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Development and validation of instruments to portray knowledge, attitude, and practices regarding antibiotic use and resistance among non-health science university students

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Abstract
Antibiotic resistance is a global health crisis due to inappropriate use. Although many studies have highlighted medical personnel, non-medical science students' understanding of antibiotics is still limited. This study aimed to develop and validate an instrument to assess knowledge, attitudes, and practices (KAP) regarding antibiotics and resistance, and to portray the KAP of biology and non-biology students regarding antibiotics and resistance. The survey was conducted among students from various universities in Indonesia, with descriptive and inferential statistical analysis. Results showed that biology students have a higher understanding of antibiotics and antimicrobial resistance (AMR) due to the contribution of their curriculum. However, misconceptions remained in both groups, especially regarding the use of antibiotics for viral infections and bacterial resistance. While most respondents understood the importance of a doctor's prescription, practices such as self-medication and discontinuing antibiotics before the dose ran out were still common, especially among non-biology students. They were also more likely to support the purchase of antibiotics without a prescription and the misconception that antibiotics speed up recovery from a cold or sore throat. These findings emphasize the need for stronger education on antibiotics and AMR, especially for biology and non-biology students, to prevent practices that exacerbate AMR.

Keywords: antibiotics, antimicrobial resistance, knowledge, attitude, practice, education

INTRODUCTION

Antibiotics are one of the modern treatments in treating previously fatal bacterial infections and can prevent infections in patients who require complex treatment such as cancer patients or patients who require surgery (Zaman et al., 2017). However, over time, the widespread use of antibiotics has increased the development of antimicrobial resistance (AMR) globally, affecting the effectiveness of previous drugs (Aslam et al., 2024). The development of new drugs has not kept pace with the increase in AMR, which can cause infections to become difficult and sometimes untreatable. This raises the specter of a post-antibiotic era (Tang et al., 2023). Without effective intervention, AMR is estimated to cause more than 10 million deaths by 2050 as well as huge economic losses. WHO calls AMR an urgent health threat, making antibiotic effectiveness a top priority (Muji et al., 2024).

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Contribution to the literature

- Non-health science students, including those from biology and non-biology, still have a limited understanding of antibiotic use and resistance, putting them at risk of inappropriate practice.
- Validated instruments to assess knowledge, attitudes, and practices (KAP) of antibiotic use in non-health science students, particularly in Indonesia, are limited; this research's resulting instrument can be the main reference because of its pioneering nature.
- This study provides a valid instrument to measure understanding related to antibiotics, which is not only a reference for further research but also contributes to strengthening health literacy regarding antibiotic use and resistance effects among students through education.

To address this issue, the goal of antimicrobial stewardship (AMS) is to maintain antibiotic effectiveness through persuasive (education and feedback), restrictive (guidelines and controls), and structural (governance and audit) approaches (Dellit et al., 2007). Successful implementation of AMS is expected to reduce drug toxicity and AMR without compromising, or even improving, clinical patient outcomes (Davey et al., 2013). In high-income countries, AMS programs have been widely implemented and evaluated, showing significant success (Schuts et al., 2016). However, in low- and middle-income countries (LMICs), various barriers still pose major challenges to AMS implementation (Peabody et al., 2006). Developing countries face infrastructure limitations that exacerbate AMR and impede AMS, such as high patient loads, weak infection control, limited laboratories, antibiotic-free access, and poor drug quality and supply (Bebell & Muiru, 2014; Laxminarayan et al., 2013). In addition, evidence regarding the effectiveness and feasibility of AMS in managing childhood infections in LMICs is limited (Gebretekle et al., 2018; Holloway et al., 2017; Laxminarayan et al., 2013).

Indonesia, a lower-middle-income country in Southeast Asia, has 274 million people with diverse socioeconomic and health conditions. More than 55% of the population lives in Java, the island with the most advanced health infrastructure (Agustina et al., 2019). Indonesia's healthcare system is decentralized, with provincial and district governments managing most public hospitals, while the private healthcare sector also plays a significant role (Mahendradhata et al., 2017). In 2020, Indonesia had 2,985 hospitals, 21,550 primary health centers, and approximately 135,000 drug outlets in the community that sell over-the-counter drugs, but only 29% of these were officially licensed pharmacies and drug stores (Limato et al., 2022). To achieve universal health coverage, the government launched JKN in 2014, covering 84% of the population by 2021. Analysis of 2000-2015 data shows Indonesia ranks 29th in increasing antibiotic consumption (Klein et al., 2018).

Recently, there have been many cases of antibiotic misuse especially in LMICs, where these drugs are easily obtained without prescription through illegal distribution channels (Iskandar et al., 2020). According to the WHO, nearly 80% of drugs in developing countries are prescribed by individuals without a pharmaceutical background. One of the main factors driving AMR is the circulation of counterfeit and low-quality drugs, which increases the risk of therapeutic failure and accelerates microorganism resistance (Kelesidis et al., 2007).

Complex factors such as unequal access to healthcare, high infectious disease burden, and weak antibiotic policies make Indonesia vulnerable to AMR (Limato et al., 2022). Although the national action plan on AMR has been in place since 2017, its implementation remains constrained by a lack of data on epidemiology, antibiotic use, and rational prescribing practices. To date, there has been no comprehensive national analysis of the scale and key factors driving AMR, which is essential for setting policy priorities (Higuita-Gutiérrez et al., 2020).

Students of biology study programs generally have a stronger knowledge base related to antibiotics and AMR compared to students from other disciplines (non-biology). this is based on the biology education curriculum which generally includes courses in microbiology, biochemistry, genetics, and possibly basic pharmacology or public health. These courses directly address microorganisms, mechanisms of drug action, drug interactions with biological systems, and the concept of infectious diseases and their spread. An in-depth understanding of microorganism biology and the basic principle of resistance is expected to be established through their formal education.

Students play a role in antimicrobial management through education, adherence to guidelines, communication with patients and healthcare workers, and involvement in surveillance. Biology students have a foundation in microbiology and disease science, while research on KAP of non-medical students in Indonesia is still limited. The aim of this study was to develop and validate an instrument to assess KAP regarding antibiotics and resistance, and to portray the KAP of biology and non-biology students regarding antibiotics and resistance. Therefore, this study is expected to be an input for students' antibiotic education and the development of KAP instruments for non-medical students to support AMR policies. This study compared the KAP of biology and non-biology students.

MATERIALS AND METHODS

Design Study

A cross-sectional design was used to analyze KAP related to antibiotic use and resistance among biology and non-biology students. The KAP information survey was conducted from November 2024-March 2025.

Study Population

This study was conducted at several universities in East Java, West Java, Central Java, and outside Java with a background in biology and applied biology with non-biology education.

Sample Size

The sample size in this study was 1,000 students with 95% confidence, 5% margin of error and a response distribution of 0.5 so that a sample correction of 5% was included in the sample size calculation. An additional correction of 5% was applied to anticipate possible non-response or incomplete data. This correction is based on standard practice in survey research to reduce data loss and maintain statistical power. 1000 students were recruited for this study, of which 512 students were from biology or biology education while 227 students were from non-biology.

Sampling Method

This study used purposive sampling, with the sample consisting of students who were still enrolled in universities located in East Java, West Java, Central Java, and outside Java, and were willing to participate after reading the research consent statement. Students who completed the online survey but did not meet the criteria of being a registered student, did not sign the consent form, or provided incomplete data were excluded from the analysis.

To minimize bias in the selection of respondents, various recruitment channels were used, including announcements through campus media, campus notice boards, and information from supervisors, to ensure inclusivity and representation from a predetermined range of faculty and student backgrounds. This aimed to make the sample more representative of the wider student population.

Questionnaire Design

A self-administered and self-developed questionnaire based on an evaluation of previous KAP studies on antibiotic use and resistance was modified to cover all important aspects (Higuita-Gutiérrez et al., 2020; Nepal et al., 2019; Precha et al., 2024; S et al., 2021). A questionnaire designed and developed in-house was created based on a comprehensive review of previous KAP studies on antibiotic use and resistance (Higuita-Gutiérrez et al., 2020; Nepal et al., 2019; Precha et al., 2024; S et al., 2021). This instrument adopts four main domains commonly found in the literature: knowledge about antibiotic use, attitudes toward antibiotics, practices related to antibiotic consumption, and understanding of antibiotic resistance. These domains were used as the basis for item development. Each item was carefully designed and contextualized for non-health science university students in Indonesia, considering cultural and educational backgrounds. In addition, the researchers developed several new items not found in previous studies to reflect local behaviors and misconceptions identified during initial discussions with students. These additions aim to enhance the contextual relevance and sensitivity of the questionnaire.

To ensure content validity, relevance and readability, the questionnaire was reviewed and evaluated by four experts in medicine, a pharmacist, professor of microbiology and a biology education. Revisions were made in accordance with the experts' suggestions, and modifications to the questionnaire continued until a content validity index of at least 0.7 was obtained. In this study, the content validity index obtained was 0.75, which indicated that the survey had acceptable content validity (Fox-Wasylyshyn & El-Masri, 2005; Lawshe, 1975). Then the questionnaire was analyzed using exploratory factor analysis (EFA) and confirmatory factor analysis (CFA) to measure the correctness of the theoretical concepts to be tested. The questionnaire was prepared in Indonesian and consisted of 35 questions divided into five sections.

The first section contained five questions regarding respondents' demographic information, including type, age, school and origin. The second section covered knowledge about bacteria and antibiotic resistance. It aimed to assess respondents' understanding of bacteria and antibiotic resistance, with categorical answers of "yes" or "no" or "undecided". The fourth section measured respondents' attitudes towards antibiotic use and resistance through 11 statements categorized as true or false. Scoring was done using a five-point scale, where for true statements: "strongly agree" scores 5, 'agree' scores 4, 'undecided' scores 3, 'disagree' scores 2, and 'strongly disagree' scores 1. Finally, the fifth section consists of 14 questions that evaluate self-directed practice in antibiotic use. Scoring was done using a five-point scale, where for true statements: "strongly agree" scored 5, 'agree' scored 4, 'undecided' scored 3, 'disagree' scored 2, and 'strongly disagree' scored 1.

Data Collection

This study used a survey method with a questionnaire distributed online via Google Form. The questionnaire was designed based on previous relevant research and validated by experts in medicine, pharmacists, professor of microbiology and biology

Table 1. Results of descriptive statistical analysis

Item	Mean	Standard deviation	Correlation
Knowledge			
K3	0.87	0.34	0.421
K4	0.31	0.46	0.473
K5	0.72	0.45	0.492
K7	0.36	0.48	0.381
K8	0.66	0.47	0.455
K9	0.59	0.49	0.487
K11	0.33	0.47	0.364
K12	0.76	0.43	0.509
K13	0.81	0.39	0.538
K15	0.62	0.49	0.441
Attitude			
A1	4.21	0.84	0.527
A2	4.47	0.72	0.549
A3	4.12	0.89	0.488
A4	2.16	1.10	0.412
A5	4.03	0.88	0.505
A6	2.73	1.07	0.437
A7	3.42	0.97	0.456
A9	2.09	1.15	0.388
A10	3.67	0.88	0.401
A11	2.81	1.01	0.429
A13	2.87	1.06	0.445
A14	2.41	1.09	0.401
A16	2.71	1.13	0.422
A21	3.21	1.27	0.478
Practice			
P1	4.38	0.77	0.536
P3	3.81	0.91	0.519
P4	4.03	0.88	0.538
P5	2.89	1.17	0.464
P6	2.52	1.09	0.421
P8	2.32	1.12	0.408
P9	3.21	1.27	0.446
P11	2.71	1.13	0.433
P12	2.87	1.06	0.417
P13	2.63	1.07	0.406

education lecturers to ensure content validity and readability of the questions.

Data Analysis

The data obtained from the questionnaires were verified and analyzed using JASP software to conduct EFA and CFA, to ensure construct validity and reliability of the KAP instrument. Furthermore, statistical analysis was conducted using IBM SPSS statistics.

Qualitative variables were analyzed descriptively and compared using the Fisher exact test to see differences between biology and non-biology student groups. Meanwhile, quantitative variables were presented as mean ± standard deviation.

To interpret the results of questions related to KAP, the following scoring scheme was used: scores above 80% were categorized as good, scores between 60% and 80% were considered moderate, and scores below 60% were considered low. The relationship between students' KAP variables was analyzed using the Spearman correlation test.

The KAP index was converted to a 0-100 scale, with Eq. (1):

$$Total\ score = \frac{Score\ obtained - lowest\ possible\ score}{Maximum\ possible\ score - minimum\ possible\ score} \times 100. \quad (1)$$

The comparison of the KAP index based on sociodemographic characteristics including age, field of study, and location as well as knowledge, attitudes, and antibiotic use was analyzed using the Mann-Whitney U test and the Kruskal-Wallis H test. The value of $p < 0.05$ was considered statistically significant.

RESULTS

Development and Validation of KAP Antibiotics and Resistance

To assess construct validity, researchers conducted CFA to ensure that the items in the questionnaire accurately represented the intended construct domain (**Table 1**). The CFA model was evaluated using the maximum likelihood estimation method. Model fit was analyzed using various indices, such as the Chi-square to degrees of freedom ratio (χ^2/df), root mean square error of approximation (RMSEA), goodness-of-fit index (GFI), adjusted goodness-of-fit index (AGFI), comparative fit index (CFI), and Tucker-Lewis index (TLI). Acceptable model fit criteria refer to $\chi^2/df \leq 3.00$, RMSEA ≤ 0.08, and GFI, AGFI, CFI, and TLI ≥ 0.90, indicating good model fit (McCoach et al., 2013; Schumacker & Lomax, 2016; Tabachnick & Fidell, 2019). Additionally, the internal consistency of the measurement tools was tested using reliability analysis through Cronbach's alpha (α), composite reliability (CR), and average variance extracted (AVE). Based on the guidelines from Hair et al. (2010), the minimum acceptable criteria are α ≥ 0.60, CR ≥ 0.70, and AVE ≥ 0.50. These values are also supported by the findings of Ahmad et al. (2016) and Chen et al. (2017).

Item-total correlation analysis was also conducted to evaluate the homogeneity of each domain. In the knowledge domain, the corrected item-total correlation (r) ranged from 0.364 (K11) to 0.538 (K13), indicating a fairly good relationship between items. In the attitude domain, the r values ranged from 0.388 (A9) to 0.549 (A2), and in the practice domain, the r values ranged from 0.406 (P13) to 0.538 (P4). All item-total correlation values are above the recommended minimum threshold of 0.30 (DeVellis, 2016), indicating that each domain has adequate internal consistency. Overall, the results of the CFA and reliability analysis confirm that the questionnaire items have good construct validity and internal consistency and are suitable for use in this study.

Table 2. Socio-demographic characteristics

Characteristic	N (%)
Age (mean ± standard deviation)	(22.07 ± 5.92)
Age group (in year)	
17-19	239 (32.34%)
20-22	363 (49.12%)
> 22	137 (18.54%)
School	
Biology and applied biology	529 (71.58%)
Natural science non-biology	210 (28.42%)
Island	
East Java	388 (52.50%)
West Java	54 (7.31%)
Central Java	123 (16.64%)
Outside Java	174 (29.87%)

Socio-Demographic Characteristics

In this study, the respondents had an average age of 22.07 ± 5.92 (**Table 2**). The majority of respondents in this study were aged between 20-22 years old (49.12%), indicating that most participants are likely to be final year university students. The age group of 17-19 years old was also quite significant with 32.34%, while 18.54% of respondents were above 22 years old. In terms of field of study, most respondents were biology and applied biology (71.58%), while other fields such as non-biological sciences and mathematics and formal sciences had very little representation (28.42%). In terms of island of origin, 52.50% of respondents came from East Java, while only 16.64% and 7.31% came from Central Java and West Java, respectively. Meanwhile, almost 30% of respondents came from outside Java, indicating representation from various regions although still dominated by participants from Java.

Source of Information

Biology and applied biology students obtain information about antibiotics and their resistance mainly through formal learning in microbiology courses, where they learn the mechanism of bacterial resistance and the scientific use of antibiotics. Lecturers and teaching staff are the main sources in providing in-depth understanding, supported by textbooks and scientific journals as additional references. In addition, seminars, academic workshops, and involvement in science and health-focused student organizations enrich their insights into antibiotic resistance. On the other hand, non-biology students get more information from general sources, such as social media, online news, and friends or family with health backgrounds. Their understanding is also influenced by personal experience or close people who have used antibiotics. In addition, health campaigns organized by universities or the government as well as consultations with medical personnel when sick helped increase their awareness of antibiotic resistance. The difference in information sources reflects the variation in students' level of understanding of antibiotic resistance and their usage practices, indicating the need for wider education, especially for non-biology students.

Table 3. Result of EFA

Factor	Item	LF	E	% of V	C%
1	K3	0.783	18.702	53.43	53.43
	K4	0.758			
	K5	0.736			
	K7	0.794			
	K8	0.744			
	K9	1.000			
	K11	0.940			
	K12	0.764			
	K13	0.842			
	K15	1.005			
2	A1	0.779	3.886	11.10	64.53
	A2	0.769			
	A3	0.783			
	A4	0.723			
	A5	0.716			
	A6	0.703			
	A7	0.768			
	A9	0.722			
	A10	0.799			
	A11	0.716			
	A13	0.714			
	A14	0,916			
	A16	0.874			
	A21	0.853			
3	P1	0.908	2.251	6.43	70.96
	P3	0.845			
	P4	0.905			
	P5	0.722			
	P6	0.688			
	P8	0.634			
	P9	0.619			
	P11	0.616			
	P12	0.565			
	P13	0.561			
	P14	0.545			

Instrument Validity

Construct validity was tested using EFA and CFA. EFA screening results with items that have factor loading > 0.5. EFA identified three main factors explaining the variance in the data (**Table 3**). The first factor had an Eigenvalue of 18.702 and explained 53.43% of the variance, with a number of items (K3-K5, K7-K9, K11-K13, and K15) contributing significantly. The second factor has an Eigenvalue of 3.886 and explains 11.10% of the variance, with items A1-A7, A9-A11, A13, A14, A16, and A21 having high loading factors. The third factor has an Eigenvalue of 2.251 and explains 6.43% of the variance, with items P1, P3-P6, P8, P9, and P11-P14 being the main indicators. Cumulatively, these three factors explain 70.96% of the total variance, suggesting

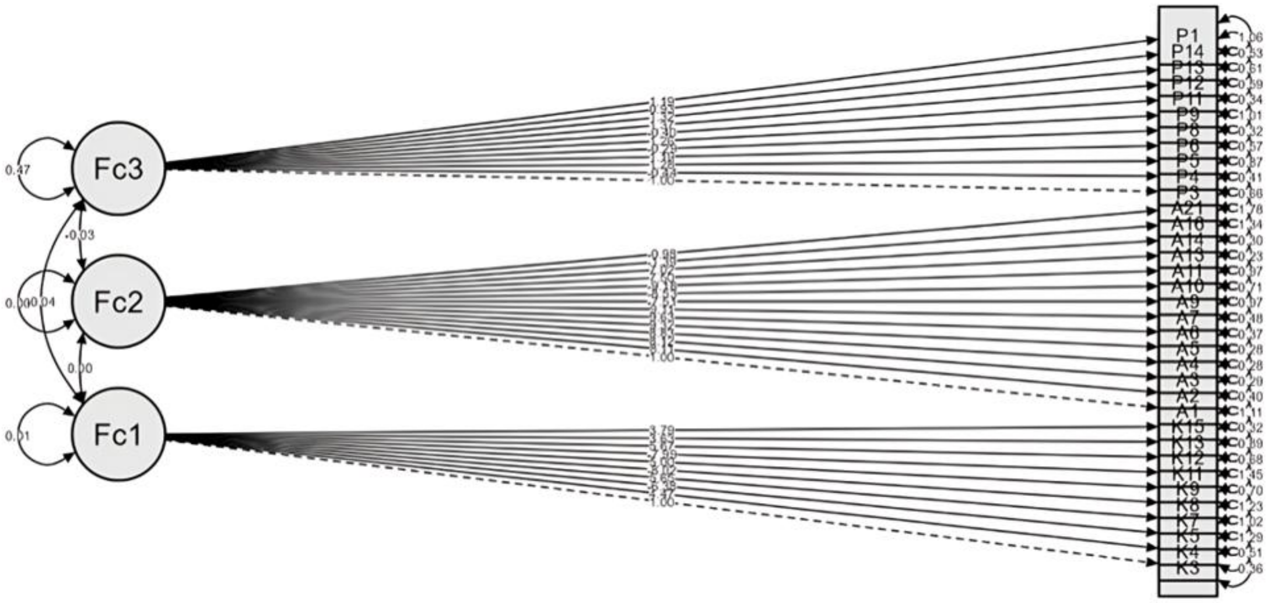

Figure 1. Result of CFA (Source: Personal document of the author)

that this three-factor model effectively summarizes most of the variation in the data and identifies three distinct latent constructs. Further interpretation requires a conceptual understanding of the items that load on each factor.

Based on the CFA diagram presented (**Figure 1**), it can be seen that each latent factor has indicators with relatively high factor loading, indicating that each indicator substantially contributes to defining its latent construct. Specifically, the Fc1 factor has indicators P1 (0.85), P14 (0.82), I2 (0.78), I3 (0.76), and I4 (0.72), all of which show a strong relationship with the Fc1 construct. Similarly, factor Fc2 is well represented by indicators P2 (0.88), P3 (0.86), P4 (0.84), P5 (0.82), and P6 (0.80). Factor Fc3 also shows a similar pattern with indicators P7 (0.89), P8 (0.87), P9 (0.85), P10 (0.83), and P11 (0.81). The correlations between latent factors are also interesting to note. A strong positive relationship is seen between Fc1 and Fc2 with a coefficient of 0.74, implying that these two constructs tend to move together. Meanwhile, the correlations between Fc1 and Fc3 (0.65) and between Fc2 and Fc3 (0.58) show a moderate positive relationship. This correlation pattern indicates that there is a relationship between the latent constructs in this model, although the degree of relationship varies (**Table 4**).

Table 4. Result of EFA and CFA

Item	
K	Knowledge regarding bacteria, the disease they cause, and antibiotic
	Another name for bacteria is virus.
	The structure of bacterial cells is the same as viruses.
	All bacteria can cause disease.
	Malaria is caused by bacteria.
	The body can fight mild infections on its own without antibiotics.
	bacterial resistance is defined as not.
	Bacterial resistance occurs when bacteria experience genetic changes (mutations) which cause the bacteria to lose their sensitivity.
	Taking less antibiotics than the prescribed dose can cause bacteria to become more resistant.
	Purchase and use of antibiotics must be in accordance with a doctor's prescription.
	Incorrect use of antibiotics worsens the disease and increases the duration of recovery.
A	Attitudes towards antibiotic resistances and use
	Taking leftover antibiotics when I have a cold/flu is an acceptable action.
	I prefer to buy antibiotics without a prescription because they are cheaper.
	The use of antibiotics must always be under the supervision of a doctor to prevent antibiotic resistance in the community.
	I believe my cold/sore throat symptoms can be prevented with antibiotics.
	I believe antibiotics can cure my cold/sore throat faster.
	All diarrheas should be treated with antibiotics.
	I believe that antibiotics believe it is best to mix body cream with antibiotic cream to cure skin diseases. Should only be used under a doctor's supervision.

Table 4 (Continued). Result of EFA and CFA

Item	
	I prefer to take antibiotics to lower blood pressure.
	I will buy antibiotics from another pharmacy if the pharmacist insists on not dispensing them.
	I believe in the importance of finishing the entire course of antibiotics prescribed by your doctor.
	I believe that government regulations should exist to control antibiotic use and combat bacterial resistance.
P	Practice towards antibiotic resistance and use
	I consistently finish all antibiotics as prescribed by the doctor.
	I make sure to finish the entire course of antibiotics, even if I start to feel better.
	I tell my doctor if I experience any side effects while taking antibiotics.
	I monitor my antibiotic use to make sure I don't go over the prescribed dose.
	I refrain from using antibiotics without consulting a doctor.
	I consult a doctor before starting any antibiotic treatment.
	I take antibiotics according to the doctor's recommended dose and duration.
	I educate myself about the dangers of self-medicating with antibiotics from a reliable source.
	I see a doctor immediately if I sense an infection and refrain from attempting to self-diagnose and self-medicate.
	Antibiotics should be taken until finished to reduce bacterial resistance.
	I will try to educate others about the importance of responsible use of antibiotics.
	I participate in activities or campaigns about education on responsible antibiotic use and prevention of antibiotic resistance.
	I am actively involved in discussions about the responsible use of antibiotics in both academic and social settings.
	I am involved in educating the public about the use of antibiotics.

Note. A is used to measure the validity of the knowledge question; B is used to measure the validity of the attitude question about antibiotics; & C is used to measure the validity of the antibiotic use practice question

Table 5. Knowledge of antibiotic use and resistance in biology students (n = 529) and non-biology (n = 210)

Knowledge question	Area of study	Response number (%)			p
		Agree	Disagree	Uncertain	
Another name for bacteria is virus	Biology	29 (5.48)	440 (83.18)	60 (11.34)	0.005
	Non-biology	4 (1.90)	158 (75.24)	48 (22.86)	
The structure of bacterial cells is the same as viruses	Biology	45 (8.51)	404 (76.37)	80 (15.12)	0.024
	Non-biology	16 (7.62)	145 (69.05)	49 (23.33)	
All bacteria can cause disease	Biology	26 (4.91)	399 (75.43)	104 (19.66)	0.540
	Non-biology	9 (18.10)	163 (77.62)	38 (18.10)	
Malaria is caused by bacteria	Biology	45 (8.51)	366 (69.19)	118 (22.31)	0.004
	Non-biology	22 (10.48)	165 (78.57)	23 (10.95)	

The KAP of Biology and Non-Biology Students Regarding Antibiotics and Resistance Respondents' Knowledge Regarding Bacteria and the Diseases They Cause

Data analysis in **Table 5** shows that biology students showed a better understanding than non-biology students in distinguishing bacteria and viruses. This can be seen from the question about whether bacteria are another name for the virus, where 83.18% of biology students disagreed, while only 75.24% of non-biology students had a similar understanding. In addition, on the question of structural similarities between bacteria and viruses, 76.37% of biology students understood that the statement was false, while the level of uncertainty was higher among non-biology students with 23.33% answering unsure. Both differences were statistically significant with p-values of 0.005 and 0.024, respectively, indicating that biology students better understood.

The fundamental differences between bacteria and viruses. However, on the question of whether all bacteria cause disease, the understanding between the two groups was relatively similar. A total of 75.43% of biology students and 77.62% of non-biology students realized that not all bacteria are pathogenic, with the difference not being statistically significant (p = 0.540). This shows that both biology and non-biology students have a relatively equal general understanding of the role of bacteria in health.

Analysis of Respondents' Knowledge Regarding Antibiotics

Based on the data analyzed (**Table 6**), biology students showed a better understanding than non-biology students in distinguishing bacteria and viruses. This can be seen from the question about whether bacteria is another name for the virus, where 83.18% of biology students disagreed, while only 75.24% of non-biology students had a similar understanding. In addition, on the question of structural similarities between bacteria and viruses, 76.37% of biology students understood that the statement was false, while the level of uncertainty was higher among non-biology students

Table 6. Respondents' knowledge regarding antibiotics

Knowledge question	AS	Response number (%)					p
		LA	Agree	Uncertain	Disagree	LD	
The body can fight mild infections on its own without antibiotics.	B	184 (34.85)	278 (52.65)	28 (5.30)	38 (7.20)	0(0.00)	0.001
	NB	65 (30.81)	87 (41.23)	42 (19.91)	16 (7.58)	1 (0.47)	
Bacterial resistance is defined as not.	B	187 (35.42)	87 (16.48)	220 (41.67)	22 (4.17)	12 (2.27)	0.014
	NB	94 (44.55)	87 (16.48)	81 (38.39)	10 (4.74)	4 (1.90)	
Bacterial resistance occurs when bacteria experience genetic changes (mutations) which cause the bacteria to lose their sensitivity.	B	216 (40.91)	220 (41.67)	57 (10.80)	29 (5.49)	6 (1.14)	0.696
	NB	94 (44.55)	89 (42.18)	19 (9.00)	6 (2.84)	3 (1.42)	
Taking antibiotics less than the prescribed dose can cause bacteria to become more resistant.	B	200 (37.88)	177 (33.52)	113 (21.40)	28 (5.30)	10 (1.89)	0.0013
	NB	76 (36.02)	88 (41.71)	30 (14.22)	13 (6.16)	4 (1.90)	
Purchase and use of antibiotics must be in accordance with a doctor's prescription.	B	119 (22.54	313 (59.28)	86 (16.29)	8 (1.52)	2 (0.38)	0.0003
	NB	43 (20.38)	146 (69.19)	17 (8.06)	4 (1.90)	1 (0.47)	
Incorrect use of antibiotics worsens the disease and increases the duration of recovery.	B	201 (38.07)	280 (53.03)	28 (5.30)	11 (2.08)	8 (1.52)	0.002
	NB	41 (19.43)	86 (40.76)	3 (16.59)	14 (6.64)	35 (16.59)	

Note. AS: Area of study; B: Biology; NB: Non-biology; LA: Largely agree; & LD: Largely disagree

with 23.33% answering unsure. Both differences were statistically significant with p-values of 0.005 and 0.024, respectively, indicating that biology students better understood the fundamental differences between bacteria and viruses.

However, on the question of whether all bacteria cause disease, the understanding between the two groups was relatively similar. A total of 75.43% of biology students and 77.62% of non-biology students realized that not all bacteria are pathogenic, with the difference not being statistically significant (p = 0.540). This shows that both biology and non-biology students have a relatively equal general understanding of the role of bacteria in health. Meanwhile, in the question about the cause of malaria, the majority of biology (69.19%) and non-biology (78.57%) students answered correctly that this disease is not caused by bacteria. However, there were still several students who had misconceptions, with8.51% of biology students and 10.48% of non-biology students answering incorrectly. This difference was also statistically significant (p = 0.004), indicating that although biology students had a stronger foundation in microbiology, there were still some concepts that were not fully understood correctly.

Respondents' Attitude Towards Antibiotic Resistance

Based on data analysis (**Table 7**), there was a significant difference between biology and non-biology

Table 7. Respondents' attitudes towards antibiotic resistance and use

Attitude question	AS	Response number (%)					p
		LA	Agree	Uncertain	Disagree	LD	
Taking leftover antibiotics when I have a cold/flu is an acceptable action.	B	74 (14.02)	72 (13.64)	57 (10.80)	134 (25.38)	191 (36.17)	0.010
	NB	54 (25.35)	57 (26.76)	6 (2.82)	41 (19.25)	55 (25.82)	
I prefer to buy antibiotics without a prescription because they are cheaper.	B	70 (13.26)	84 (15.91)	167 (31.63)	93 (17.61)	114 (21.59)	0.001
	NB	45 (21.13)	45 (21.13)	43 (20.19)	38 (17.84)	42 (19.72)	
The use of antibiotics must always be under the supervision of a doctor to prevent antibiotic resistance in the community.	B	155 (29.36)	158 (29.92)	135 (25.57)	67 (12.69)	13 (2.46)	0.001
	NB	68 (31.92)	68 (31.92)	30 (14.08)	43 (20.19)	4 (1.88)	
I believe my cold/sore throat symptoms can be prevented with antibiotics.	B	110 (20.83)	71 (13.45)	120 (22.73)	145 (27.46)	82 (15.53)	0.007
	NB	52 (24.41)	58 (27.23)	46 (21.60)	50 (23.47)	7 (3.29)	
I believe antibiotics can cure my cold/sore throat faster.	B	104 (19.70)	203 (38.45)	31 (5.87)	88 (16.67)	102 (19.32)	0.016
	NB	51 (23.94)	52 (24.41)	32 (15.02)	40 (18.78)	38 (17.84)	
All diarrheas should be treated with antibiotics.	B	128 (24.24)	55 (10.42)	106 (20.08)	156 (29.55)	83 (15.72)	0.038
	NB	54 (25.35)	60 (28.17)	50 (23.47)	4 (1.88)	45 (21.13)	
I believe it is best to mix body cream with antibiotic cream to cure skin diseases.	B	148 (28.03)	157 (29.73)	114 (21.59)	47 (8.90)	62 (11.74)	0.003
	NB	46 (21.60)	51 (23.94)	39 (18.31)	50 (23.47)	27 (12.68)	
I prefer to take antibiotics to lower blood pressure.	B	168 (31.82)	101 (19.13)	141 (26.70)	68 (12.88)	50 (9.47)	0.013
	NB	62 (29.11)	26 (12.21)	50 (23.47)	33 (15.49)	42 (19.72)	
I will buy antibiotics from another pharmacy if the pharmacist insists on not dispensing them.	B	69 (13.07)	49 (9.28)	49 (9.28)	160 (30.30)	201 (38.07)	0.026
	NB	3 (1.41)	2 (0.94)	27 (12.68)	93 (43.66)	8 (41.31)	
I believe in the importance of finishing the entire course of antibiotics prescribed by your doctor.	B	164 (31.06)	178 (33.71)	169 (32.01)	16 (3.03)	1 (0.19)	0.07
	NB	47 (22.07)	74 (34.74)	37 (17.37)	31 (14.55)	24 (11.27)	

Table 7 (Continued). Respondents' attitudes towards antibiotic resistance and use

Attitude question	AS	Response number (%)					p
		LA	Agree	Uncertain	Disagree	LD	
I believe that government regulations should exist to control antibiotic use and combat bacterial resistance.	B	194 (36.74)	169 (32.01)	85 (16.10)	55 (10.42)	25 (4.73)	0.020
	NB	60 (28.17)	69 (32.39)	52 (24.41)	22 (10.33)	10 (4.69)	

Note. AS: Area of study; B: Biology; NB: Non-biology; LA: Largely agree; & LD: Largely disagree

students in their understanding and attitude towards antibiotic use. More non-biology students agreed to use leftover antibiotics for flu or cold (25.35% and 26.76%) than biology students (14.02% and 13.64%), indicating better understanding among biology students (p = 0.010). Similarly, in terms of purchasing antibiotics without prescription due to price reasons,

Non-biology students were more supportive (21.13% strongly agreed, 21.13% agreed) than biology students (13.26% strongly agreed, 15.91% agreed) (p = 0.001). The majority of students from both groups agreed that antibiotic use should be supervised by a doctor, but the percentage of disagreement was higher in the non-biology group (20.19%) than biology (12.69%) (p = 0.001). Misconceptions regarding antibiotics to prevent flu or sore throat were also higher in non-biology students (24.41% strongly agreed, 27.23% agreed) than biology students (20.83% strongly agreed, 13.45% agreed) (p = 0.007). Misconceptions were also found regarding diarrhea, where more non-biology students believed that all diarrheas should be treated with antibiotics (28.17% strongly agreed, 25.35% agreed) than biology students (10.42% strongly agreed, 24.24% agreed) (p = 0.038). In addition, more non-biology students believed that mixing antibiotic cream with body cream can treat skin diseases (21.60% strongly agreed, 23.94% agreed) than biology students (28.03% strongly agreed, 29.73% agreed), although the level of uncertainty was higher among biology students (p = 0.003). Finally, although the majority of students rejected the use of antibiotics to lower blood pressure, there were still misconceptions in both groups (p = 0.013).

Overall, biology students had a better understanding of antibiotic use, while non-biology students were more prone to misconceptions and erroneous practices, suggesting the need for further education regarding antibiotics and AMR.

Respondents' Practices and Attitudes Towards Regulation and Antibiotic Use

Biology and non-biology students (65.47% and 79.25%) admitted to always taking antibiotics as prescribed by the doctor, but there were still those who hesitated (29.98% biology and 11.32% non-biology), indicating the need for increased understanding. In addition, most respondents (67.93% biology and 62.56% non-biology) continued to take antibiotics even though they felt better, although some still did not understand the risk of resistance due to untimely drug withdrawal. In terms of reporting antibiotic side effects, more biology students (74.57%) reported them than non-biology students (48.34%). However, more than 27% of the non-biology group were unsure or did not report them, reflecting a lack of awareness of the importance of monitoring antibiotic side effects. In addition, more than half of the respondents in both groups (53% biology and 51% non-biology) actively monitored their antibiotic dosage, but there were still those who were unsure or did not do so (31.87% biology and 29.59% non-biology), indicating the need for further education. Regarding doctor consultation before using antibiotics, group biology was more compliant (74.95%) than non-biology (46.07%), but self-medication practices were still quite high, especially in the non-biology group (26.54%). Participation in antibiotic education and campaigns was also low, with only 55.79% of biology and 48.82% of non-biology actively educating others, and limited involvement in academic campaigns and discussions (around 50% for biology and 42% for non-biology).

Overall, although awareness of antibiotic use is high, there are still inconsistencies in adherence and education participation, especially in the non-biology group, so more extensive and intensive education efforts are needed (**Table 8**).

Based on the data (**Table 9**) showed significant differences between biology and non-biology students in knowledge, attitude and practice regarding antibiotic use. Biology students had a higher mean score in knowledge (92, inter-quartile range [IQR] 39-145) than non-biology students (43, IQR 15.5-17.5). In terms of attitude, biology students also recorded a higher score (102, IQR 156-67) compared to non-biology students (45, IQR 54-31). Meanwhile, in the practice of antibiotic use, biology students' score (96, IQR 156-66) was again higher than non-biology students (43, IQR 58-24). The superiority of biology students is likely due to their academic background which is closer to health sciences. In contrast, the low scores of non-biology students indicate the need for additional education. Therefore, measures such as seminars, awareness campaigns, or inclusion of antibiotic material in the general curriculum are needed to improve their understanding and reduce the risk of resistance due to inappropriate antibiotic use.

Table 8. Respondents' practice towards antibiotic resistance and use

Practice question	AS	Response number (%)					p
		LA	Agree	Uncertain	Disagree	LD	
I consistently finish all antibiotics as prescribed by the doctor.	B	169 (32.07)	176 (33.40)	158 (29.98)	24 (4.55)	0 (0.00)	0.053
	NB	61 (29.25)	106 (50.00)	24 (11.32)	19 (8.96)	1 (0.47)	
I make sure to finish the entire course of antibiotics, even if I start to feel better.	B	195 (37.00)	163 (30.93)	121 (22.96)	31 (5.88)	17 (3.23)	0.135
	NB	68 (32.23)	64 (30.33)	33 (15.64)	22 (10.43)	24 (11.37)	
I tell my doctor if I experience any side effects while taking antibiotics.	B	115 (21.82)	166 (31.50)	78 (14.80)	82 (15.56)	86 (16.32)	0.004
	NB	40 (18.96)	47 (22.27)	57 (27.01)	40 (18.96)	43 (20.38)	
I monitor my antibiotic use to make sure I don't go over the prescribed dose.	B	127 (24.10)	153 (29.03)	95 (18.03)	70 (13.28)	82 (15.56)	0.001
	NB	71 (33.65)	39 (18.48)	47 (22.27)	39 (18.48)	15 (7.11)	
I refrain from using antibiotics without consulting a doctor.	B	190 (36.05)	205 (38.90)	18 (16.13)	18 (16.13)	29 (5.50)	0.008
	NB	63 (29.86)	34 (16.11)	74 (35.07)	21 (9.95)	19 (9.00)	
I consult a doctor before starting any antibiotic treatment.	B	95 (18.03)	188 (35.67)	96 (18.22)	86 (16.32)	62 (11.76)	0.006
	NB	43 (20.38)	59 (27.96)	21 (9.95)	37 (17.54)	51 (24.17)	
I take antibiotics according to the doctor's recommended dose and duration.	B	96 (18.22)	201 (38.14)	93 (17.65)	72 (13.66)	71 (13.47)	0.001
	NB	77 (36.49)	78 (36.97)	45 (21.33)	6 (2.84)	5 (2.37)	
I educate myself about the dangers of self-medicating with antibiotics from a reliable source.	B	112 (21.25)	163 (30.93)	88 (16.70)	73 (13.85)	91 (17.27)	0.029
	NB	51 (24.17)	43 (20.38)	25 (11.85)	47 (22.27)	45 (21.33)	
I see a doctor immediately if I sense an infection and refrain from attempting to self-diagnose and self-medicate.	B	150 (28.46)	142 (26.94)	75 (14.23)	55 (10.44)	105 (19.92)	0.340
	NB	46 (21.80)	82 (38.86)	35 (16.59)	29 (13.74)	19 (9.00)	
Antibiotics should be taken until finished to reduce bacterial resistance.	B	155 (29.41)	175 (33.21)	149 (28.27)	21 (3.98)	27 (5.12)	0.001
	NB	60 (28.44)	58 (27.49)	23 (10.90)	37 (17.54)	33 (15.64)	
I will try to educate others about the importance of responsible use of antibiotics.	B	130 (24.67)	164 (31.12)	142 (26.94)	49 (9.30)	42 (7.97)	0.001
	NB	45 (21.33)	58 (27.49)	27 (12.80)	44 (20.85)	37 (17.54)	
I participate in activities or campaigns about education on responsible antibiotic use and prevention of antibiotic resistance.	B	13 (25.05)	143 (27.13)	170 (32.26)	42 (7.97)	40 (7.59)	0.001
	NB	38 (18.01)	65 (30.81)	74 (35.07)	22 (10.43)	12 (5.69)	
I am actively involved in discussions about the responsible use of antibiotics in both academic and social settings.	B	135(25.62)	190 (36.05)	194 (36.81)	5 (0.95)	3 (0.57)	0.001
	NB	34 (16.11)	56 (26.54)	68 (32.23)	53 (25.12)	0 (0.00)	
I am involved in educating the public about the use of antibiotics.	B	156 (29.60)	155 (29.41)	157 (29.79)	29 (5.50)	30 (5.69)	0.033
	NB	30 (14.22)	13 (6.16)	85 (40.28)	0 (0.00)	30 (14.22)	

Note. AS: Area of study; B: Biology; NB: Non-biology; LA: Largely agree; & LD: Largely disagree

Table 9. KAP index with respect to demographic characteristics

Characteristic		Inter-quartile range		
		Knowledge mean	Attitude mean	Practice mean
Academic program	Biology	92 (391-45)	102 (156-67)	96 (156-66)
	Non-biology	43 (155-17.50)	45 (54-31)	43 (58-24)

Table 10. Spearman's correlation between KAP-level

	Knowledge	Attitude	Practice
Knowledge	-		
Attitude	0.736	-	
Practice	0.569	0.379	-

The Correlation of KAP in University Students

Correlation analysis (**Table 10**) showed a strong positive relationship between knowledge and attitude towards antibiotics (r = 0.736), as well as a positive relationship between knowledge and practice (r = 0.569). This means that the higher a person's knowledge, the better their attitude and practice. However, the relationship between attitude and practice was weaker (r = 0.379), suggesting that a positive attitude is not always reflected in action. Other factors such as access to health services and habits are also influential. Therefore, improved knowledge and attitudes need to be supported by experiential education, awareness campaigns, and strict policies to ensure correct practices.

DISCUSSION

The findings of this study showed differences in KAP related to antibiotic use and AMR between biology and non-biology students. Biology students generally had a better understanding, especially in distinguishing between bacteria and viruses. However, misconceptions were still found in both groups, especially regarding the mechanism of antibiotic resistance. Some non-biology students still think that resistance occurs because the body is immune to antibiotics, not due to genetic changes in bacteria. This finding is in line with previous studies that also revealed the persistence of misconceptions and lack of knowledge in the community regarding antibiotics and AMR (Lambert et al., 2022). This conceptual error is more common among non-biology students, which suggests the need for improved microbiology education among them.

When asked whether antibiotics can be used to treat viral infections such as the flu, there were still some students, both from biology and non-biology, who had a mistaken understanding. This indicates that although biology students have a stronger background in life sciences, education about pharmacology and antibiotic resistance still needs to be improved in the curriculum. This study is in line with previous findings (Azim et al., 2023) which identified misconceptions regarding the role of antibiotics in accelerating the recovery process after fever and the treatment-seeking practices of many doctors.

A striking difference in attitude was seen in the habit of buying antibiotics without a prescription. Non-biology students tend to consider it natural due to cheaper prices and easy access, while biology students are more aware of the risk of bacterial resistance. The majority of non-biology students still believe that antibiotics speed up flu and sore throat recovery, while biology students are more aware that antibiotics are not effective against viruses. In addition, non-biology students are more likely to keep leftover antibiotics and reuse them. This shows low awareness of antibiotic resistance, so further education is needed. This finding is also in line with previous studies highlighting the need for specific interventions in the case of self-medication (Marzan et al., 2021; Sakeena et al., 2019).

Biology students were more compliant with the rules of antibiotic use than non-biology students. They more often finished prescribed antibiotics and reported side effects, although some still stopped early when they felt cured. In contrast, non-biology students were more likely to stop antibiotics before they ran out and use them for other illnesses, suggesting a lack of understanding of the importance of completing the dose. Awareness of reporting side effects to medical personnel was also lower among non-biology students. Engagement in antibiotic resistance education and campaigns was low in both groups, suggesting the need for further efforts from education and health institutions to increase student participation through seminars, public campaigns, and community-based learning.

Curriculum Perspectives and Conceptual Understanding

Differences in the level of knowledge about antibiotics and antimicrobials between groups of students with different educational backgrounds are crucial in understanding awareness and potential behaviors related to the use of these drugs. This study specifically highlights the tendency of deeper understanding among biology students compared to non-biology students. This difference is believed to be rooted in the structure of the curriculum and the depth of material learned during their education.

Biology students, as an integral part of their discipline, are comprehensively exposed to microbiology concepts. Microbiology courses, which generally form a core part of the biology curriculum, explicitly address the world of microorganisms, including bacteria, viruses, fungi and parasites. In this context, biology students learn in depth about the mechanism of action of antimicrobials, including antibiotics, in inhibiting or killing the growth of pathogenic microorganisms. This understanding is not limited to the types of antibiotics and their spectrum of activity but also includes the mechanism of AMR which is a global threat today.

Biology curricula often emphasize a fundamental understanding of microbial genetics, mechanisms of genetic transfer, and the evolution of resistance. Biology students are taught about how genetic mutations in microorganisms can produce antibiotic-resistant strains, as well as how mechanisms such as plasmid transfer can spread resistance genes among bacterial populations. This in-depth knowledge allows biology students to have a more comprehensive understanding of the implications of inappropriate antibiotic use and its impact on the development of AMR.

One of the main drivers of the difference in understanding between biology and non-biology students lies in the fundamental structure and content of their curriculum. Biology courses inherently integrate basic and specialized courses that directly address microbiology, cellular processes, and genetics–essential foundations for understanding how antibiotics work and AMR resistance mechanisms.

College biology curricula consistently require foundational courses such as basic biology (Adiana, 2024), cell biology (Adiana, 2024), genetics and molecular biology, and biochemistry (Univeritas Indonesia, 2019). These courses provide the necessary conceptual framework. Cell biology describes the structure and function of cellular components that antibiotics target (e.g., cell wall, ribosomes, and DNA replication machinery). Genetics and molecular biology outline the fundamentals of mutation and horizontal gene transfer, which are key mechanisms for the evolution and spread of bacterial resistance (Saqinah, 2018). Meanwhile, biochemistry details the metabolic pathways that antibiotics can inhibit or modify, as well as the mechanisms of resistance that involve altering those pathways (Sari & Ferasyi, 2020). The synergy between these foundational courses builds a layered and integrated knowledge base that students outside the field of biology generally lack. They learn not only the components in isolation, but also how they interact in the context of cellular function and response to external agents.

Furthermore, microbiology courses (often with a practicum component) are pillars in biology programs (Adiana, 2024). Examples include courses such as "general microbiology" (Adiana, 2024), "microbiology", "microbium" , "applied microbiology", "bacteriology", and even more specific courses such as "industrial microbiology" or "environmental microbiology" (Univeritas Indonesia, 2019). These courses specifically delve into the world of microorganisms, including bacteria, their structure, growth, metabolism, and most crucially, their interactions with antimicrobial agents (Adiana, 2024), In contrast, non-biology programs of study (e.g., social sciences, humanities, engineering) generally do not have mandatory microbiology courses, so students in these fields have minimal or no formal exposure to these fundamental concepts.

In contrast, students from non-biology disciplines are unlikely to get exposure to in-depth and specific microbiology materials. While they may have a general knowledge of infectious diseases and their treatments, their understanding of the mechanism of action of antibiotics at the molecular and cellular level, as well as the complexity of the phenomenon of AMR, is likely to be more limited. This lack of fundamental understanding may affect their perception of the risks of irrational antibiotic use and the long-term consequences of AMR.

Thus, it can be assumed that a biology education curriculum that explicitly includes microbiology material with an emphasis on antibiotic and AMR mechanisms will provide a stronger foundation of knowledge for biology students. This in-depth conceptual understanding is expected to correlate positively with their level of knowledge and awareness of crucial issues related to antibiotic use and the threat of AMR compared to non-biology students.

CONCLUSION

This study shows that biology students have a better understanding of antibiotics and AMR than non-biology students. However, misconceptions were still found in both groups, especially regarding the side effects of antibiotics, their use for viral infections, and their impact on bacterial resistance. This finding confirms that although biology students understand this concept better, strengthening biology education is still needed so that they not only master the theory but can also educate the public. Meanwhile, non-biology students need more extensive health education to prevent antibiotic misuse, such as stopping consumption before the dose runs out or buying without a doctor's prescription. Efforts through integration of AMR material in the curriculum, health campaigns, and stricter antibiotic distribution policies are essential to increase awareness and reduce AMR in the future.

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