Jurnal Ners Volume 9 Nomor 4 Tahun 2025 Halaman 5993 - 6001
JURNAL NERS
Research & Learning in Nursing Science
http://journal.universitaspahlawan.ac.id/index.php/ners

INTEGRATION OF HEALTH EDUCATION AND MULTIMODAL LEARNING IN ENHANCING ANTIBIOTIC LITERACY TO PREVENT ANTIMICROBIAL RESISTANCE

Zakia Asrifah Ramly[1] Asnurbaety Dwiyana[2], Maipha Deapati Arief[3], Anik Nur Janah[4], Nur Anisa[5]
[1,2,3,4,5] Health Analysis Program, East Indonesia University
zakiaasrifah28@gmail.com ,asnurbaety@gmail.com ,Dheaspenkhus@gmail.com ,anik.nurjanah@gmail.com , nur.anisa01@gmail.com

Abstrak

Resistensi antimikroba (AMR) merupakan ancaman kesehatan global yang semakin meningkat. Hal ini dikarenakan penyalahgunaan antibiotik, terutama didaerah dengan literasi antibiotik yang rendah. Penelitian ini mengevaluasi dampak pembelajaran multimodal dalam meningkatkan literasi antibiotik di kalangan siswa sekolah menengah pertama di Kabupaten Jeneponto. Sebanyak 47 siswa dari SMP Negeri 6 Tamalatea berpartisipasi dalam desain pretest-posttest yang melibatkan sesi tatap muka, modul cetak, video pembelajaran, dan kegiatan bermain peran. Data dikumpulkan melalui kuesioner yang telah divalidasi sebelum dan sesudah intervensi. Hasil menunjukkan peningkatan signifikan pada skor literasi antibiotik, dengan sebagian besar siswa berpindah dari tingkat rendah atau sedang sebelum intervensi ke tingkat tinggi setelahnya. Analisis statistik mengonfirmasi adanya korelasi positif yang kuat antara pendekatan pembelajaran multimodal dan peningkatan literasi. Temuan ini menunjukkan bahwa penggabungan berbagai metode pembelajaran secara efektif melibatkan gaya belajar siswa yang beragam, sehingga meningkatkan pemahaman dan retensi. Studi ini mendukung integrasi strategi pendidikan multimodal dalam program kesehatan sekolah untuk mendorong penggunaan antibiotik yang bertanggung jawab dan membantu mencegah AMR sejak usia dini.

Kata Kunci: Resistensi Antimikroba, Pembelajaran Multimodal, Remaja, Literasi, Edukasi kesehatan

Abstract

Antimicrobial resistance (AMR) is a growing global health threat driven by the misuse of antibiotics, particularly in areas with low antibiotic literacy. This study evaluated the impact of multimodal learning on improving antibiotic literacy among high school students in Jeneponto Regency. A total of forty-seven students from SMP Negeri 6 Tamalatea participated in a pretest-posttest design involving face-to-face sessions, printed modules, instructional videos, and role-playing activities. Data were collected via a validated questionnaire before and after the intervention. Results showed a significant increase in antibiotic literacy scores, with most students moving from low or moderate levels before the intervention to high levels afterward. Statistical analysis confirmed a strong positive correlation between the multimodal learning approach and literacy improvement. These findings demonstrate that combining various learning methods effectively engages diverse student learning styles, enhancing understanding and retention. The study supports the integration of multimodal educational strategies in school health programs to promote responsible antibiotic use and help prevent AMR from an early age.

Keywords*: *Antimicrobial resistance, Multimodal Learning, Adolescent, Literacy, health education

* Corresponding author :
Address: East Indonesia University
Email : nur.anisa01@gmail.com

INTRODUCTION

Antibiotics are considered one of the cornerstones of modern medicine, having successfully transformed the prognosis of previously fatal infectious diseases and saved millions of lives worldwide (Anggarwal et al., 2024). However, this success has also given rise to a significant global health challenge: antimicrobial resistance (AMR). AMR occurs when bacteria develop mechanisms to counteract the effects of antibiotics, ultimately threatening decades of medical progress (Gani et al., 2025).

The impacts of AMR are far-reaching, leading to increased morbidity, mortality, and economic burdens due to more complex and expensive treatments (Munita et al., 2016; Poudel et al., 2023). Without effective global intervention, AMR is projected to cause up to 10 million deaths annually by 2050, surpassing cancer as the leading cause of death, while also triggering serious economic consequences (Jee et al., 2018; Ahmad et al., 2021).

Several studies have reported increased resistance in key bacterial pathogens, including Klebsiella pneumoniae (Sulistiyawati et al., 2024), Escherichia coli (Chetri et al., 2025), Staphylococcus aureus (Meriyani et al., 2025; Chambers & Fowler, 2024; Michalik et al., 2025), Pseudomonas aeruginosa (Ng et al., 2023), and Mycobacterium tuberculosis (Xiong et al., 2024), with increasing cases of resistance to first-line antibiotics such as rifampicin and isoniazid (Rahmawati & Lestari, 2024). Additionally, the COVID-19 pandemic has exacerbated the situation by increasing the excessive and inappropriate use of antibiotics (Zhang et al., 2021; Abubakar et al., 2023).

One of the main factors driving this crisis is the low level of antibiotic literacy among the general public (Wulandari et al., 2025), reflected in widespread self-medication practices, antibiotic use without a prescription, and non-adherence to treatment guidelines. This lack of awareness significantly contributes to the spread of resistance, even making simple medical procedures, such as routine surgeries or treatment of mild infections, increasingly risky (Maeda & Yamaguchi, 2025).

Adolescents, particularly junior high school students, are a key target group for improving antibiotic literacy (Bawazir et al., 2025). Studies show that many adolescents, both globally and in Indonesia, still have misconceptions about antibiotic use, such as the mistaken belief that antibiotics can cure viral infections like the flu or the common cold (Sinuraya et al., 2023; Oktariza, 2025). In fact, students play a strategic role as the next generation who will influence health behaviors within their families and communities (Akhila et al., 2025; Sharma et al., 2025).

Adolescence is a critical period in the development of knowledge, attitudes, and health behaviors. Improving antibiotic literacy at the school level is expected to foster a generation that is more critical, knowledgeable, and responsible in the use of antibiotics (Chung, 2025). However, research indicates that many students still struggle to distinguish between bacterial and viral infections, recognize the risks of resistance, and understand the dangers of inappropriate antibiotic use (Drymiotou et al., 2025; Angelillo et al., 2025). This issue is further complicated in areas with limited access to healthcare and education, such as Jeneponto District, South Sulawesi. Jeneponto is one of the areas still facing significant health challenges, including relatively low education levels, limited health infrastructure, and high use of antibiotics without adequate medical supervision.

Initial observations in several schools in Jeneponto indicate that many students still have misconceptions about antibiotics, including the belief that antibiotics can cure all types of diseases, including viral infections. If left unaddressed, these misconceptions can reinforce patterns of antibiotic misuse and increase the risk of AMR spread at the community level. To address this issue, an engaging, effective, and student-centered educational approach is needed. One promising method is multimodal learning, which combines various visual, auditory, textual, and kinesthetic media to improve understanding and retention of complex topics (Yuan et al., 2025), including the appropriate use of antibiotics and AMR prevention. Evidence suggests that multimodal learning, through interactive videos, educational games, simulations, and role-playing, can significantly increase student engagement, strengthen understanding, and promote positive health behaviors (Sellberg & Sharma, 2025; Mulyati et al., 2025), including the ability to distinguish between bacterial and viral infections.

Based on this background, this study aims to evaluate the effectiveness of implementing multimodal learning in improving antibiotic literacy among junior high school students in Jeneponto District. This intervention is expected not only to enhance knowledge but also to shape more responsible attitudes and behaviors toward antibiotic use, thereby contributing to broader AMR prevention efforts at both the community and national levels.

METHOD

Research

This study is a quantitative research with a pre-experimental design using a *one-group pretest-posttest* approach. This design was chosen to measure the extent of changes in antibiotic literacy among students before and after the implementation of the multimodal learning model. The independent variable in this study is the multimodal educational intervention, while the dependent variable is the level of antibiotic literacy among students. The *one-group pretest-posttest* design in this study is illustrated as follows:

O1 X O2

Explanation:
O1 → = → Pretest
X = Treatment (Multimodal Learning)
O2 = Posttest

The learning interventions provided included face-to-face sessions, printed modules, instructional videos, and role-playing activities designed to accommodate various learning styles (visual, auditory, and kinesthetic).

Research Location and Time

This study was conducted at SMP Negeri 6 Tamalatea, located in Jeneponto District, South Sulawesi Province. Data collection took place over one month, from June to July 2025.

Population and Sample

The population in this study was all students enrolled at SMP Negeri 6 Tamalatea. The total number of students at the school in the 2024/2025 academic year was 47. The sampling technique used was *total sampling*, whereby all students were invited to participate in this study to ensure comprehensive coverage of the target population. After screening based on data completeness and *informed consent*, the final number of respondents analyzed was 47 students, resulting in a response rate of 100%.

Data Collection

Data was collected using a structured questionnaire consisting of three components:

1. Knowledge Assessment: Multiple-choice questions that measure students' understanding of antibiotic use and antimicrobial resistance.
2. Attitude Measurement: Statements measured using a 5-point Likert scale, ranging from "strongly disagree" (1) to "strongly agree" (5), to assess students' perceptions and attitudes toward antibiotic use.
3. Behavioral Practices: Self-reported antibiotic use practices by students, also assessed using a 5-point Likert scale.

The combination of these three components provides a comprehensive measurement of students' antibiotic literacy, encompassing cognitive, affective, and behavioral dimensions.

Data Analysis and Processing

The collected data were analyzed using quantitative statistical methods. Descriptive statistics were used to calculate the mean, standard deviation, frequency, and percentage of knowledge, attitude, and behavior scores before and after the educational intervention. Students' antibiotic literacy levels are categorized as "low" or "high" based on whether the total score is below or above the calculated average value.

Before conducting inferential statistical tests, the normality of data distribution is analyzed using the Shapiro-Wilk test, which is recommended for small to medium sample sizes. If the data is normally distributed ($p > 0.05$), parametric tests are used.

To evaluate the effectiveness of multimodal learning interventions, a *paired sample t-test* was conducted to compare pretest and posttest scores in terms of knowledge, attitude, and behavior. This test was used to determine whether there was a statistically significant improvement after the intervention was administered.

RESULTS AND DISCUSSION

The respondent profile data in this study provides an overview of the participants' background characteristics, including age, gender, and grade level. A total of 47 secondary school students from Jeneponto District participated in this study. These demographic details ensure balanced representation across various educational levels. Students' antibiotic literacy levels were measured using pretest and posttest instruments, with results categorized into three levels: low, moderate, and high. The distribution of respondents and their literacy scores are presented in the following diagram:

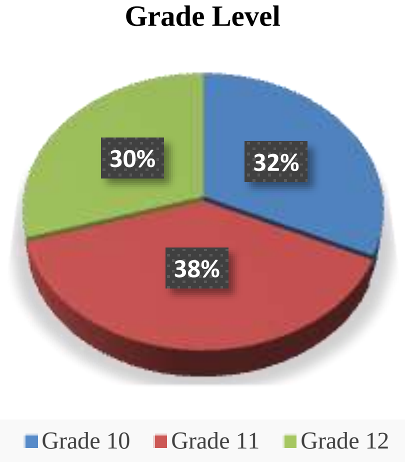

Figure 1. Distribution of Students at SMP Negeri 6 Tamalatea (Primary Data, 2025)

Figure 1 shows the distribution of respondents based on their grade level. A total of 47 junior high school students participated in this study. The largest proportion of participants came from grade 8, with 18 students (38.30%), followed by grade 7 with 15 students (31.91%), and grade 9 with 14 students (29.79%). This indicates a relatively balanced representation across the three grade levels, which helps ensure that perspectives from various stages of education at the junior high school level are reflected in this study.

Table 1 presents further details regarding the characteristics of the respondents, including age and gender. The age data is in line with the grade levels of the students, where all 7th grade students are 13 years old, all 8th grade students are 14 years old, and all 9th grade students are 15 years old.

Table 1. Frequency Distribution of Respondent Profiles

Variable	Category /Score	Grade VII	Grade VIII	Grade IX	Total
Age	12 years	2 (13.3%)	-	-	2 (4.3%)
	13	13 (86.7%)	2 (11.1%)	-	15 (31.9%)
	14 years	-	14 (77.8%)	2 (14.3%)	16 (34.0%)
	15 years	-	1 (5.6%)	12 (71.4%)	11 (23.4%)
	16 years	-	1 (5.6%)	2 (14.3%)	3 (6.4%)
Gender	Male	8 (53.3%)	10 (55.6%)	6 (42.9%)	24 (51.1%)
	Female	7 (46.7%)	8 (44.4%)	8 (57.1%)	23

Based on gender, the sample consisted of 24 male students (51.1%) and 23 female students (48.9%), indicating an overall balanced distribution. At each grade level, the gender ratio is also relatively balanced. In Grade VII, there are slightly more male students (8 students or 53.3%) than female students (7 students or 46.7%). Grade VIII shows the most balanced distribution, with 10 male students (55.6%) and 8 female students (44.4%). Meanwhile, in Grade IX, the proportion of female students is higher (8 students or 57.1%) than male students (6 students or 42.9%).

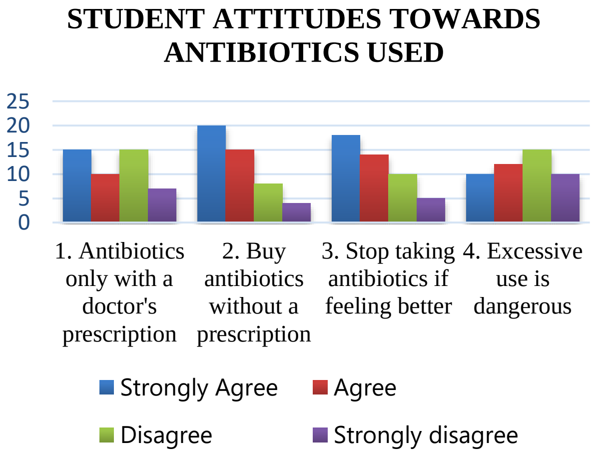

Figure 2. Students' Attitudes Toward Antibiotic Use (Primary Data, 2025)

Based on students' responses to four statements, this data illustrates their perceptions and misconceptions regarding antibiotic use. For the first statement, "*Antibiotics should only be taken with a doctor's prescription,*" student opinions were divided: 15 students strongly agreed, 10 agreed, 15 disagreed, and 7 strongly disagreed. This indicates that most students are still unaware of the importance of using antibiotics under medical supervision.

In the second statement, *"I can buy antibiotics at a pharmacy without a doctor's prescription,"* most students, 20 strongly agreed and 15 agreed, believed that they could access antibiotics without medical authorization, reflecting a low understanding of antibiotic distribution regulations.

The third statement, *"If I feel better, I can stop taking antibiotics before finishing the course,"* also indicates a concerning misunderstanding, with 18 students strongly agreeing and 14 agreeing. This suggests that many students are unaware of the risks of discontinuing antibiotic treatment prematurely.

Meanwhile, for the fourth statement, *"I believe that excessive use of antibiotics can be harmful,"* only 10 students strongly agreed and 12 agreed, while 15 disagreed and 10 strongly disagreed. This shows that many students still do not fully understand the adverse effects of excessive antibiotic use.

Overall, the research results show significant differences in knowledge, attitudes, and practices related to antibiotic use among students, emphasizing the need for targeted educational efforts to improve antibiotic literacy among students.

Table 2. Students' Behavior Regarding Antibiotic Use

	Question	Answer Option	Number of Respondents	Percentage
1	Have you ever taken antibiotics without a doctor's prescription?	Yes	3	6
		Never	17	36.17
2	What do you do first when you feel sick?	Take medicine at home	20	42.55
		Go to the doctor	15	31.91
		Seeking advice from family/friends	9	19
		Other	3	6.39
3	Did you finish the antibiotic	Yes	20	42.55
		No	17	36.17
		Depends	10	21.28

treatment even though you felt better?

Table 2 presents information regarding student behavior in the use of antibiotics. In the first question regarding whether they had ever taken antibiotics without a doctor's prescription, the majority of respondents (63.83%) admitted to having done so, while only 36.17% stated that they had never done so. These findings indicate that self-medication with antibiotics is quite common among the students surveyed.

In response to the second question about the first action taken when feeling sick, 42.55% of students stated that they chose to take medicine at home, 31.91% preferred to go to the doctor, 19.15% sought advice from family or friends, and 6.39% chose other actions.

For the third question regarding whether they completed their antibiotic treatment even after feeling better, 42.55% of students answered "Yes," 36.17% answered "No," and 21.28% answered "It depends."

This study shows that although some students already have a correct understanding of antibiotic use, there is still a significant proportion who engage in risky practices, such as self-medication and not completing treatment as prescribed.

Table 3. Frequency Distribution and Percentage of Antibiotic Literacy Levels Among Students by Grade Before and After Intervention

Variable	Category/ Score	Grade VII	Grade VIII	Grade IX	Total
Antibiotic Literacy Pre-test Score (O_1)	Low	12 (85.7 %)	18 (100.0 %)	14 (93.3 %)	44 (91.7 %)
	Moderate	2 (14.3 %)	0 (0.0%)	1 (6.7 %)	3 (6.3 %)
	High	0 (0.0%)	0 (0.0%)	0 (0.0 %)	0 (0.0 %)
Post-test Score for Antibiotic Literacy (O_1)	Low	0	0	0 (0.0 %)	0 (0.0 %)
	Moderate	0 (0.0%)	6 (33.3 %)	5 (33.3 %)	11 (23.4 %)
	High	14 (100.0 %)	12 (66.7 %)	10 (66.7 %)	36

Table 3 shows the frequency distribution and percentage of antibiotic literacy levels among students (categorized as low, moderate, and high) in each grade level (VII, VIII, and IX) before and after the multimodal learning intervention.

In the pre-test phase (O_1), the majority of students in all grade levels were in the low literacy category. Grade VIII had the highest proportion in the low category (100%), followed by grade IX (93.3%) and grade VII (85.7%). A small proportion of students in grade VII (14.3%) and grade IX (6.7%) were classified as having moderate literacy. No students in any grade level achieved high literacy before the intervention was implemented.

After the intervention (post-test/O_2), there was a significant increase in the level of antibiotic literacy. All students in grade VII (100%) achieved a high level of literacy. In grades VIII and IX, the majority of students (66.7% each) also achieved high literacy, while the rest (33.3%) were in the moderate category. No students were in the low literacy category in any grade level after the intervention, indicating the overall effectiveness of the multimodal learning approach.

Table 4. Results of the Effect Test (Cohen's d) of Multimodal Learning Intervention on Antibiotic Literacy Based on Grade Level

Grade	Mean Difference	Std. Deviation	N	Cohen's d	Interpretati
VII	7.43	1.91	14	***3.89***	Very Large Effect
VIII	9.00	1.94	18	***4.64***	Very Large Effect
IX	8.80	2.37	15	***3.72***	Very Large Effect

Table 4 summarizes the effect sizes (Cohen's d) of the multimodal learning intervention on antibiotic literacy among seventh, eighth, and ninth grade students. Cohen's d values were calculated based on the difference between the pretest and posttest scores divided by the standard deviation of the difference.

The results of the analysis indicate that this intervention had a very large effect on all grade levels.

1. Grade VII showed an average difference of 7.43 with a standard deviation of 1.91, resulting in a Cohen's d value of 3.89.
2. Grade VIII showed the highest effect size, with an average difference of 9.00 and a standard deviation of 1.94, resulting in a Cohen's d value of 4.64.
3. Grade IX had an average difference of 8.80 and a standard deviation of 2.37, with a Cohen's d value of 3.72.

Based on commonly used effect size thresholds (0.2 = small, 0.5 = moderate, and >0.8 = large), all classes experienced a **very large** effect size. This indicates that the multimodal learning strategy, which includes print modules, instructional videos, and role-playing, has a very significant impact on improving students' antibiotic literacy.

Table 5. Average Pretest and Posttest Scores of Students' Antibiotic Literacy Based on Grade Level

Grade Level	Pre-test Mean	Post-test Mean	Mean Difference
VII	5.57	13.00	7.43
VIII	2.56	11.56	9:00
IX	3.27	12.07	8.80
Total	3.68	12.15	8.47

Table 5 presents the average pretest and posttest scores for antibiotic literacy among students in grades VII, VIII, and IX after the implementation of an integrated multimodal learning approach. The data show a clear increase in scores across all grade levels after the intervention.

1. Students in grade VII experienced a significant increase, with the average score rising from 5.57 on the pretest to 13.00 on the posttest, showing an average difference of 7.43 points.
2. Eighth-grade students showed the highest improvement, with the average pretest score increasing from 2.56 to 11.56, reflecting an average difference of 9.00 points.
3. Grade 9 students also showed meaningful progress, with scores increasing from 3.27 to 12.07, reflecting an average increase of 8.80 points.

Overall, the average score of all participants increased from 3.68 before the intervention to 12.15 after the intervention, resulting in an average difference of 8.47 points. These results indicate that the use of multimodal learning methods that integrate face-to-face learning, printed modules, instructional videos, and role-playing effectively improves students' understanding of antibiotic use and overall antibiotic literacy.

DISCUSSION

This study explores the effectiveness of multimodal learning in improving antibiotic literacy among junior high school students in Jeneponto District, an area facing significant public health challenges related to antibiotic misuse and antimicrobial resistance (AMR). The findings of this research reveal important insights into students' basic knowledge, misconceptions, behavioral patterns, and the transformative impact of interactive educational interventions.

The Effectiveness of Multimodal Learning in Improving Antibiotic Literacy in Jeneponto

This study explores the effectiveness of multimodal learning in improving antibiotic literacy among junior high school students in Jeneponto District, an area facing significant public health challenges related to antibiotic misuse and antimicrobial resistance (AMR). The findings reveal important insights into students' prior knowledge, common misconceptions, risky behavior patterns, and the positive impact of interactive educational interventions.

- *Student Behavior and Misconceptions Regarding Antibiotic Use*

The results of the study indicate the spread of misconceptions and risky antibiotic use among students. A total of 42.55% of respondents disagreed or strongly disagreed with the statement that antibiotics should only be used based on a prescription from a medical professional. This reflects a low level of awareness regarding the rational use of antibiotics and a tendency toward normalization of self-medication among adolescents.

In addition, 53.19% of students believe that they can obtain antibiotics without a doctor's prescription. This finding not only shows a weak understanding of regulations on antibiotic use but also highlights the ease of access to antibiotics without a prescription in Indonesia. Furthermore, 51.06% of respondents agreed with the statement that stopping antibiotic consumption when feeling better is an acceptable practice. Such practices have the potential to accelerate the development of antimicrobial resistance due to incomplete treatment. Only 12.77% of students in the survey strongly agreed that excessive use of antibiotics can be harmful to health. This percentage indicates a lack of understanding of the risks of antimicrobial resistance, which may be linked to low health literacy in rural areas.

This situation is exacerbated by limited access to sustainable health education. During data collection, it was also found that a number of students aged 15 to 16 were still in the eighth or ninth grade. This indicates a delay in starting or continuing formal education. Several factors contributing to this condition include poverty, minimal parental involvement in children's education, and children's involvement in domestic work and agriculture. These factors directly or indirectly limit students' access to health information and education.

The results of this study are in line with research conducted by Adeoya (2025), which revealed that the majority of students, both domestic and international, studying at various universities in Japan have low levels of health literacy. This study involved 1,366 respondents from six regions in Japan. The results showed that around 60% of students were in the "inadequate" health literacy category, while the remaining 32% were in the "problematic" category. Thus, overall, 92% of students demonstrated low levels of health literacy. These findings indicate that low understanding of health information is not limited to the general public but also extends to educated populations such as students, both local and international. This highlights that health literacy is a cross-cultural and cross-national issue that requires greater attention within higher education systems, particularly in addressing global challenges such as antimicrobial resistance and irrational self-medication.

- *Antibiotic Literacy Levels Before Intervention*

Before the intervention was implemented, the majority of students (**89.4%**) were in the low literacy category, with none classified in the high category. Eighth-grade students showed the lowest performance (**100% low literacy**), followed by ninth grade (**93.3%)** and seventh grade (**71.4%)**. The low level of antibiotic literacy among students, as indicated by 89.4% of respondents who were in the low literacy category before the intervention, reflects fundamental problems in the education system and access to health information. The absence of any students in the high literacy category, as well as the lowest performance shown by students from all grade levels, indicates that advancing to higher grades does not automatically lead to improved understanding of health issues, particularly the use of antibiotics.

This phenomenon shows a significant educational gap, which is likely caused by several factors, such as the lack of integration of health material in the formal curriculum, teaching methods that are not contextual or applicable, and minimal training for teachers in conveying contemporary health issues. Additionally, limited access to accurate health information, low parental involvement in children's education, and uneven community-based educational interventions exacerbate this situation, especially in areas with limited educational infrastructure.

- *Effectiveness of Multimodal Learning*

This study provides strong evidence that a multimodal learning approach significantly improves students' antibiotic literacy across various grade levels. Following the implementation of the intervention, there was a statistically significant increase in post-test scores ($p < 0.001$) across all grade levels, with the majority of students shifting from the low literacy category to the moderate or high levels. The multimodal approach, which combines visual, auditory, textual, and kinesthetic elements, has proven effective in deepening conceptual understanding while enhancing students' memory retention. The effectiveness of this method aligns with previous research findings ( ) highlighting the importance of multisensory learning in improving students' learning outcomes (Ismi & Witasoka, 2025; Tian & Lei, 2025; Wang et al., 2025).

From a microbiological perspective, this increase in literacy reflects students' better understanding of how antibiotics work at the molecular level. Students demonstrated improved ability in recognizing the mechanisms of antibiotic action, such as β-lactams that inhibit bacterial cell wall synthesis, macrolides that disrupt protein synthesis, particularly in *Mycobacterium tuberculosis*, and fluoroquinolones that target topoisomerase enzymes and inhibit DNA replication in *Escherichia coli.*

Additionally, this increase in knowledge is associated with a decrease in risky behaviors that could potentially accelerate the development of antimicrobial resistance (AMR) (Nhestricia et al., 2025; Daneshi et al., 2025; Tran et al., 2025). Students' understanding of the spread of resistant genes through horizontal gene transfer mechanisms, such as conjugation and plasmid exchange, provides a strong scientific basis for behavioral changes that support the prudent use of antibiotics (Kallu et al., 2024; Jianvitayakij et al., 2024; Masadeh et al., 2025).

The effect size of the intervention, measured using Cohen’s d, as presented in Table 4, shows a very large impact on improving antibiotic literacy in all three grade levels (VII, VIII, and IX). Cohen’s d values for each grade far exceed the standard threshold for large effects (>0.8), with scores above 3.7 in all grades. This confirms that the multimodal learning strategy integrating print modules, educational videos, and role-playing games is highly effective in enhancing students’ understanding of antibiotic use.

Grade VIII recorded the highest increase in antibiotic literacy with a Cohen's d value of 4.64, indicating the success of the intervention at that level. Grades VII and IX also experienced significant increases with effect values of 3.89 and 3.72, which may have been influenced by differences in cognitive readiness, learning motivation, and how students absorbed the material in each class.

The results of this study are in line with the literature which states that multimodal learning can effectively improve health literacy because it accommodates various learning styles, such as visual, auditory, and kinesthetic, thereby strengthening understanding and memory of the material (Ketaren et al., 2025; Amelia et al., 2025). Additionally, these findings support constructivist learning theory, which emphasizes the importance of active student engagement in the learning process through interaction and real-life simulations, as exemplified in role-playing games and educational videos (Azzahra et al., 2025).

In practical terms, the results of this study indicate that the implementation of multimodal learning is an effective strategy for improving antibiotic literacy. This improvement in literacy has the potential to reduce inappropriate antibiotic use and reduce the risk of antimicrobial resistance among adolescents. Therefore, this learning method is highly recommended for integration into the health education curriculum in secondary schools to strengthen education on the appropriate and responsible use of antibiotics.

CONCLUSION

The initial level of antibiotic literacy among junior high school students in Jeneponto District is generally low, with the majority of students in all grade levels categorized as having low literacy levels, especially in grade VIII. This study also revealed widespread misconceptions and risky behaviors related to antibiotic use, including the belief that antibiotics can be purchased without a prescription and the tendency to stop taking antibiotics when feeling better, accompanied by low awareness of the dangers of excessive antibiotic use. Multimodal learning interventions significantly improved students' antibiotic literacy, as evidenced by a marked increase in posttest scores and a shift of students from the low category to the moderate and high categories, with no students remaining in the low category after the intervention. Interactive learning methods, particularly educational videos and role-playing games, proved highly effective in improving students' understanding and engagement. These findings underscore the importance of integrating diverse and engaging educational strategies into school curricula to address antibiotic misuse and contribute to efforts to prevent antimicrobial resistance.

REFERENCES

Abubakar, U., Al-Anazi, M., & Rodríguez-Baño, J., 2023. Impact of COVID-19 pandemic on multidrug resistant gram positive and gram negative pathogens: A systematic review. *Journal of Infection and Public Health*, 16(3): 320–331.

Adeoya, A.A., 2025. Exploring health literacy among Japanese and international university students in Japan: A comparative cross-sectional study. *Journal of Migration and Health*, 100334.

Aggarwal, R. et al., 2024. Antibiotic resistance: a global crisis, problems and solutions. *Critical Reviews in Microbiology*, 50(5): 896–921.

Ahmad, I., Malak, H.A., & Abulreesh, H.H., 2021. Environmental antimicrobial resistance and its drivers: a potential threat to public health. *Journal of Global Antimicrobial Resistance*, 27: 101–111.

Akhila, P., Christabel, S., & Alva, J., 2025. Antibiotics awareness: exploring the knowledge and attitude towards the usage and resistance among non-health professional students. *Critical Public Health*, 35(1): 2500114.

Amelia, R., Izzah, S.N.R., Hikmah, M.A., & Bakar, M.Y.A., 2025. Understanding students' learning styles: The key to successful personalized learning. *Jurnal Ilmiah Nusantara*, 2(1): 287–300.

Angelillo, S. et al., 2025. Exploring knowledge, attitudes, and behaviors toward antibiotic use among adolescents in Southern Italy. *Microorganisms*, 13(2): 290.

Azzahra, N.T., Ali, S.N.L., and Bakar, M.Y.A., 2025. Constructivism Theory in the World of Learning. Research Student Journal, 2(2): 64-75.

Bawazir, A. et al., 2025. Knowledge, attitude, and practice toward antibiotic use and resistance among non-medical university students, Riyadh, Saudi Arabia. *International Journal of Environmental Research and Public Health*, 22(6): 868.

Chambers, H.F. & Fowler, V.G., 2024. Intertwining clonality and resistance: *Staphylococcus aureus* in the antibiotic era. *The Journal of Clinical Investigation*, 134(19).

Chetri, S., 2025. *Escherichia coli*: An arduous voyage from commensal to antibiotic resistance. *Microbial Pathogenesis*, 198: 107173.

Chung, P.Y., 2025. One Health strategies in combating antimicrobial resistance: a Southeast Asian perspective. *Journal of Global Health*, 15: 03025.

Daneshi, S. et al., 2025. Prevalence and contributing factors of drug-resistant tuberculosis (DR-TB) in Iran: A systematic review. *BMC Infectious Diseases*, 25(1): 1–14.

Drymiotou, I. et al., 2025. Open schooling to raise student awareness and engagement: The case of tackling antimicrobial resistance. *Journal of Biological Education*, 1–24.

Gani, Z., Kumar, A., Raje, M., & Raje, C.I., 2025. Antimicrobial peptides: An alternative strategy to combat antimicrobial resistance. *Drug Discovery Today*, 104305.

Ismi, R. & Witasoka, D., 2025. The influence of multisensory effects on learning outcomes and student engagement in inclusive " " learning. *Pendiri: Journal of Educational Research*, 2(2): 89–97.

Jee, Y. et al., 2018. Antimicrobial resistance: A threat to global health. *The Lancet Infectious Diseases*, 18(9): 939–940.

Jianvitayakij, S. et al., 2024. Knowledge of antibiotics and antibiotic resistance, antibiotic use and eHealth literacy among nursing students in Thailand: A cross-sectional study. *BMJ Open*, 14(11): 090956.

Kallu, S.A. et al., 2024. Knowledge, attitudes, practices, and risk perception of antimicrobial use and antimicrobial resistance among dairy farm owners/workers in Addis Ababa, Ethiopia. *Infection and Drug Resistance:* 1839–1861.

Ketaren, M.A., Purba, Y.A., Siagian, E.A., & Siregar, A., 2025. The use of animation-based educational videos in improving elementary school students' memory. *Jurnal Pendidikan Inovatif*, 7(3).

Maeda, M. & Yamaguchi, K., 2025. Impact of education on antibiotic literacy and awareness among pharmacy students at a Japanese university: A questionnaire survey. *Journal of Pharmaceutical Health Care and Sciences*, 11(1): 12.

Masadeh, M., Harun, S.N., Mukattash, T., & Alrabadi, N., 2025. Parental knowledge and attitudes towards antibiotic resistance in children: A review article. *Current Pediatric Reviews*.

Meriyani, H., Sanjaya, D.A., & Adrianta, K.A., 2021. Antibiotic consumption and resistance pattern of 3 coagulase-negative *Staphylococci* species: An ecological study. *Indonesian Journal of Pharmacy*, 32(2): 251–257.

Michalik, M., Podbielska-Kubera, A., & Dmowska-Koroblewska, A., 2025. Antibiotic resistance of *Staphylococcus aureus* strains searching for new antimicrobial agents. *Pharmaceuticals*, 18(1): 81.

Mulyati, S., Iskandar, I., Nurjanah, S., & Agustianingsih, D., 2025. Analysis of multimodal learning and learning skills and their influence on digital literacy competencies of students. *Equilibrium: Journal of Education and Economics Research*, 22(2): 259–269.

Munita, J.M. & Arias, C.A., 2016. Mechanisms of antibiotic resistance. *Virulence Mechanisms of Bacterial Pathogens:* 481–511.

Ng, Q.X. et al., 2023. Trends in *Pseudomonas aeruginosa* bacteremia during the COVID-19 pandemic: A systematic review. *Antibiotics*, 12(2): 409.

Nhestricia, N. et al., 2025. Analysis of public knowledge related to antibiotic usage and its impact on antibiotic resistance. *FITOFARMAKA: Jurnal Ilmiah Farmasi*, 15(1): 19–29.

Oktariza, Y., 2025. Public knowledge and awareness of appropriate antibiotic use in Indonesia: A review of regional patterns and misconceptions. *Pharmacy Reports*, 5(1): 70–100.

Poudel, A.N. et al., 2023. The economic burden of antibiotic resistance: A systematic review and meta-analysis. *PLoS ONE*, 18(5): 0285170.

Sellberg, C. & Sharma, A., 2025. Toward multimodal learning analytics in simulation-based collaborative learning: A design ethnography of maritime training. *International Journal of Computer-Supported Collaborative Learning*, 20(2): 201–221.

Sharma, G. et al., 2025. Knowledge, attitude, and practice on antibiotic use and resistance among undergraduates, Pokhara Metropolitan, Nepal. *BioMed Research International*, 2025(1): 9928264.

Sinuraya, R.K. et al., 2023. Understanding public knowledge and behavior regarding antibiotic use in Indonesia. *Infection and Drug Resistance:* 6833–6842.

Sulistiyawati, I., Wahyono, D.J., & Siswandari, W., 2024. Biofilm production by antibiotic-resistant *Klebsiella pneumoniae* strains. *BioWallacea: Journal of Biological Research*, 11(2): 154–166.

Tran, T.T.T. et al., 2025. Knowledge, behaviors, and treatment associated with sexually transmitted diseases: A one-group pretest-posttest study among Vietnamese patients. *The Open Public Health Journal*, 18(1).

Wang, M. et al., 2025. 2D piezo-ferro-opto-electronic artificial synapse for bio-inspired multimodal sensory integration. *Advanced Materials*, 2500049.

Xiong, X.S. et al., 2024. Identification of *Mycobacterium tuberculosis* resistance to common antibiotics: An overview of current methods and techniques. *Infection and Drug Resistance*, 1491–1506.

Yuan, Y., Li, Z., & Zhao, B., 2025. A survey of multimodal learning: Methods, applications, and future. *ACM Computing Surveys*, 57(7): 1–34.

Zhang, X., Guo, Y., & Huang, Y., 2021. The impact of COVID-19 on education: Shifts to remote learning and implications for health literacy. *Educational Technology Research and Development*, 69(2): 1867–1885.