCTION

Microbes include bacteria, fungi, and viruses that affect human health. Microbes can cause various infectious diseases but also play an important role in the human body and life support systems for all organisms (Jovel et al., 2018; Yaseen et al., 2024). Learning Microbiology is very important so that students can connect the concepts of fungi with everyday life through the learning process. Knowledge about microorganisms in students must be improved to eliminate microbe-phobia that can hinder students' interest in learning. Students feel afraid when they hear the term microorganism. They assume that all microorganisms cause disease, whereas some microbial species are proven not to cause disease (Timmis et al., 2019). One example is *Rhizopus sp* and *Mucor sp,* which are components of tempeh yeast, so they do not cause disease.

Students' lack of understanding of microorganisms can lead to misconceptions regarding their role in nature and relation to disease (Ruiz-Gallardo & Paños, 2018). These misconceptions can lead to fear and a lack of interest in microbiology, potentially hampering public health efforts, as happened during the COVID-19 pandemic (Amo-Adjei, 2016). A survey of elementary school students revealed that most students defined microorganisms as pollutants and harmful, indicating misconceptions (Karadon & Şahin, 2010). This incorrect definition of microorganisms is due to a lack of accurate information about microorganisms, leading to a lack of knowledge about their benefits and risks, potentially affecting people's health decisions and behaviours (Fonseca et al., 2012).

The microbiology knowledge that students acquire can shape the way they think, feel, and act towards things (Brandriet et al., 2013). When someone has good knowledge about a topic, such as microbiology, they are likelier to develop a more positive and informational attitude towards it. Conversely, lack of knowledge or misunderstanding can lead to negative attitudes, fear, or misconceptions (Asekun-Olarinmoye et al., 2014). For example, in microbiology, someone who understands the benefits of microorganisms in everyday life, such as in the fermentation process or in maintaining ecosystem balance, will probably have a more positive attitude towards microorganisms. In contrast, someone who only knows microorganisms as the cause of disease will probably develop a negative attitude towards them.

Students' attitudes towards a microbiological phenomenon often shape how they perceive or assess it (Jeffery et al., 2016). A positive attitude towards something can result in a better perception, while a negative attitude tends to form a poor perception (Kurniawan et al., 2019). For example, someone with a positive attitude towards science and microbiology is likely to view microbes more objectively and less scary.

Knowledge, attitudes, and perceptions are closely related to Microbiology literacy. Students who are literate in microbiology can be reflected when faced with a phenomenon or issues about microbiology, such as giving the COVID-19 vaccine (Motoki et al., 2021; Saeed et al., 2023). For example, there are pros and cons in society. Some people want to be vaccinated, and others even avoid being vaccinated for fear of it negatively impacting their bodies. People who want to be vaccinated are literate in understanding the concept of Microbiology, which is reflected in positive actions. Based on this, it is true that microbiology literacy includes knowledge and understanding of microorganisms.

The development of microbiological literacy is critical in shaping people's attitudes and behaviours towards microorganisms (Timmis et al., 2019). Previous studies have shown that good microbiological literacy can increase people's awareness and understanding of the importance of microorganisms in their daily lives (Scalas et al., 2017). In addition, adequate microbiological literacy can help people make better health and environmental decisions (Lloyd & Berry, 2022). Good microbiology literacy can also improve the knowledge of specific health issues and increase scientific interest and awareness of correct behaviours for a safer lifestyle (Naoe et al., 2019). However, there are still gaps in microbiological literacy across different groups of people, which may affect their perceptions and attitudes towards microorganisms (DeSalle et al., 2022). Therefore, this study aims to describe the relationship between microbiological literacy and students' knowledge, attitude, and perception towards microorganisms. This research will provide deeper insights into how microbiological literacy can be improved to form more positive perceptions and attitudes toward microorganisms.

METHODS

Research Design

This study used a systematic literature review (SLR) procedure by selecting articles from the Scopus database. The SLR method can help summarize the current knowledge on a particular topic systematically and transparently to answer research questions, especially on microbiological literacy with public perceptions and attitudes toward microorganisms (Maghfiroh et al., 2023). The stages of the SLR procedure adopted a framework from Arksey & O'Malley (2005) that provides a systematic and structured approach to conducting scoping reviews, ensuring the review process is comprehensive, transparent, and reproducible. This framework has been widely adopted and adapted across various disciplines, highlighting its utility and effectiveness in synthesizing existing research.

Identifying the research question

The stage of identifying research questions was carried out to determine the scope and develop a focus on the topic to be investigated in this study. There are questions in this study to guide the systematic literature review (SLR), namely: What is the relationship between microbiological literacy and people's knowledge, perceptions, and attitudes toward microorganisms?

Identifying relevant studies

The stage of identifying relevant studies was to retrieve studies by determining the databases and keywords used. A comprehensive literature search was conducted using the Scopus database. Furthermore, data search with the following keywords, namely ("literacy" OR "education" OR "knowledge" OR "awareness") AND ("microbiology" AND "Literacy") AND ("perception" OR "attitude" OR "belief" OR "view").

Eligibility criteria

The eligibility criteria stage was used to select studies for the review. Eligible studies met the following inclusion criteria: i) articles published between 2019 and 2024; ii) articles published in English; iii) journal sorting with open access criteria.

Study selection

The article screening stage was based on the research question and relevant studies. The article screening protocol refers to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework (Gallagher et al., 2017). The study selection stage consists of several pathways, namely: Study selection began with searching for articles in the Scopus database and found 40 documents. Then, the documents obtained were sorted based on open access criteria into 22 articles. Further sorting was carried out again based on the criteria of year and English language journals into 19 articles. The article data was then selected based on the study objectives and 11 articles were suitable for review. The flow of searching for article documents is described in Figure 1.

Collating, summarizing, comparing, and reporting the results

The reporting stage was carried out by analyzing the components of microbiological literacy and people's perceptions and attitudes toward microorganisms from qualified literature. Data analysis was carried out through four processes, according to Trilling & Jonkman (2018): i) coding and summarizing by reviewing definitions and concepts from eligible articles. ii) Summarizing each article, including the following components: author and year of publication, subject, core concepts, skills, item type, core information, and additional information.

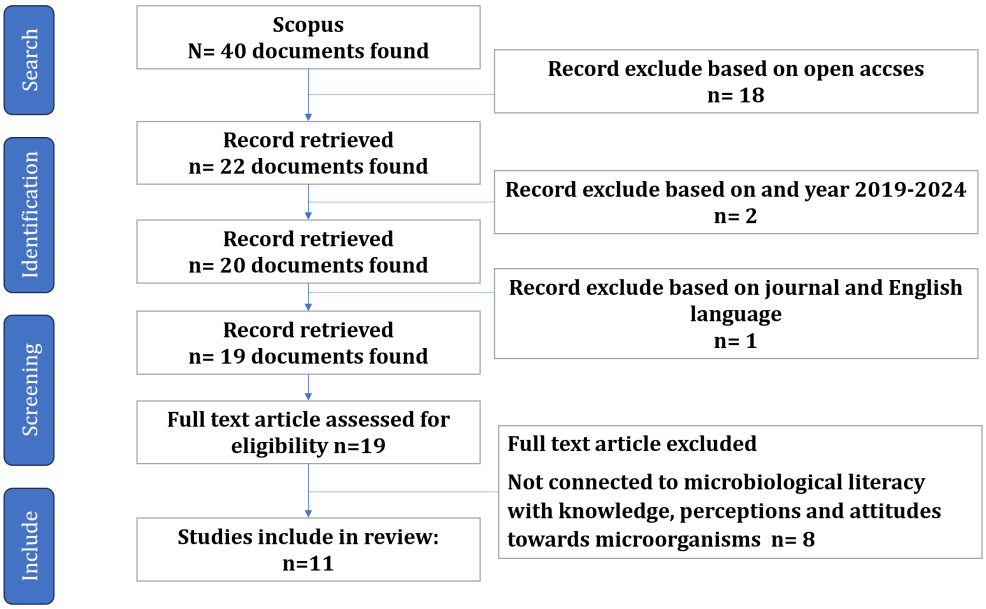

Figure 1. Flow of study selection stages

RESULTS AND DISCUSSION

A wide variety of literature has a diverse scope of research on microbiological literacy. To ensure the research objectives were met, the researcher conducted a rigorous selection process of articles. The criteria for selection included relevance to the research topic, recent publication, and methodological soundness. This process resulted in 11 articles that focused on discussing the knowledge, attitudes, and perceptions of respondents toward microorganisms. Furthermore, the research team compared and produced concepts related to knowledge, attitudes, and perceptions of microorganisms, which are explained as follows.

Public knowledge of microorganisms

Based on the study results in Table 1, it is evident that a low knowledge of the characteristics and impact of microorganisms indicates a lack of education about the role of bacteria in oral health. This may lead to behaviors not supporting dental health, such as bad habits and neglect in maintaining oral hygiene. In addition, knowledge of Tuberculosis was low, suggesting that the extension methods used may not have been practical or reached a wider audience. However, the respondents' improved knowledge of Tuberculosis, compared to previous studies, offers hope. This improvement could be attributed to more effective education programs, indicating their potential to enhance public understanding of Tuberculosis.

Table 1.
Community knowledge of microorganisms

Study	Topic	Knowledge
(Thomson et al., 2022)	Oral and dental health	Respondents did not know that bacteria can cause tooth decay
(Lin et al., 2017)	Tuberculosis	Less than half of respondents knew about TB meningitis (41%)and TB osteomyelitis (49%).
(Behnaz et al., 2014)	Tuberculosis	Most respondents had moderate to high levels of knowledgeabout TB.

These three studies show variations in community knowledge of various health issues. Low knowledge of the role of bacteria in oral health and TB meningitis and osteomyelitis suggests gaps in microbial knowledge. This emphasizes the need for more effective, targeted educational strategies to improve public understanding. Studies showing better knowledge of TB indicate that appropriate educational programs can improve microbial knowledge. Therefore, a more holistic and sustainable approach is needed to improve microbiology and general health literacy.

Communicating microbiology effectively is challenging due to the invisible nature of microorganisms. Strategies such as using comics can be used to improve microbiology literacy in learning (Scavone et al., 2019), video-based learning (Lacey & Wall, 2021) and affordable origami-based microscopes have been proposed to improve microbiology literacy (Gardner et al., 2024). In addition, inquiry-based learning approaches and innovative learning methods, such as problem-based learning, flipped classrooms, and collaborative learning, have improved microbiology literacy in higher education (Lloyd & Berry, 2022; Timmis, 2023).

Public perception of microorganisms

Based on studies on the perception of microorganisms, people fear microbes (microbe phobia). This fear indicates a lack of understanding of the positive role of microbes in health and the environment. Better education is needed to reduce unfounded fears due to microbe phobia. Concerns about vaccines reflect mistrust of existing health information. This suggests that more transparent and evidence-based communication is needed to increase public confidence in vaccines. Based on these three studies, negative perceptions of microorganisms make people more likely to see microbes as a threat rather than an essential component of health. This emphasizes the importance of educational campaigns highlighting the benefits of microbes and providing examples in everyday activities. For example, by developing student-centered teaching resources to promote microbiological literacy in schools, emphasizing the learning of microbiology in everyday activities (Crispim et al., 2021). In addition, practicum classes and lab work have significantly increased students' interest and retention of microbiology knowledge (Scalas et al., 2017).

These three studies show that a lack of knowledge and mistrust of health information influences public perceptions of microbes and vaccines. Fear of microbes and vaccine concerns reflect the need for better education and effective communication. By improving microbiological literacy and health information transparency, it is hoped that these negative perceptions can be transformed into a more balanced and positive understanding. Educational campaigns can focus on approaching and supporting individuals with engaging, evidence-based educational content that can be shared through social media to reach a wider audience (Puspitasari et al., 2020).

Table 2.
Public perception of microorganisms

Study	Topic	Perception
(Timmis, 2023)	microbial activity	People have a fear of microbes (Microbe phobia)
(Morra et al., 2022)	Covid-19 Vaccine	Respondents were wary of vaccines, citing a lack of researchand concerns about side effects.
(Karayanni et al., 2024)	Microbes	Most respondents (80%) associated microbes with the categories of "Biology" and "Health", with many showingnegative perceptions towards microbes.

Public attitude towards microorganisms

The literature study results on community attitudes towards microorganisms show that respondents understand public health practices such as social distancing, wearing masks, and maintaining hand hygiene. This understanding demonstrates the effectiveness of public health campaigns during the pandemic, but they must be maintained and improved for future pandemic preparedness. Respondents are more cautious about antibiotics because they understand the impact on health. This awareness shows increased microbiology literacy related to antibiotic use, essential to prevent antibiotic resistance. Respondents also understand the role of microbes in daily life through excursion activities. Educational activities such as excursions can increase children's understanding of microbes, essential to forming a positive attitude toward microbiology from an early age. Furthermore, 63% of respondents believe public health institutions should use genomics to understand and control infectious diseases. This support shows that the public recognizes the importance of genomic technologies in public health but also highlights the need for further education on genomics.

These five studies show that people have varied interests and understanding of health and microbiology. Interest in online education, understanding of health practices during the pandemic, awareness about antibiotic use, and support for genomic technologies suggest that various educational approaches can improve health and microbiology literacy. Continuous and innovative education is essential to shape a more aware and prepared society for future health challenges.

Mitsou et al., (2024); and Precup et al., (2022) stated that in order for the public to have confidence and trust in a microbiological product, it is necessary to inform the public about the relationship between certain food ingredients and health outcomes in a transparent way and based on a rigorous assessment of scientific evidence. For example, in the study (Alqaydi et al., 2024), people believe that probiotics and prebiotics are safe. However, they stated that health claims are only marginally credible.

Table 3.
Study of respondents' perception of microbes

Study	Topic	Attitude
(Verran, 2021)	Infectious diseases	Respondents are interested in joining the Bad Bugs Bookclub which is conducted online about recognizing covid 19 and infectious diseases.
(Ç akar et al., 2021)	Pandemic covid19	Respondents understood about public health practices such as social distancing, wearing masks, and maintaining hand hygiene.
(Abu-Humaidan et al., 2021)	Human Microbiota	Respondents are more cautious in using antibiotics becausethey understand the impact on health.
(McGenity et al., 2020)	Children's Enthusiasmfor Microbes	Respondents understand the role of microbes in daily lifethrough excursion activities
(Van Goethem et al., 2020)	Feasibility of PathogenGenomics for Public Health Practice	63% of respondents believe that public health organizations should use genomics to understand and control infectious diseases.

Relationship of microbiology literacy to knowledge, attitude, and perception

Based on the results of the literature study on the knowledge, attitudes, and perceptions of respondents towards microorganisms, it can be concluded that respondents' knowledge level varies about various health issues. Regarding respondents' attitudes, it is known that respondents are interested in education and health awareness. Based on this, microbiology literacy can be improved through various educational approaches. Based on respondents' perceptions, a lack of knowledge and distrust of health information influences people's perceptions of microbes and vaccines. Based on this conclusion, the research team modeled 11 articles using the VOS Viewer described in Figure 2.

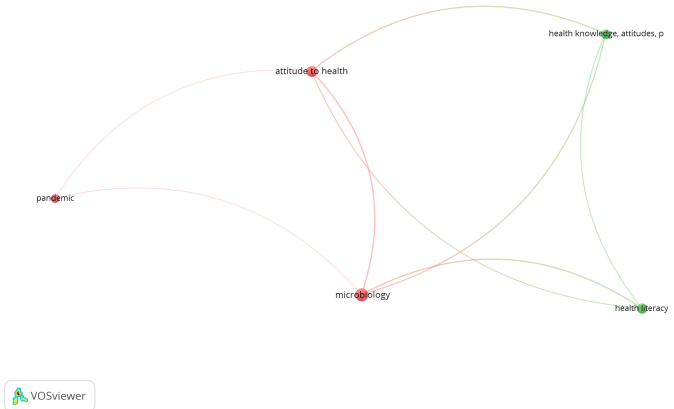

Figure 2. The relationship between microbiology literacy, knowledge, attitude and perception

The relationship between microbiology and health literacy, health knowledge, attitudes and perceptions, and attitudes towards health and the pandemic are complex and interrelated. Here is a

critical analysis that combines and connects these elements:

1. Microbiology and Health Literacy

   Microbiology is the study of microorganisms, which includes bacteria, viruses, fungi, and protozoa (Timmis, 2023). Health literacy is an individual's ability to obtain, understand, and use health information to make informed decisions (Peerson & Saunders, 2009). Poor health literacy affects the ability to obtain and evaluate information about health issues, including microbiology concepts (Ornago et al., 2022). Good microbiology knowledge can improve health literacy because individuals who understand microorganisms can better apply the information in everyday health contexts (Azevedo et al., 2020; Chan et al., 2024). Microbiology learning is essential in improving health literacy, emphasizing the need for comprehensive teaching resources and engaging students with socially relevant microbiology concepts (Critchley et al., 2020; Gardner et al., 2024; Timmis, 2023).

2. Health Knowledge

   Health knowledge includes an understanding of disease, prevention, and treatment. A strong understanding of microbiology is essential for advancing health knowledge, as microbiology covers various aspects of human health, environmental sustainability, and disease prevention. (Fatton et al., 2021; Morra et al., 2022; Walpole et al., 2020). For example, they understand how bacteria and viruses' disease can help individuals take appropriate preventive measures, such as vaccinations and hand hygiene.

3. Attitude and Perception

   Attitudes and perceptions toward health are strongly influenced by microbiology knowledge (Abramczyk et al., 2023; Špernjak et al., 2023). For example, fear of microbes (microbe phobia) can be overcome with proper education about the positive role of microbes in health and the environment (Timmis et al., 2019). Conversely, lack of knowledge can lead to negative perceptions and mistrust of health interventions, such as vaccinations (Bechini et al., 2019). Studies on vaccination attitudes and behaviors found that knowledge about vaccination is associated with vaccination-related attitudes and behaviors. It was seen that more excellent vaccine-related knowledge was associated with more positive vaccination attitudes. In addition, health workers were identified as key influencers in disseminating vaccination advice, and trust in health workers positively impacted vaccination attitudes (Foster et al., 2022; Montuori et al., 2023).

4. Attitude towards health

   Attitudes towards health include how individuals respond to health information and take action (Fava GA, Cosci F, Sonino N, 2023). Good microbiology knowledge can improve positive attitudes toward health, such as wise use of antibiotics and support for public health programs. (Abu-Humaidan et al., 2021). For example, understanding antibiotic resistance may encourage more responsible antibiotic use. In contrast, individuals with low health information orientation are more likely to have poor knowledge about antibiotic use (Guo et al., 2022).

5. Pandemic

   The COVID-19 pandemic has highlighted the importance of health literacy and microbiology knowledge. Knowledge of the virus and how it is spread has influenced people's attitudes and behaviors toward preventive measures, such as mask-wearing and vaccination (Ceylan et al., 2023; Lastrucci et al., 2021). Studies show that good health literacy is associated with higher adherence to health protocols during the pandemic (Balcı et al., 2024). Some studies suggest that a good understanding of microbiology can increase awareness of the importance of microorganisms in ecosystems and human health (Timmis et al., 2019). Meanwhile, another study found that low microbiology literacy can lead to fears and misconceptions about the role of microorganisms (Fidiastuti et al., 2024). Despite evidence supporting the importance of microbiological literacy, there is still disagreement regarding the best methods to improve this literacy among the public. Some researchers argue that formal education in schools and public campaigns can be effective (Debrah et al., 2021) while others emphasize the importance of hands-on experience and project-based learning (Joji et al., 2022).

FUTURE IMPLICATION

Understanding microbiology is relevant to science and has far-reaching impacts on everyday life and the future. We can take lessons from the current coronavirus pandemic about the importance of microbiological literacy in making informed policy decisions, especially when discussing public health system preparedness for disease outbreaks and pandemics. However, there is a big challenge in appreciating the role of microbes in our well-being and the planet. Microbes are often invisible to the naked eye. We only notice them when we are sick with an infection. Unfortunately, the public perception of microbes is often only associated with 'germs' and negative images. Therefore, it is essential to make microbes more visible. We can use interesting images and examples of positive outcomes involving microbes. In this way, we can connect everyday information with our visual, olfactory, and tactile

experiences with microbes. The more we understand the role of microbes, the better we can make relevant decisions (McGenity et al., 2020). In addition, introducing visual arts in microbiology learning is an interdisciplinary approach between science and art, as well as how art strategies have been applied in undergraduate biology classes. For example, in one case study, students who took an introductory microbiology laboratory course and engaged in an open-ended inquiry activity involving gelatinous art showed increased confidence in their role as future scientists (Adkins et al., 2018). Read-write assignments based on popular science books stimulate engagement in microbiology, encouraging critical thinking and practical application of microbiology.

CONCLUSION

Good microbiology knowledge can improve health literacy, affecting an individual's attitude and perception towards health. Positive attitudes towards health can promote actions that support public health, whereas individuals with low health information orientation are more likely to develop negative perceptions and distrust of health interventions. Continuous evidence-based education is essential to improve health literacy and shape more positive attitudes toward health interventions.

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