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Increasing Antibiotic Resistance Cases: The Role of Medical Students in Rational Drug Use Practices

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Abstract

Background: Antibiotic resistance is one of the greatest global health threats of the 21st century, largely driven by irrational antibiotic use in communities and health-care settings. **Objective:** This study aimed to analyze the role of medical students in promoting rational antibiotic use and contributing to antibiotic resistance prevention efforts. **Methods:** This study used a descriptive qualitative approach with purposive sampling involving 15 medical students. Data were collected through in-depth interviews and participant observation, then analyzed using thematic analysis to identify key themes related to students' knowledge, attitudes, and practices regarding antibiotic use. **Results:** Most students demonstrated good conceptual understanding of antibiotic resistance, including its biological mechanisms and public health consequences. However, a gap remained between theoretical knowledge and clinical application. Student behavior was influenced by internal factors, such as knowledge, motivation, and professional ethics, as well as external factors, including clinical supervisors, academic culture, patient expectations, and institutional policies. Medical students also acted as agents of change through public education, community outreach, digital campaigns, and service-based learning activities. **Conclusion:** Medical education should strengthen integration between theory, clinical practice, antimicrobial stewardship, and community service to develop future physicians who are competent, ethical, and actively involved in preventing antibiotic resistance more effectively.

Keywords: Antibiotic Resistance; Medical Students; Rational Use; Health Education; Antimicrobial Stewardship.

Introduction

Antibiotic resistance has become one of the greatest global health challenges of the 21st century. This phenomenon occurs when microorganisms, particularly bacteria, undergo genetic changes that enable them to survive the effects of antibiotics that were previously effective in killing or inhibiting their growth[1,2]. The World Health Organization (WHO) has classified antibiotic resistance as a serious threat to public health, food security, and global development[3]. Antibiotic resistance not only threatens the effectiveness of modern medical therapy but also increases morbidity, mortality, and economic burden because infections caused by resistant bacteria often require longer treatment, more expensive medicines, prolonged hospitalization, and more complex clinical management.

Globally, cases of antibiotic resistance continue to increase significantly in both developed and developing countries. WHO estimates that, if effective control efforts are not implemented, antimicrobial resistance may cause more than 10 million deaths each year by 2050[4,5]. In Indonesia, Ministry of Health reports have shown an increasing number of infections caused by resistant bacteria, including Escherichia coli, Klebsiella pneumoniae, and Staphylococcus aureus[6]. This situation is

worsened by irrational antibiotic use in the community and in health-care facilities, including self-medication, use without prescription, inappropriate selection of antibiotics, incomplete treatment courses, and weak supervision of antibiotic use in hospitals.

One of the main factors contributing to the increase in antibiotic resistance is drug use that is not aligned with medical indications. Antibiotic use without accurate diagnosis, selection of an inappropriate antibiotic type, and patient non-adherence in completing the prescribed course are common causes of resistance[7,8]. In addition, socioeconomic pressure and cultural beliefs that consider antibiotics as a "medicine for all diseases" further aggravate the problem. Limited understanding among the community and health workers regarding the principles of rational drug use accelerates the emergence of resistance, thereby requiring systemic intervention from multiple sectors, including medical education institutions[9].

Rational drug use is an important approach to slowing the rate of antibiotic resistance. According to WHO, drug use is considered rational when patients receive medicines appropriate to their clinical needs, in correct doses, for an adequate duration, and at an affordable cost[10,11]. In the context of antibiotics, this principle includes selecting antibiotics based on clinical indication and sensitivity testing, prioritizing the narrowest effective spectrum, and avoiding antibiotics for non-bacterial infections. The application of this concept requires the active involvement of all health workers, especially physicians and future physicians, in applying evidence-based medicine and professional ethics in clinical practice[12].

Medical students, as future health professionals, occupy a strategic position in promoting rational antibiotic use. Medical education is not only a process of learning medical theory but also a stage for developing professional attitudes, clinical reasoning, ethical responsibility, and public health awareness[13]. A deep understanding of antibiotic resistance and the consequences of irrational drug use is an important foundation for students to participate actively in community education and future implementation of antibiotic-use policies[14,15]. Therefore, the integration of clinical pharmacology, microbiology, infectious disease management, public health policy, and antimicrobial stewardship into the medical curriculum is essential for building awareness and responsibility toward this problem.

The learning process in medical faculties has great potential to shape rational drug-use behavior. Through academic learning, clinical skills training, bedside teaching, and community service activities, students can be trained to understand antibiotic mechanisms, indications, adverse effects, resistance patterns, and the consequences of misuse[16,17]. Educational activities such as public campaigns, scientific seminars, antimicrobial stewardship training, and case-based discussions can strengthen students' competence[18]. In addition, problem-based learning can improve students' critical thinking skills in determining appropriate therapy according to the patient's clinical condition and available evidence.

Nevertheless, the role of medical students in rational antibiotic use is not free from challenges. These challenges include limited access to updated scientific literature, limited clinical experience, inconsistent role modeling in clinical settings, and the influence of community culture that normalizes inappropriate antibiotic use[19,20]. At the same time, advances in information technology and the growth of inter-institutional collaboration provide major opportunities for students to become agents of change. Medical students can

use digital platforms, community education programs, and peer-based learning to promote more responsible antibiotic use.

Based on this background, it is important to examine in greater depth how medical students can play a strategic role in encouraging rational antibiotic use. This article aims to analyze the urgency of strengthening medical students' knowledge, attitudes, and practices regarding antibiotic resistance and rational drug use. The study also explores factors that influence student behavior and identifies their potential contribution to community education and resistance prevention. The findings are expected to provide input for medical education institutions in designing learning strategies, clinical exposure, and community-based programs that support the development of future physicians who are scientifically competent, ethically responsible, and socially responsive.

Materials and Methods

Study Design

This study used a descriptive qualitative approach to gain an in-depth understanding of medical students' perceptions, attitudes, and behaviors regarding rational drug use in the context of increasing antibiotic resistance. This design was selected because qualitative research allows exploration of participants' experiences, meanings, motivations, and reflections that cannot be fully captured through quantitative measurement. The study focused on how students understand antibiotic resistance, how they interpret rational antibiotic use, and how academic, clinical, social, and institutional factors shape their behavior.

Sample

The participants in this study were 15 medical students selected using purposive sampling, namely the intentional selection of informants based on their knowledge, experience, and relevance to the topic of rational antibiotic use. Participants were selected from students who had received learning materials related to pharmacology, microbiology, infectious diseases, or clinical practice, and who were considered able to provide rich information regarding antibiotic use and resistance. The sample size was considered sufficient because data collection was continued until thematic saturation was reached, meaning that no substantially new themes emerged from additional interviews.

Data Collection Technique

Data were collected through in-depth interviews and participatory observation using a semi-structured interview guide that had been validated by experts in pharmacology and medical education[26–28]. Interviews were conducted individually to allow participants to express their opinions, experiences, and reflections freely. Participatory observation was carried out to understand how students communicated, discussed, and responded to issues related to antibiotic use in academic and community contexts. The interview guide covered students' understanding of antibiotic resistance, attitudes toward rational drug use, experiences in clinical learning, exposure to antimicrobial stewardship, and involvement in community education. All data were documented carefully while maintaining participant confidentiality.

Data Analysis Technique

Data analysis was conducted using thematic analysis, which included coding, categorization, and identification of major themes related to students' knowledge, attitudes, and practices regarding antibiotic use[29]. Interview transcripts and observation notes were read repeatedly to obtain a comprehensive understanding of the data. Meaningful units were then coded and grouped

into categories reflecting conceptual understanding, behavioral factors, and educational roles. Themes were developed inductively by comparing patterns across participants. Data trustworthiness was maintained through triangulation between interview and observation findings, peer discussion among researchers, and repeated checking of interpretations to ensure consistency between the data and the resulting themes. The final analysis was presented in narrative form and supported by tables, figures, and representative quotations from participants.

Ethical Consideration

This study obtained ethical approval from the Ethics Committee of the Faculty of Medicine, University X, with approval number 015/KEPK/FK/2025. All participants were given clear information regarding the purpose, procedures, benefits, and potential risks of the study before the interviews and observations were conducted. Written informed consent was obtained from each participant. Participation was voluntary, and participants had the right to withdraw at any stage without academic or personal consequences. Confidentiality and anonymity were maintained by using participant codes instead of personal identifiers. All collected data were used only for research purposes and stored securely by the research team.

Result

Antibiotic resistance has become one of the most urgent global health issues of the 21st century. The World Health Organization places antimicrobial resistance as a serious threat to the effectiveness of modern treatment, with consequences that include increased morbidity, mortality, and health-care costs. In the context of this study, medical students recognized antibiotic resistance as a complex problem involving biological, clinical, behavioral, and policy-related dimensions. Their understanding was shaped by academic exposure, clinical discussions, and community experiences.

Medical students occupy a unique position in the health system because they are in transition between academic learners and clinical practitioners[34,35]. During their education, students are not only required to understand theoretical aspects of pharmacology, microbiology, and infectious disease management, but also to develop professional judgment in prescribing and educating patients. The findings showed that students were aware that irrational antibiotic use may occur not only because of insufficient knowledge but also because of patient pressure, habits in the community, and inconsistent clinical practices.

However, several studies and the findings of this research indicate a gap between students' theoretical knowledge and actual behavior regarding antibiotic use[37,38]. Academic culture, clinical environment, limited direct experience, and lack of structured antimicrobial stewardship exposure can influence how students translate knowledge into practice. Some participants reported that although they understood the concept of resistance, they still felt uncertain when discussing antibiotic indications in real clinical situations.

In addition to being learners and future practitioners, medical students also have strong potential as agents of change in the community. Through health education, community service, peer education, and digital campaigns, students can contribute to improving public understanding of the dangers of antibiotic misuse. This role is particularly relevant in communities where self-medication and incomplete antibiotic use remain common. Therefore, strengthening students' educational and communication roles is essential for resistance prevention.

Discussion

Medical Students' Conceptual Understanding of Antibiotic Resistance

Based on in-depth interviews with 15 medical students, most informants had a relatively good conceptual understanding of antibiotic resistance. Students understood resistance as a biological phenomenon in which bacteria adapt and become less responsive or non-responsive to antibiotics that were previously effective. They also recognized that resistance is not caused by the patient's body becoming resistant, but by changes in microorganisms. This understanding indicates that students had acquired basic scientific knowledge from pharmacology, microbiology, and infectious disease learning.

Students with deeper understanding were generally able to explain antibiotic resistance from several perspectives, including biological mechanisms, behavioral factors, and drug-use policy[43,44]. One participant explained that resistance is not only a microbiological event but also the consequence of repeated irrational antibiotic exposure. This view shows that some students had begun to connect scientific knowledge with social and clinical realities. Students who had more clinical exposure or participated in public health activities tended to provide broader explanations.

However, some students still showed limited conceptual understanding. Several informants described resistance simply as "the patient's body becoming immune to antibiotics," without being able to explain the underlying biological mechanism[35]. This misconception is important because inaccurate understanding may influence how future physicians communicate with patients and make clinical decisions. Therefore, medical education should place greater emphasis on conceptual clarity, mechanism-based learning, and repeated application of antibiotic-resistance concepts in clinical scenarios.

In addition to biological understanding, this study found that some students had critical awareness of the role of health professionals in preventing resistance[5,31]. They recognized the importance of rational antibiotic use based on proper indication, dose, duration, and monitoring. Students also understood that physicians have ethical responsibility to prevent unnecessary antibiotic exposure and to educate patients about completing therapy. This awareness is an important foundation for professional development and antimicrobial stewardship.

Table 1 presents three main themes from thematic analysis describing the depth of students' understanding of antibiotic resistance, namely biological, social-behavioral, and policy-ethical dimensions. Scientifically, the table shows that students' understanding was not limited to the microbiological domain but also included ethical and social aspects. This indicates that antibiotic resistance was perceived as a multidimensional problem that requires biomedical knowledge, rational decision-making, and social responsibility.

The data in Table 1 show that medical students had conceptual abilities that extended beyond scientific knowledge to include ethical and social domains. Students with greater exposure to clinical discussion and community education were more likely to understand the connection between irrational antibiotic use, public behavior, and health policy. However, variations in depth of understanding indicate that curriculum reinforcement is still needed to ensure that all students develop the same level of conceptual competence.

Table 1. Medical Students' Conceptual Understanding of Antibiotic Resistance

Main Theme	Qualitative Finding Description	Example of Student Quotation
Biological Understanding	Students understood resistance as bacterial adaptation caused by inappropriate antibiotic use.	"Bacteria can adapt; if antibiotics are used too often, over time they no longer work." (M3)
Social and Behavioral Understanding	Students linked resistance to community habits of using antibiotics without a physician's prescription.	"Many people buy antibiotics by themselves at pharmacies without prescriptions, and that also causes resistance." (M7)
Policy and Ethical Understanding	Some students understood the importance of antibiotic-use policies and physicians' responsibility in supervision.	"If doctors prescribe antibiotics carelessly, the impact can spread widely to the community." (M10)

On the other hand, observations showed that students' understanding was not always fully implemented in practice. Some students still showed hesitation in assessing indications for antibiotic use or differentiating between bacterial and non-bacterial infections. This finding suggests that knowledge alone is insufficient to produce rational behavior. Learning strategies must therefore connect theory, case-based reasoning, clinical supervision, and reflective practice so that students can apply scientific knowledge in real decision-making situations.

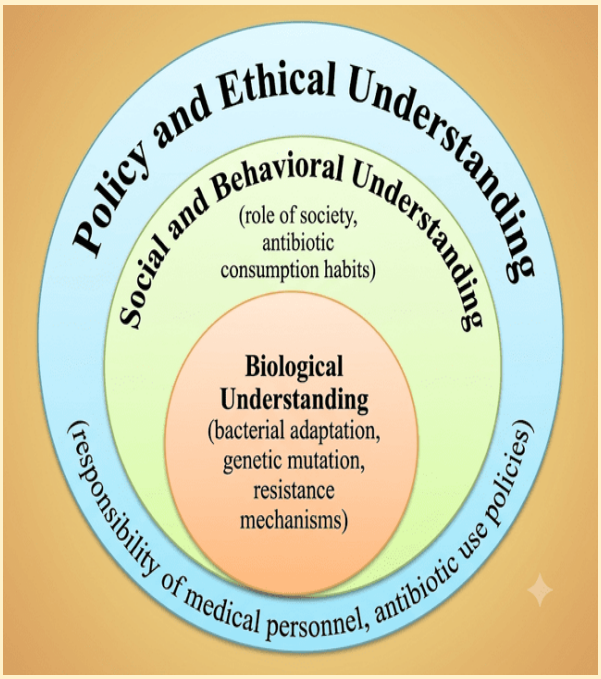

Figure 1. Thematic Map of Medical Students' Conceptual Understanding of Antibiotic Resistance

Figure 1 illustrates that students' conceptual understanding is hierarchical and interrelated. The core layer reflects scientific knowledge as the foundation, while the outer layers describe reflective and ethical abilities obtained through clinical and social learning experiences. This model indicates that medical students' understanding develops progressively from basic biomedical concepts toward broader awareness of professional responsibility, patient safety, and public health consequences.

The findings of this study support Al-Khalifa et al. (2023), who stated that medical education integrating social and ethical dimensions into pharmacology learning is more effective in increasing students' awareness of antimicrobial resistance. When students are encouraged to understand resistance as a clinical, social, and ethical problem, they become more prepared to participate in rational antibiotic-use practices and public education.

Overall, the results show that medical students' conceptual understanding of antibiotic resistance is progressive but not yet

evenly distributed. Students with more clinical experience and social interaction demonstrated more comprehensive understanding, whereas students with limited exposure tended to provide simpler explanations. This finding emphasizes the need for continuous learning, early clinical exposure, antimicrobial stewardship training, and structured reflection throughout medical education.

Factors Influencing Students' Attitudes and Behaviors in Antibiotic Use

In-depth interviews and focus group discussions with clinical-stage medical students showed that students' attitudes and behaviors toward antibiotic use were influenced by various internal and external factors. Internal factors included knowledge, motivation, professional values, ethical awareness, and self-confidence in clinical reasoning. External factors included the role of lecturers and clinical supervisors, academic culture, hospital policy, patient expectations, and the availability of guidelines and scientific literature.

Knowledge and scientific understanding were the main foundations for shaping students' attitudes. Students with deeper understanding of resistance mechanisms and antimicrobial stewardship principles tended to show more careful and analytical attitudes when considering antibiotic use. They were more likely to ask whether an infection was bacterial, whether culture or sensitivity testing was needed, and whether the selected antibiotic was appropriate. This indicates that cognitive competence influences clinical judgment and responsible behavior.

In addition to cognitive factors, learning motivation and professional values also influenced student behavior. Students with high intrinsic motivation, ethical awareness, and a sense of responsibility toward patients tended to apply rational-use principles more consistently. They viewed antibiotic use not only as a technical decision but also as a professional responsibility that may affect patients, families, communities, and future treatment effectiveness. Such attitudes are important for building responsible prescribing habits.

Table 2. Factors Influencing Medical Students' Attitudes and Behaviors in Antibiotic Use

Factor Category	Qualitative Subfactor	Impact on Attitudes and Behavior
Internal	Scientific knowledge, learning motivation, awareness of resistance	Shapes rational thinking and professional responsibility
Academic External	Clinical supervisors, teaching methods, clinical culture	Provides models of clinical behavior imitated by students
Social and Environmental	Patient pressure, community expectations, hospital policies	Encourages compromise behavior in clinical practice
Institutional	Curriculum, antibiotic-use policy, access to literature	Determines exposure and habituation to rational practice

The clinical learning environment also played an important role in shaping student behavior. Students who rotated in hospitals with active antimicrobial stewardship programs demonstrated more rational behavior in discussing antibiotic use. Conversely, students who observed inconsistent prescribing practices or limited supervision reported confusion in applying rational antibiotic-use principles. This finding shows that role

modeling and institutional culture strongly influence student behavior during clinical education.

Table 2 shows four main categories of factors shaping students' attitudes and behaviors in antibiotic use. Internal factors determine students' readiness to adopt rational-use principles. Academic external factors, such as lecturer guidance, teaching methods, and clinical culture, provide models of professional behavior. Social and environmental factors may encourage compromise in practice, especially when patients expect antibiotics. Institutional factors, including curriculum, antibiotic-use policies, and access to literature, determine students' exposure to rational antibiotic-use practices.

In addition to academic factors, this study found that social pressure and patient expectations significantly influenced students' clinical behavior[34]. Several students stated that they felt uncomfortable when patients expected antibiotics even when they were not clinically indicated. This situation may create tension between scientific reasoning and patient satisfaction. Therefore, students need communication training to explain why antibiotics are unnecessary in certain conditions while maintaining patient trust.

Institutional policy also played a major role in shaping student behavior. Universities or teaching hospitals that had written guidelines on antibiotic use, therapy audit systems, and continuous training were more successful in familiarizing students with rational antibiotic-use practices. Institutional support helps transform individual knowledge into consistent behavior because students learn within a structured environment that promotes accountability and patient safety.

The thematic analysis found an interactive relationship among factors. Good knowledge without support from a positive clinical environment was often insufficient to produce sustainable rational behavior. Conversely, an ideal clinical environment would not produce optimal results if students lacked internal awareness and motivation. Therefore, the formation of rational attitudes and behavior toward antibiotics requires a comprehensive approach that combines scientific learning, professional role modeling, institutional policy, and direct social experience[18,20].

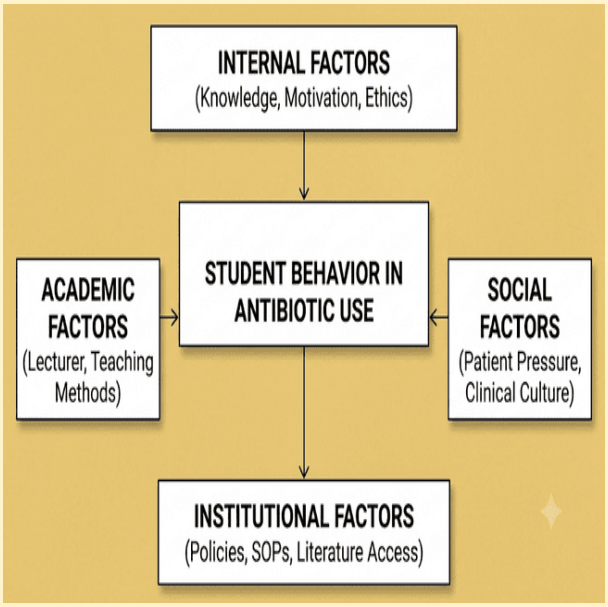

Figure 2. Interactive Model of Factors Influencing Students' Attitudes and Behaviors toward Antibiotic Use

The model in Figure 2 describes interactive relationships among factors influencing students' attitudes and behaviors in antibiotic use. The model emphasizes that student behavior is not formed by a single factor but is the result of interaction between knowledge, motivation, clinical environment, patient expectations, institutional policy, and professional identity. These factors may strengthen or weaken one another depending on the learning context experienced by students.

Social and institutional factors function as reinforcing factors that can strengthen or weaken rational behavior through environmental influence and formal policy[44]. In

other words, students are more likely to behave rationally when scientific knowledge, personal motivation, clinical role models, patient communication skills, and institutional policy support one another. Therefore, rational antibiotic-use behavior should be developed through integrated educational strategies rather than through theoretical learning alone.

The Role of Medical Students in Community Education and Prevention of Antibiotic Resistance

The findings show that medical students have a strategic role in preventing antibiotic resistance through community education. Based on in-depth interviews, most students realized that antibiotic resistance is not only a clinical problem but also a social problem related to drug-use behavior in the community. This awareness emerged because students often encountered people who used antibiotics without prescriptions, purchased antibiotics freely, or stopped therapy before completion[6,34]. These conditions encouraged students to participate actively in health education, both individually and collectively through campus-based programs.

Medical students involved in community service activities, such as health education at public health centers, schools, and village communities, demonstrated a higher understanding of the importance of effective communication in delivering health messages[18,21]. Based on focus group discussions, students reported that many community members mistakenly believed that antibiotics were "multipurpose medicines" that could cure all diseases[4]. Therefore, two-way communication was considered the most effective strategy, in which students not only provided information but also listened to and understood community perceptions regarding antibiotic use.

In this context, students function as agents of change who bridge the academic world and the wider community. They play a role in translating scientific knowledge into information that can be easily understood by the public[3,6]. Activities such as "Stop Antibiotics Without Prescription" campaigns, health education competitions, and community health days represent concrete contributions of students in changing community behavior. Observations showed that people who received education from students had better understanding of antibiotic use than those who did not receive similar interventions.

Table 3 describes various forms of medical student contribution to community education programs related to antibiotic resistance. These activities not only increase public knowledge but also strengthen students' communication skills, leadership, and social empathy. The findings indicate that direct interaction and digital campaigns were the most effective approaches because they reached a wider audience using relevant and communicative strategies.

In addition to direct counseling, students also played an important role in digital media-based education. In the era of health digitalization, social media has become an effective tool for disseminating information quickly and widely[20]. Medical students used platforms such as Instagram, TikTok, and YouTube to educate the public about the dangers of antibiotic use without prescription and the importance of completing therapy according to physician instructions. This strategy was considered effective because students used communicative delivery styles and simple language that could be understood by the public. This strengthens the concept of digital health literacy as an important approach in community health promotion[4,6,20].

Table 3. Forms of Medical Student Involvement in Education and Prevention of Antibiotic Resistance

Form of Educational Activity	Main Target	Educational Objective	Qualitative Impact Found
Direct counseling at public health centers or schools	General public and students	Increase knowledge about correct antibiotic use	Improved awareness and changes in antibiotic consumption behavior
Social media campaign (#UseAntibioticsWisely)	Youth and university students	Disseminate evidence-based information through digital media	Improved digital health literacy related to antibiotic resistance
Community Health Education Program	Village communities and vulnerable groups	Integrate academic knowledge with local needs	Strengthened relationship between educational institutions and the community
Peer educator training	Students and young health workers	Develop antibiotic education cadres in academic environments	Formation of a student community concerned with antibiotic resistance

From an academic perspective, student involvement in educational activities also strengthened professional competence and social empathy. Students who were active in community service showed improvement in therapeutic communication skills, preparation of evidence-based health messages, and application of medical ethics in social contexts. These skills are highly relevant for developing future physicians who are not only clinically competent but also able to serve as public health educators and advocates[3].

However, the study also found challenges and barriers in implementing community education. Some students stated that limited time, lack of health communication training, and low public interest in antibiotic resistance were major obstacles. In addition, not all medical education institutions had structured and sustainable community service programs[3,34,36]. Therefore, systematic support from universities and professional organizations is needed to integrate antibiotic-resistance education into curricula or mandatory social programs.

The conceptual model in Figure 3 describes the continuous relationship between mastery of scientific knowledge, communication skills, and implementation of community education by medical students. This process is dynamic and reflective, in which each stage strengthens the next. Scientific knowledge provides the foundation that enables students to deliver accurate information, while communication skills serve as a bridge between medical science and public understanding[37].

Field-based educational implementation becomes a practical means of applying theory learned in class. Through counseling, digital campaigns, and peer education, students do not merely act as information providers but also as facilitators of behavior change. The impact of these activities can be seen in increased community awareness of the dangers of antibiotic resistance and increased public trust in young health workers[6].

The final stage in this model is the strengthening of professionalism, where students reflect on field experiences as part of the formation of their professional identity. Direct interaction with the community develops empathy, social responsibility, and a deeper understanding that medical education aims not only to produce clinicians but also ethical and visionary community educators[33,35]. Thus, medical students act not only as recipients of knowledge but also as key drivers in global efforts to prevent antibiotic resistance through education, collaboration, and community empowerment.

Figure 3. Model of Medical Students' Role in Education and Prevention of Antibiotic Resistance

Conclusion

Based on the findings, it can be concluded that antibiotic resistance is a growing global health challenge caused by irrational drug use in both the community and health-care facilities. Medical students have a strategic role in reducing this problem through scientific understanding, professional attitudes, and active involvement in public education. The analysis showed that students' conceptual knowledge of antibiotic resistance was generally good but not evenly distributed. Their rational behavior was influenced by internal factors, including knowledge, motivation, and ethics, as well as external factors, including academic environment, social pressure, and institutional policy. Through education, clinical practice, and community service, medical students can serve as agents of change in increasing public awareness of wise antibiotic use. Therefore, multidisciplinary learning integration, strengthening of campus policies, clinical role modeling, antimicrobial stewardship training, and sustainable community education systems are needed to develop future physicians who are competent, ethical, and committed to preventing antibiotic resistance.

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