Journal of Academic Biology and Biology Education
Vol. 3, No. 1, June 2026, pp. 166~174
ISSN: 3062-9705, DOI: 10.37251/jouabe.v3i1.3457

Knowing Microbes, Living Healthier: The Association Between Microbiology Literacy and Health-Promoting Behaviors

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Article Info

Article history:

Received May 15, 2026
Revised Jun 3, 2026
Accepted Jun 29, 2026
Online First Jun 30, 2026

Keywords:

Biology Education
Health Literacy
Health-Promoting Behaviors
Microbiology Literacy
Pre-Service Biology Teachers

ABSTRACT

Purpose of the study: This study aimed to determine the relationship between microbiology literacy and health-promoting behaviors among pre-service biology teachers. It also sought to examine the strength of the association and the contribution of microbiology literacy to students' health-promoting behaviors.

Methodology: A quantitative correlational design was employed. Participants consisted of 60 Biology Education students selected through simple random sampling from a population of 134 students. Data were collected using a microbiology literacy multiple-choice test and a health-promoting behavior questionnaire based on a four-point Likert scale. Instrument validity and reliability were reviewed by experts. Data were analyzed using IBM SPSS Statistics through descriptive statistics, normality testing, linearity testing, Pearson's Product-Moment correlation, and coefficient of determination analysis.

Main Findings: The results revealed a significant positive relationship between microbiology literacy and health-promoting behaviors. The correlation coefficients were r = 0.521 and r = 0.451, indicating moderate positive associations. The significance tests confirmed that the relationships were statistically significant at the 5% level. Microbiology literacy explained 27.14% and 20.34% of the variance in health-promoting behaviors, suggesting that students with higher microbiology literacy tended to demonstrate better health-promoting behaviors.

Novelty/Originality of this study: This study extends existing research by specifically examining microbiology literacy rather than general health literacy as a predictor of health-promoting behaviors. It provides empirical evidence on how microbiological knowledge acquired through higher education is associated with students' daily health practices, contributing to the integration of biology education, health literacy, and behavioral science.

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1. INTRODUCTION

Microorganisms play an essential role in human health, environmental sustainability, and disease transmission [1], [2]. Understanding the characteristics and functions of microorganisms is therefore an important component of scientific literacy in the twenty-first century. Knowledge of microbiology helps

individuals recognize the causes of infectious diseases and the importance of preventive health measures [3], [4]. Increased awareness of microbial interactions can encourage people to adopt healthier lifestyles and maintain personal hygiene [5], [6]. Consequently, microbiology literacy has become increasingly relevant in promoting public health and well-being.

Health-promoting behaviors refer to actions undertaken by individuals to maintain and improve their physical, mental, and social health [7], [8]. These behaviors include handwashing, maintaining personal hygiene, consuming safe food and water, and practicing disease prevention measures. The adoption of such behaviors is influenced by multiple factors, including knowledge, attitudes, beliefs, and environmental conditions. Among these factors, knowledge is often considered a key determinant that shapes individual decision-making and behavior [9], [10]. Therefore, understanding the relationship between scientific knowledge and health-related practices is important for educational and public health development [11], [12].

University students represent a strategic population for promoting healthy behaviors because they are in a transitional phase toward adulthood and professional life [13], [14]. As future educators, Biology Education students are expected to possess adequate scientific knowledge and demonstrate healthy behaviors that can serve as examples for others [15], [16]. Their academic background provides opportunities to develop a deeper understanding of microbiological concepts related to health and disease prevention [17], [18]. However, possessing scientific knowledge does not always guarantee the implementation of healthy practices in daily life. This condition highlights the need to examine whether microbiology literacy is associated with students' actual health-promoting behaviors.

Several studies have reported that health literacy and scientific knowledge contribute positively to health-related behaviors among students and the general population [19], [20]. Research has shown that individuals with higher levels of health knowledge tend to exhibit better hygiene practices and disease prevention behaviors [21], [22]. Other studies have focused on the effects of health education programs in improving healthy lifestyles among adolescents and university students. Nevertheless, most existing studies emphasize general health literacy, health education, or environmental health awareness rather than microbiology-specific knowledge. As a result, empirical evidence regarding the relationship between microbiology literacy and health-promoting behaviors remains limited.

The research gap becomes more apparent when considering the context of pre-service biology teachers. Although Biology Education students receive formal instruction in microbiology courses, few studies have specifically investigated how their microbiological knowledge influences their daily health practices [23], [24]. Previous studies generally assess learning outcomes, academic achievement, or attitudes toward science without linking these variables to actual health behaviors. Furthermore, research examining microbiology literacy as a determinant of health-promoting behavior among university students is still scarce, particularly in developing countries. This lack of evidence indicates the need for further investigation to clarify the relationship between these variables.

This study offers a novel perspective by focusing specifically on microbiology literacy and its association with health-promoting behaviors among pre-service biology teachers. Unlike previous studies that primarily examine general health knowledge, this research investigates microbiology knowledge as a distinct educational variable. The study also contributes to biology education by exploring whether scientific understanding acquired through coursework is reflected in students' everyday behaviors. The findings are expected to provide insights into the practical impact of microbiology education beyond academic achievement. Therefore, this research can enrich the literature at the intersection of biology education, health literacy, and behavioral science.

The urgency of this study is strengthened by the increasing importance of preventive health behaviors in reducing the spread of infectious diseases and improving public health outcomes. Future biology teachers are expected not only to understand scientific concepts but also to apply and promote healthy behaviors within their communities. Understanding the relationship between microbiology literacy and health-promoting behaviors may help educational institutions design more effective learning experiences that integrate knowledge and practice. Such information can support curriculum development aimed at fostering both scientific competence and responsible health behavior among students. Therefore, this study aims to determine the relationship between microbiology literacy levels and health-promoting behaviors among Biology Education students.

2. RESEARCH METHOD

2.1. Research Design

This study employed a quantitative approach using a correlational research design to examine the association between microbiology literacy and health-promoting behaviors among pre-service biology teachers. A correlational design was selected because it allows the investigation of relationships between variables without manipulating the research setting [25], [26]. The independent variable was microbiology literacy, while health-promoting behavior served as the dependent variable. Data were collected using research instruments designed to

measure students' levels of microbiology knowledge and their health-promoting behaviors. The collected data were analyzed using Pearson's Product-Moment Correlation to determine the strength and direction of the relationship between the two variables [27], [28]. Prior to hypothesis testing, the data were screened to ensure that the assumptions required for parametric analysis were met. Statistical analyses were performed using appropriate statistical software, with a significance level of 0.05.

2.2. Participants and Sampling

The population of this study consisted of undergraduate students enrolled in the Biology Education program who had completed the Microbiology course. Students who had taken the course were selected because they were expected to possess fundamental knowledge related to microbiological concepts, microorganisms, and their relevance to human health [17], [29]. Participants were selected using a probability sampling technique with a simple random sampling method, ensuring that each member of the population had an equal opportunity to be included in the study. From a total population of 134 students, 60 students were randomly selected as research participants. The sample represented students from different academic cohorts who met the inclusion criteria. This sampling approach was employed to obtain a representative sample and minimize selection bias.

2.3. Data Collection Instruments

Data were collected using two research instruments: a microbiology literacy test and a health-promoting behavior questionnaire [30], [31]. Microbiology literacy was assessed using an objective multiple-choice test developed based on key microbiology concepts covered in the undergraduate curriculum. The test measured students' understanding of microorganisms, microbial roles in daily life, disease transmission, hygiene, and infection prevention. Each item consisted of one correct answer and several distractors. Correct responses were scored as 1, while incorrect responses were scored as 0. The total score represented each participant's level of microbiology literacy. Health-promoting behaviors were measured using a structured questionnaire consisting of closed-ended statements related to personal hygiene, environmental cleanliness, disease prevention, and healthy lifestyle practices. Responses were rated using a four-point Likert scale ranging from 1 (Strongly Disagree) to 4 (Strongly Agree). Negatively worded items were reverse-coded prior to analysis. Higher scores indicated a greater tendency to engage in health-promoting behaviors. Table 1 presents the scoring system used in the questionnaire.

Table 1. Scoring Criteria for the Health-Promoting Behavior Questionnaire

Response Category	Positive Statements	Negative Statements
Strongly Agree (SA)	4	1
Agree (A)	3	2
Disagree (D)	2	3
Strongly Disagree (SD)	1	4

Prior to data collection, both instruments were reviewed by experts to ensure content validity and were subjected to reliability testing. Only valid and reliable items were included in the final analysis.

2.4. Data Analysis

Data analysis was conducted using IBM SPSS Statistics. Descriptive statistics were first calculated to summarize participants' microbiology literacy scores and health-promoting behavior scores. Prior to hypothesis testing, assumption tests were performed. Data normality was assessed using the Kolmogorov–Smirnov test, while the linearity of the relationship between microbiology literacy and health-promoting behaviors was examined through a linearity test. Data were considered normally distributed and linear when the significance value exceeded 0.05 [32], [33]. To examine the relationship between microbiology literacy and health-promoting behaviors, Pearson's Product–Moment Correlation analysis was employed. The correlation coefficient (r) was used to determine the strength and direction of the association between the two variables. Correlation coefficients were interpreted as very weak (0.00–0.19), weak (0.20–0.39), moderate (0.40–0.59), strong (0.60–0.79), and very strong (0.80–1.00). In addition, the coefficient of determination (R^2) was calculated to estimate the proportion of variance in health-promoting behaviors explained by microbiology literacy. Statistical significance was determined at the 0.05 level. Therefore, a p-value less than 0.05 indicated a statistically significant relationship between the variables.

2.5. Research Procedure

The study was conducted in five sequential stages. First, the researchers developed the research instruments, including a microbiology literacy test and a health-promoting behavior questionnaire. The instruments were then reviewed by experts to establish content validity and subsequently tested for reliability. Second, the research population was identified, and participants were selected using a simple random sampling

technique. Third, data were collected by administering the microbiology literacy test and the health-promoting behavior questionnaire to the selected participants. Fourth, the collected data were coded, scored, and entered into IBM SPSS Statistics for analysis. Finally, descriptive and inferential statistical analyses were performed, including normality testing, linearity testing, Pearson's Product-Moment correlation analysis, and coefficient of determination analysis. The results were then interpreted to determine the relationship between microbiology literacy and health-promoting behaviors among pre-service biology teachers.

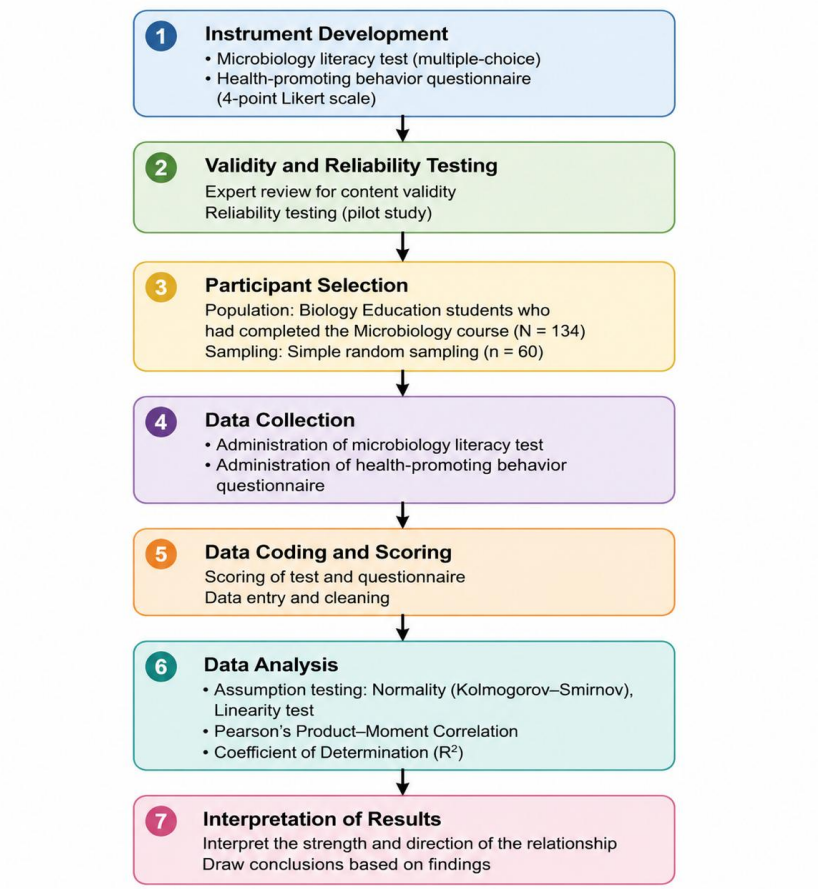

Figure 1. Flowchart of the Research Procedure

3. RESULTS AND DISCUSSION

Data analysis was conducted using product-moment correlation. Prerequisite tests were conducted prior to data analysis to identify relationships between the variables used in the study, including normality and linearity tests.

3.1. Normality Test

The normality test is used to determine whether the data obtained is normally distributed. The results for the level of microbiology knowledge and clean and healthy living behaviors can be seen in the following table:

Table 2. Normality Test of Microbiology Knowledge

Group	X^2_{Count}	X^2_{Table}	Information
A	10.9203	11.07	Normal
B	9.6239	11.07	Normal

The results of the normality test presented in Table 2 indicate that the microbiology knowledge scores in both groups were normally distributed. Group A obtained a χ^2 value of 10.9203, while Group B obtained a χ^2 value of 9.6239. Since both calculated χ^2 values were lower than the critical χ^2 value of 11.07 at the 5% significance level, the null hypothesis of normality was accepted. These findings demonstrate that the microbiology knowledge data met the assumption of normal distribution. Therefore, the data were considered suitable for subsequent parametric statistical analyses, including Pearson's Product-Moment correlation.

Table 3. Normality Test of Clean and Healthy Living Behavior

Group	X^2_{Count}	X^2_{Table}	Information
A	6.2224	11.7	Normal
B	4.0613	11.7	Normal

The results of the normality test presented in Table 3 indicate that the health-promoting behavior scores in both groups were normally distributed. Group A obtained a χ^2 value of 6.2224, while Group B obtained a χ^2 value of 4.0613. Both calculated χ^2 values were lower than the critical χ^2 value of 11.70 at the 5% significance level. Therefore, the null hypothesis of normality was accepted, indicating that the health-promoting behavior data met the assumption of normal distribution. Consequently, the data were considered appropriate for further parametric statistical analyses.

3.2. Linearity Test

The linearity test was conducted to determine whether the relationship between microbiology knowledge and health-promoting behaviors followed a linear pattern. The results showed that Group A obtained an F value of -0.55, which was lower than the critical F value of 2.393 at the 5% significance level. Similarly, Group B obtained an F value of -0.97, which was lower than the critical F value of 2.460. Since the calculated F values for both groups were lower than the corresponding critical F values, the relationship between microbiology knowledge and health-promoting behaviors was considered linear. These findings indicate that the linearity assumption was satisfied, allowing the use of Pearson's Product-Moment correlation analysis to examine the association between the two variables.

3.3. Hypothesis Test Analysis

3.3.1. Correlation Analysis Between Microbiology Knowledge and Health-Promoting Behaviors

Pearson's Product-Moment correlation analysis was conducted to examine the relationship between microbiology knowledge and health-promoting behaviors among Biology Education students. The results showed that the correlation coefficient for Group A was r = 0.521, while Group B obtained a correlation coefficient of r = 0.451. Both values exceeded the critical correlation coefficient (r = 0.361) at the 5% significance level (df = 28), indicating that the correlations were statistically significant. These findings demonstrate a positive relationship between microbiology knowledge and health-promoting behaviors. In other words, students with higher levels of microbiology knowledge tended to exhibit better health-promoting behaviors. Based on the correlation coefficient interpretation criteria, the obtained coefficients (r = 0.521 and r = 0.451) fall within the range of 0.40–0.59, indicating a moderate relationship between the two variables. Therefore, the results support the hypothesis that microbiology knowledge is significantly associated with health-promoting behaviors among pre-service biology teachers.

Table 4. Pearson Correlation Between Microbiology Knowledge and Health-Promoting Behaviors

Group	r-value	r-critical (α = 0.05)	Relationship Strength	Interpretation
A	0.521	0.361	Moderate	Significant Positive Correlation
B	0.451	0.361	Moderate	Significant Positive Correlation

3.3.2. Coefficient of Determination

The coefficient of determination analysis was conducted to estimate the proportion of variance in health-promoting behaviors explained by microbiology knowledge. The results showed that the coefficient of determination for Group A was 27.14% (R^2 = 0.271), indicating that microbiology knowledge accounted for approximately 27% of the variation in health-promoting behaviors. The remaining 72.86% of the variance may be attributed to other factors not examined in this study. Similarly, the coefficient of determination for Group B was 20.34% (R^2 = 0.203), suggesting that microbiology knowledge explained approximately 20% of the variation in health-promoting behaviors, while the remaining 79.66% was influenced by other variables beyond the scope of the present study. These findings indicate that microbiology knowledge contributes meaningfully to students' health-promoting behaviors; however, it is not the sole determinant. Other factors, such as attitudes, health awareness, social influences, personal habits, and environmental conditions, may also play important roles in shaping health-promoting behaviors among pre-service biology teachers.

3.3.3. Significance Test of the Correlation

To determine whether the observed correlations were statistically significant, a t-test was performed on the correlation coefficients. The results showed that Group A obtained a calculated t-value of 4.445, while Group B obtained a calculated t-value of 3.677. At the 5% significance level with 28 degrees of freedom, the critical t-value was 2.048. Since the calculated t-values for both groups exceeded the critical value (t = 2.048), the null hypothesis was rejected. These findings indicate that the positive correlations between microbiology knowledge

and health-promoting behaviors were statistically significant. Therefore, students with higher levels of microbiology knowledge tended to demonstrate better health-promoting behaviors. The results provide empirical support for the hypothesis that microbiology knowledge is significantly associated with health-promoting behaviors among pre-service biology teachers.

Table 5. Significance Test of the Correlation Between Microbiology Knowledge and Health-Promoting Behaviors

Group	t-value	t-critical (α = 0.05)	Decision	Interpretation
A	4.445	2.048	Reject H_0	Significant
B	3.677	2.048	Reject H_0	Significant

The positive association between microbiology literacy and health-promoting behaviors indicates that scientific understanding plays an important role in shaping students' everyday health-related decisions. From a behavioral perspective, individuals who possess adequate microbiological knowledge are more capable of recognizing the mechanisms of disease transmission, understanding the importance of preventive measures, and evaluating health risks [34], [35]. This cognitive foundation encourages the adoption of healthier practices because individuals are more likely to perceive the benefits of maintaining hygiene and preventing infection. Consequently, microbiology literacy functions not only as academic knowledge but also as an essential component that supports responsible health behavior among future biology teachers [3], [18].

The moderate strength of the relationship also suggests that microbiology literacy contributes meaningfully to health-promoting behaviors without being the only influencing factor. Human behavior is multidimensional and is shaped by interactions among cognitive, psychological, social, and environmental factors [36], [37]. Students may possess adequate microbiological knowledge but still fail to consistently practice healthy behaviors due to limited motivation, unfavorable social norms, inadequate facilities, or established personal habits. Therefore, strengthening microbiology literacy should be accompanied by educational strategies that encourage behavioral change through experiential learning, reflection, and continuous practice [38], [39]. Integrating microbiology concepts with authentic health-related activities may facilitate the translation of scientific knowledge into sustainable healthy lifestyles.

The findings of this study are consistent with previous research demonstrating that higher levels of health-related knowledge are associated with healthier behaviors. Ridwan et al. [19] reported that university students with better health literacy demonstrated more positive health-related behaviors, particularly in maintaining physical health and adopting preventive practices. Likewise, Jürgensen et al. [20] found that health literacy among health professional students was positively associated with healthier lifestyles and better health-related behaviors. These findings indicate that knowledge serves as a critical determinant of health behavior across different educational settings. More specifically, the present study extends this body of evidence by demonstrating that microbiology literacy, rather than general health literacy, also contributes significantly to students' health-promoting behaviors [40], [41].

The present findings are also supported by research focusing specifically on microbiology education. Mustofa et al. [3] demonstrated that microbiology literacy positively influences individuals' knowledge, perceptions, and attitudes toward microorganisms, which subsequently encourages responsible health-related behavior. Similarly, Fidiastuti et al. [30] emphasized that microbiological literacy equips individuals with scientific competencies necessary for understanding microbial roles in health and disease prevention. Furthermore, Carvalho and Lima [24] argued that improving microbiology education enhances public understanding of microorganisms and contributes to healthier societal responses to infectious diseases. Together, these studies reinforce the conclusion that microbiology literacy represents an important educational resource for promoting health-conscious behavior.

From an educational perspective, the findings have important implications for biology teacher education programs. Future biology teachers are expected not only to master microbiological concepts but also to model healthy behaviors that can influence their future students and communities [23], [42]. Therefore, microbiology instruction should emphasize the practical application of scientific knowledge through project-based learning, laboratory investigations, community health campaigns, and reflective learning experiences [43], [44]. Such approaches may strengthen the connection between conceptual understanding and everyday health practices, ultimately preparing prospective teachers who are scientifically competent and socially responsible.

The broader impact of this study extends beyond biology education to public health promotion. Improving microbiology literacy among university students may contribute to greater awareness of disease prevention, infection control, personal hygiene, and environmental sanitation [3], [45]. Since pre-service teachers often become influential agents within schools and communities, enhancing their microbiology literacy has the potential to create multiplier effects by encouraging healthy behaviors among future generations [46], [47]. Consequently, educational institutions may consider integrating microbiology literacy into broader health

promotion initiatives as part of efforts to develop healthier and more scientifically literate communities [48], [49].

Despite these contributions, several limitations should be acknowledged. First, this study employed a correlational design, which does not permit causal conclusions regarding the influence of microbiology literacy on health-promoting behaviors. Second, the sample consisted exclusively of Biology Education students from a single institution, limiting the generalizability of the findings to other academic disciplines or educational contexts. Third, health-promoting behaviors were measured using self-reported questionnaires, making the responses susceptible to social desirability and response bias. Finally, microbiology literacy explained only approximately 20–27% of the variance in health-promoting behaviors, indicating that other variables—including health attitudes, self-efficacy, motivation, social support, institutional culture, and environmental conditions—may play substantial roles [50], [51]. Future studies should therefore employ larger and more diverse samples, longitudinal or experimental designs, and incorporate additional psychological and contextual variables to develop a more comprehensive understanding of the factors influencing health-promoting behaviors among university students.

4. CONCLUSION

The findings of this study demonstrate a significant positive relationship between microbiology literacy and health-promoting behaviors among pre-service biology teachers. Pearson correlation analysis revealed moderate positive correlations in both groups, with correlation coefficients of $r = 0.521$ and $r = 0.451$, respectively. The significance test further confirmed that these relationships were statistically significant at the 5% significance level. These results indicate that students with higher levels of microbiology literacy tend to exhibit better health-promoting behaviors. In addition, microbiology literacy explained approximately 20–27% of the variance in health-promoting behaviors, suggesting that scientific knowledge contributes meaningfully to healthy lifestyle practices. However, a substantial proportion of the variance was influenced by other factors beyond the scope of this study. Therefore, strengthening microbiology literacy through biology education may support the development of healthier behaviors among future biology teachers. Further research is recommended to investigate additional factors, such as health attitudes, self-efficacy, environmental influences, and health awareness, that may affect students' health-promoting behaviors.

ACKNOWLEDGEMENTS

The authors would like to thank all participants for their valuable contributions to this study. Appreciation is also extended to colleagues and institutions that provided support during the research process. Their assistance and cooperation were essential to the completion of this work.

AUTHOR CONTRIBUTIONS

Conceptualization, F.J. and J.G.J.; Methodology, F.J.; Software, F.J.; Validation, F.J. and J.G.J.; Formal Analysis, F.J.; Investigation, F.J.; Resources, F.J. and J.G.J.; Data Curation, F.J.; Writing – Original Draft Preparation, F.J.; Writing – Review & Editing, F.J. and J.G.J.; Visualization, F.J.; Supervision, J.G.J.; Project Administration, F.J.; Funding Acquisition, J.G.J. All authors have read and agreed to the published version of the manuscript.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

USE OF ARTIFICIAL INTELLIGENCE (AI)-ASSISTED TECHNOLOGY

Not applicable.

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