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Research Article

Knowledge and perception of antibiotic resistance and stewardship among pre-health and agriculture undergraduate students

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ABSTRACT The global threat of antibiotic-resistant infections has resulted in health organizations compiling an Antibiotic Stewardship Program (ASP), in which the education of current and future medical prescribers and farmers is central to the preservation of current and future antimicrobial treatments. The purpose of this study was to assess and compare the knowledge and perceived threat of antibiotics and antibiotic resistance, as well as the perceived benefit of antibiotic stewardship education, among undergraduate students majoring in Biology and Agriculture at Fort Hays State University. I hypothesized that the difference in knowledge and perceptions between Biology and Agriculture students would be significantly different because of differences in curriculum requirements. Framed by the health belief model (HBM), a quantitative cross-sectional study was conducted using a structured online survey of 136 undergraduate student participants. A χ^2 analysis was used to assess differences between the respondents in their knowledge and perceptions of antibiotics, antibiotic resistance, and antibiotic stewardship education at the undergraduate level. Results showed that, although Agriculture students perceived antibiotic resistance as less threatening than Biology/pre-health students, both undergraduate groups were knowledgeable about the problem and wanted more academic education on the issue. These findings create a solid foundation to initiate a conversation on the curriculum development to meet ASP goals and objectives at the undergraduate level while contributing to an ongoing international effort to educate future prescribers and farmers on the importance of antibiotics in medicine and farming and to reduce antibiotic resistance.

KEYWORDS antibiotic resistance, antibiotic stewardship program, health belief model, academic major, pre-health education and agriculture education

Since the late 1920s, the introduction of antibiotic drugs in medicine and agriculture has had a noteworthy effect on decreasing morbidity and mortality rates and in preventing diseases in humans and livestock (1). For more than 50 years, antibiotic-resistant bacteria have started to arise, resulting in many available antibiotics no longer being useful to fight bacterial infections. Currently, with more than 150 antibiotic drugs available commercially, at least 50% of these drugs are no longer effective treatments due to emerging resistant bacteria (1). Consequently, antibiotic resistance has become a menace to public health worldwide. In collaboration with the World Health Organization and the United Nations, the Centers for Disease Control and Prevention (CDC), a U.S. agency, launched the Antibiotic Stewardship Program (ASP) initiative. The development of the ASP focuses on public awareness, education, global surveillance, and the reduction of antibiotic use in agriculture and medical fields (2).

The introduction of coordinated antibiotic stewardship initiatives suggests that the public understanding of antibiotic stewardship is a prerequisite for enforcing the

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suitable practice of antibiotics and restraining the spread of antibiotic resistance (3). Past researchers have focused on the role of healthcare providers and patients for the excessive use and misuse of antibiotics in the community. Such studies suggest that the rational use of antibiotics drugs is ultimately achieved by modifying the prescribing behaviors and knowledge of the healthcare providers and the behavior of patients (4). Moreover, several other studies have focused on the regulation and enforcement of antibiotic use in agriculture with the aim to detect and control antibiotic use in farming. Welsh et al. (5) suggested that in many unindustrialized countries, the level and rate of antibiotic usage in the farming sector ultimately are influenced by the manner in which most farmers obtain over-the-counter antibiotics and use these antibiotics in multiple practices. Nonetheless, the prescription and administration of antibiotics to farm animals are eventually supervised by veterinarians (5). Several researchers have found that veterinarians significantly influence the attitude of farmers toward antibiotic use.

Since the launch of antibiotic stewardship in 2002 by the CDC, ASP is based on quality improvement in healthcare settings. Evidence-based guidelines and protocols have been developed to improve patient care in a safe and timely manner. Those strategies require optimal coordination of trained staff and adequate resources (2). Many researchers have examined the behavior of healthcare providers, such as nurses and physicians, employed to address the challenges and impact of antibiotic stewardship efforts (2). As a result, these researchers offered insights on developing a system that provides adequate resources, training, and multidisciplinary efforts for healthcare providers (2). In community settings, education and training play important roles in achieving ASP goals and objectives. Previous work noted that strategies and passive educational activities should be used to complement other stewardship activities (6).

Although the rate of chronic infectious diseases has been falling globally, progress toward the treatment of multidrug-resistant chronic infections is, ultimately, a major challenge (7). The frequency with which doctors prescribe antibiotics varies between states within the United States and between other countries (8). Currently, the reasons for this disparity are under investigation, and such studies might share light on strategies to improve antibiotic prescribing (8). In Kansas alone, since the introduction of ASP, over 90% of individuals of all ages are still being prescribed antibiotics (9). However, the etiology of infection is only recorded in 7.6% of cases of patients hospitalized with a community-acquired infection (9). Consequently, treatment indication, choice of the chemotherapeutic agent, or even duration of antibiotic therapy is incorrect in 30%–50% of the cases (9). This evidence suggests that there is still improvement needed in antibiotic prescribing by physicians. In addition to misuse and overuse of antibiotic prescription, Martin et al. (10) noted that of all the antibiotics available nowadays for medical purposes, 70% are also being used in the preservation of livestock. They revealed that despite the strict enforcement of antibiotic stewardship in the medical field, there is a lower level of knowledge and perceptions of antibiotic use in agriculture (10). Such studies revealed that academic medical centers and teaching hospitals should immediately integrate education on fundamental antibiotic stewardship principles into their preclinical and clinical curricula (6). Previous studies have indeed identified a gap in knowledge of the responsible use of antibiotics by medical students. According to a cross-sectional study, medical students feel they still need more education on antibiotic use for their future practices as junior health providers (11). Thus, there has been a shift toward the training of health professions students, including future veterinarians, on the concept of antibiotic stewardship, appropriate prescribing behaviors, and stricter enforcement of antibiotic stewardship in the medical field. Nonetheless, there is still a lower level of education on antibiotic knowledge and use in agriculture (10). As the use of antibiotics in agriculture continues to routinely be described as a contributor to the clinical problem of antibiotic resistance in human medicine, the debate about agricultural use of antibiotic is ultimately further complicated by politics and economic issues (12).

Until now, most educational efforts have been targeting current medical professionals. Little attention has been given to antibiotics training at the undergraduate level, and little is known on the difference in their perceptions and knowledge on this topic or the acceptability of antibiotic stewardship for compliance in the future (2). Silverberg et al. (13) pointed that educating future prescribers can be viewed as a more effective educational strategy as the approach would focus on shaping the ideal behavior instead of changing the old behaviors. Although many passive educational techniques, such as antibiotic campaigns and traditional course curricula, have been used to increase future providers knowledge on antibiotics use, a study shows that active learning associated with real-life-specific patient cases or prescribing data has increased influence on prescribing behaviors and is ultimately longer lived (14). Still, limited curricula are currently available for undergraduate pre-health students. Reports for curricula targeting antibiotic knowledge for undergraduate students majoring in Agriculture are non-existent. However, better knowledge increased perceived benefits, and practices were associated with farmers who were engaged previously in the efforts to gather more information on antibiotic use and resistance (15).

The purpose of this study was to assess and compare the knowledge and perceptions defined as perceived threat and perceived benefits of stewardship of antibiotics among undergraduate students majoring in Biology/pre-health and Agriculture in a rural, primarily undergraduate university in Kansas and to determine how students' attitudes, behaviors, and knowledge could influence their antibiotic stewardship decision-making in their future professional career. The following questions were developed to assess the purpose of the study (see Appendix A):

RQ1—Are there differences in the knowledge of antibiotic resistance in Biology/pre-health students compared to Agriculture students?

RQ2—Are there differences in the perceived threats of antibiotic resistance in Biology/pre-health students compared to Agriculture students?

RQ3—Are there differences in the perceived benefit of antibiotic resistance education in stewardship in Biology/pre-health students compared to Agriculture students?

This research was conducted in partial fulfillment of the requirements for a Ph.D. from Walden University by C. M. Da Silva Carvalho (16).

METHODS

Institutional context

Fort Hays State University is considered the third largest of the six universities governed by the Kansas Board of Regents. Located in the rural region of Kansas, the university has an enrollment of approximately 15,000 students, including undergraduate, graduate, and virtual students. The STEM College at Fort Hays State University houses the Departments of Agriculture, Applied Technology, Biological Sciences, and Chemistry. It consists of approximately 1,400 undergraduates and 50 graduate students. The Department of Biological Sciences offered three degree options: Natural Resource, Biology Secondary Education, and Pre-Health Profession. At the beginning of the 2019–2020 academic year, the Department of Biological Sciences had approximately 200 students majoring in Biology. The Agriculture Department provides several degree options, such as Agronomy, Animal Science, and Agriculture/Business. The total enrollment of students in the Department of Agriculture was 459 students. Fifty-seven percent of Biology students were following a prehealth professional curriculum designed for students wanting to pursue a health profession career, such as medicine, dentistry, pharmacy, optometry, and veterinary. About 20% of Agriculture students were following animal sciences curriculum designed for students wanting to pursue a professional career in veterinary. The demographic characteristics of the Biology and Agriculture Departments are represented in Table 1.

TABLE 1 Sociodemographic characteristics of undergraduate students enrolled in the Biology and Agriculture departments for the 2019–2020 academic year

Sociodemographic characteristic	Total		Biology department		Agriculture department	
	N	%	*N*	%	*N*	%
Sex						
Female	289	43.8	93	32.2	196	67.8
Male	370	56.2	107	28.9	263	71.1
Race						
White	604	91.6	173	28.6	431	71.4
African American/Black	11	1.7	6	54.5	5	45.5
Hispanic/Latino	26	3.9	16	61.5	10	38.5
Asian/Pacific Islander	3	0.45	1	33.3	2	66.7
Other	15	2.28	4	26.7	11	73.3
Degree options (Agriculture major [*n* = 459)						
Animal Sciences	–[a]	–	–	–	94	20.5
Agronomy	–	–	–	–	58	12.7
Business	–	–	–	–	282	61.4
No degree option	–	–	–	–	25	5.40
Degree options (Biological Sciences major [*n* = 200])						
Health Profession	–	–	114	57.0	–	–
Natural Resources	–	–	67	33.5	–	–
Education	–	–	19	9.5	–	–

[a]–, not applicable.

Overview of institutional majors curriculum

Similarities in the curriculum structure of these two majors, particularly between Agriculture/pre-vet degree option and Biology/pre-health exist. Core courses, such as Principles of Biology, Genetics, and Microbiology, are the required foundation of both majors and are offered by the Department of Biological Sciences, ensuring that both Agriculture/pre-vet and Biology/pre-health students achieve the same learning outcomes from these foundation courses (see Table 2). In contrast, courses, such as Microbiology of the Pathogens and Virology, are considered upper-division elective courses for Biology/pre-health students. Moreover, neither of these courses is a requirement or an elective for Agriculture majors. Therefore, differences arise in the elective courses, with Biology/pre-health students potentially delving into more advances concepts of antibiotic resistance compared to Agriculture/pre-vet students (see Table 2). The curriculum of Agriculture degree options other than pre-vet emphasizes livestock production and managements, prioritizing these concepts over antibiotic stewardship.

It is noteworthy that Microbiology courses offered at Fort Hays State University (FHSU) adhere to the curriculum guidelines recommended by the American Society for Microbiology (ASM). While ASM does not mandate a specific curriculum for Microbiology courses or a specific curriculum solely focused on antibiotics and antibiotic resistance, its valuable resources and guidelines aid in designing a rigorous and up-to-date curriculum that meets the needs of students and, most importantly, aligns with current trends and advancements in microbiology. In both Microbiology courses offered at FHSU, the topics of antibiotics and antibiotic resistance are integral components of the courses. These courses involved covering topics, such as, but not limited to, antibiotic mechanisms of action, antibiotic resistance mechanisms, epidemiology of antibiotic resistance, and strategies for combatting antibiotic resistance.

Survey instrument

A quantitative cross-sectional study approach was used as a foundation to determine the extent of knowledge and perceptions of antibiotic resistance in student majoring in Agriculture and students majoring in Biology/pre-health. A structured, closed-ended

TABLE 2 Coursework and timing of Agriculture and Biology major curriculum at Fort Hays State University[a]

	Agriculture—Others	Agriculture—Animal Sciences	Biology—Others	Biology- Prehealth
First year (Freshmen)	Principles of Biology[b]	Principles of Biology[b]	Principles of Biology[b]	Principles of Biology[b]
Second year (Sophomores)		Principles of Biology[b] Microbiology[c]		Microbiology[c]
Third year (Juniors)		Genetics[b]		Genetics[b]
Fourth year (Seniors)		Reproductive Physiology of Domestic Animal[b]		Cell Biology[d] Microbiology of the Pathogens[c] Virology[d]

[a]Note: The designations above were determined by assessing the complexity concept of Antibiotic Resistance (AR) required and outcomes required for each course based on course assessments provided by the department of Biology at Fort Hays State University. These designations are not fixed and can vary depending on the institutions.
[b]Beginner concept of AR.
[c]Advanced concept of AR.
[d]Intermediate concept of AR.

survey was developed based on the construct of the Health Belief Model (HBM) to ensure content and construct validities (11). The questionnaire was divided into four sections (Appendix B). The first section consisted of questions related to demographic characteristics. The second section addressed the field of knowledge related to antibiotics and their appropriate use. The third and fourth sections consisted of questions based on the HBM constructs (benefits, threat, and severity). The HBM constructs were measured using five-point semantic differential scales (Likert scale), ranging from 1 (strongly agree) to 5 (strongly disagree) (17). The survey was emailed to Biology and Agriculture students by the principal investigator from a list of students' email provided by Fort Hays State University. The email provided a link to Survey Monkey. The participants of this study were selected based on the inclusion and exclusion criteria for the study. Criteria for inclusion for this study were determined to be Biology/pre-health students and Agriculture students enrolled in courses, such as Principles of Biology, Microbiology, Human Biology, Zoology, and Immunology. The classification of these students fell between freshman years (first-year undergraduate) to senior year (fourth year of undergraduate). The ages of the participants fell between the ages of 18 and 54 years old. Criteria for exclusion were determined to be Biology/non-pre-health majors or non-Agriculture majors. All individuals who met the inclusion criteria had the same chance to be part of the sample and be involved in the study (18).

Data analysis

Survey data cleaning was done prior to exporting the data to IBM SPSS Version 25 software licensed by Walden University. The survey data cleaning involved identifying and removing participants who either did not match my target sample criteria or did not complete the entire survey or provided inconsistent responses. Furthermore, the survey data were coded before analysis (see Appendix C). Using the IBM SPSS Version 25 software, a χ^2 analysis was used to test the hypothesis for all three research questions. When conducting the data analysis, an examination of potential confounding variables was considered. In relation to knowledge and perception, studies showed that those two variables can be influenced by confounding variables (19). It could be difficult to conclude, without a doubt, that the academic major of the students has a direct correlation or causal effect on the perception and knowledge of antibiotic resistance and antibiotic stewardship. Moreover, the academic year of the participants can influence the knowledge, and perhaps, the perception of antibiotic resistance and education is stewardship. A χ^2 analysis does not typically consider confounding variables, such as academic level or other confounding that may exist in this study. Consequently, an ordinal logistic regression was used as a sensitivity test to adjust for the potential confounders, such as the academic level of student participants.

Safety issues

There are no safety issues associated with this study. However, as this is human-based research, Institutional Review Board (IRB) approval was obtained prior to conducting this study. For the proposed study, IRB approval from FHSU was sought. For this type of study where there is no risk to the participants, the IRB application was considered to be exempt for FHSU and, therefore, relatively easy to obtain. Once FHSU IRB was approved, an IRB approval from Walden University was acquired. Walden University's approval number for this study is 06-11-20-0656434.

RESULTS

Study population demographic

The demographic characteristics of the sample population for this study are represented in Table 3. A total of 136 undergraduate students participated in the study. Eighty-seven percent of the participants were between the ages of 18 and 24. There were 55.8% Biology/Pre-health students and 42.8% Agriculture students who responded to the survey. Sixty-one percent of the students who participated were senior undergraduate students, and a smaller percentage of 15% were freshmen undergraduate students. Lastly, only 30% of the participants were first-generation college students (see Table 3). The majority of Biology/pre-health majors were women, 75.3%, whereas only 55.9% of Agriculture majors were women. Among Biology/pre-health students, 97.4 were between the ages of 18 and 24, and 72.9% of Agriculture major undergraduate students were between the ages of 18 and 24. Most Biology/pre-health and Agriculture undergraduate students who participated in this study classified themselves as senior (fourth year) undergraduate students (40.3% for Biology/pre-health and 47.5% for Agriculture). Overall, 30% of Biology/pre-health students and 29% of Agriculture students were identified as first-generation college students (See Table 3).

TABLE 3 Sociodemographic characteristics of undergraduate student participants

Baseline characteristic		Total		Biology		Agriculture	
		N	%	*N*	%	*N*	%
Sex	Female	91	67.4	58	75.3	33	55.9
	Male	45	32.6	19	24.7	26	44.1
Age	18–24	118	87	75	97.4	43	72.9
	25–34	14	10.1	2	2.6	12	20.3
	35–44	0	0	0	0	0	0
	45–54	4	2.9	0	0	4	6.8
Race	White	113	81.9	56	72.7	55	93.2
	African American/Black	6	4.3	4	5.2	2	3.4
	Hispanic/Latino	14	10.1	13	16.9	1	1.7
	Asian/Pacifier Islander	3	2.2	3	3.9	0	0
	Other	2	1.4	1	1.3	1	1.7
Class classification	Freshmen	15	11	12	15.6	3	5.1
	Sophomore	26	19.1	13	16.9	13	22
	Junior	36	26.5	21	27.7	15	25.4
	Senior	59	43.4	31	40.3	28	47.5
Are you first-generation college students?	Yes	40	29.4	23	29.9	17	28.8
	No	96	70.6	54	70.1	42	71.2

A χ^2 test showed no significant difference between Agriculture and Biology majors' overall knowledge of antibiotic resistance X^2 (4, N = 136) = 5.519, P-value > 0.05 (see Fig. 1).

The frequency of responses of questions assessing how Biology/pre-health and Agriculture undergraduate students view the concept of antibiotic resistance are shown in Table S4 in Appendix D. The questions are all related to assessing the knowledge as well as the impact of antibiotic resistance based on the academic major.

The χ^2 analysis of the different questions assessing the knowledge and impact of antibiotic resistance between the undergraduate students majoring in Biology/pre-health and Agriculture is all not statistically significant, except for the question assessing frequent use of antibiotics on the risk/impact of frequent use of antibiotics on patients' risk. There is a statistically significant difference in the perception of the frequent use of antibiotics on patients' risk between the two undergraduate academic majors.

A χ^2 test showed no significant difference between Agriculture and Biology majors' overall level of perceived benefit of antibiotic resistance education X^2 (4, N = 136) = 4.356, P-value > 0.05 (see Fig. 2).

The frequency of responses of questions assessing how Biology/pre-health and Agriculture undergraduate students perceived the benefit of antibiotic resistance education is shown in Table S5 in Appendix D. The questions are all related to assessing the level of perceived benefit as well as the impact of antibiotic resistance education based on the academic major. The χ^2 analysis of the questions assessing the perceived benefit of antibiotic resistance education between both groups of students was not statistically different.

The results of the ordinal logistics regression analysis to investigate if there is a potential relationship between class classification, defined as freshman, sophomore, junior, and senior year (additional potential predictor/factor variable), and the level of knowledge of antibiotic and perceived benefit of antibiotic resistance education

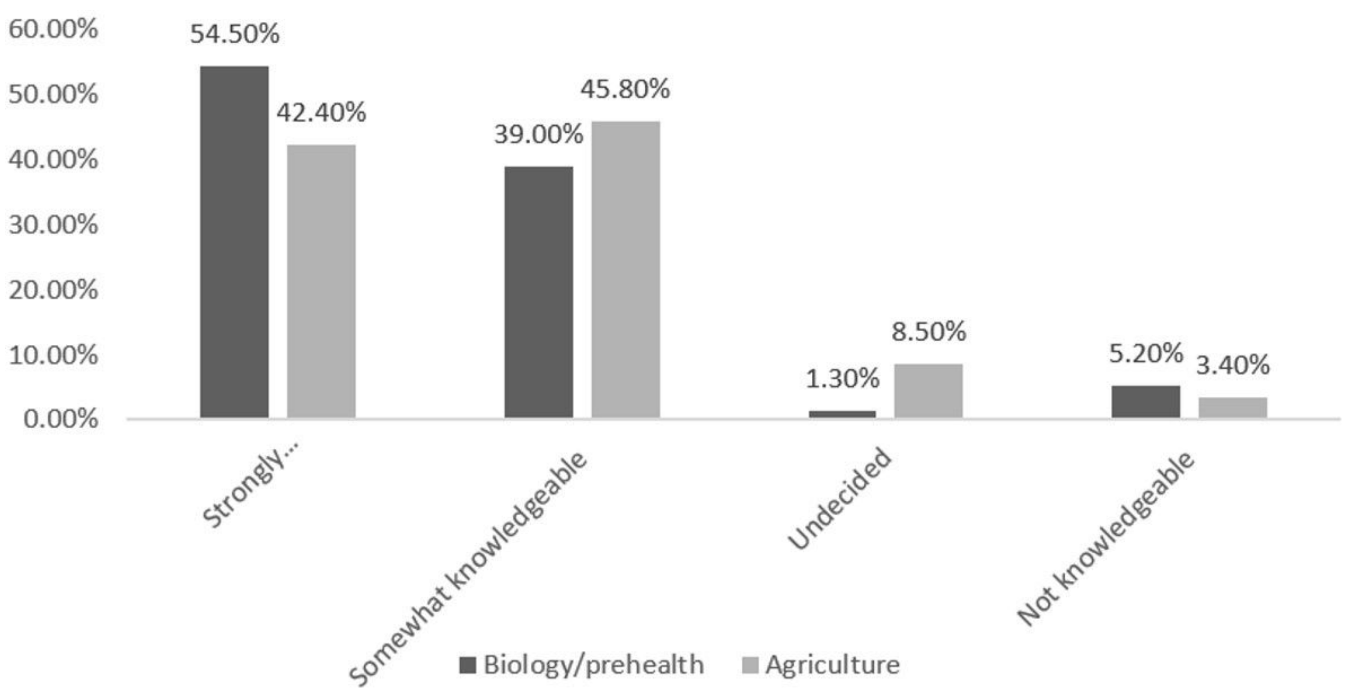

FIG 1 Comparison of frequency of responses assessing the level of knowledge of antibiotic resistant between Biology/Pre-Health and agriculture undergraduate. Undergraduate students in Biology/pre-health and agriculture programs were assessed on their overall knowledge of antibiotic resistance using question I from section II of the survey in Appendix B. Students rated their confidence in and depth of understanding of antibiotic resistance using a Likert scale. In this scale, "strongly knowledgeable" indicated a high level of proficiency in understanding, applying, and analyzing the concept of antibiotic resistance, while "somewhat knowledgeable" indicated a basic or foundational understanding of the topic.

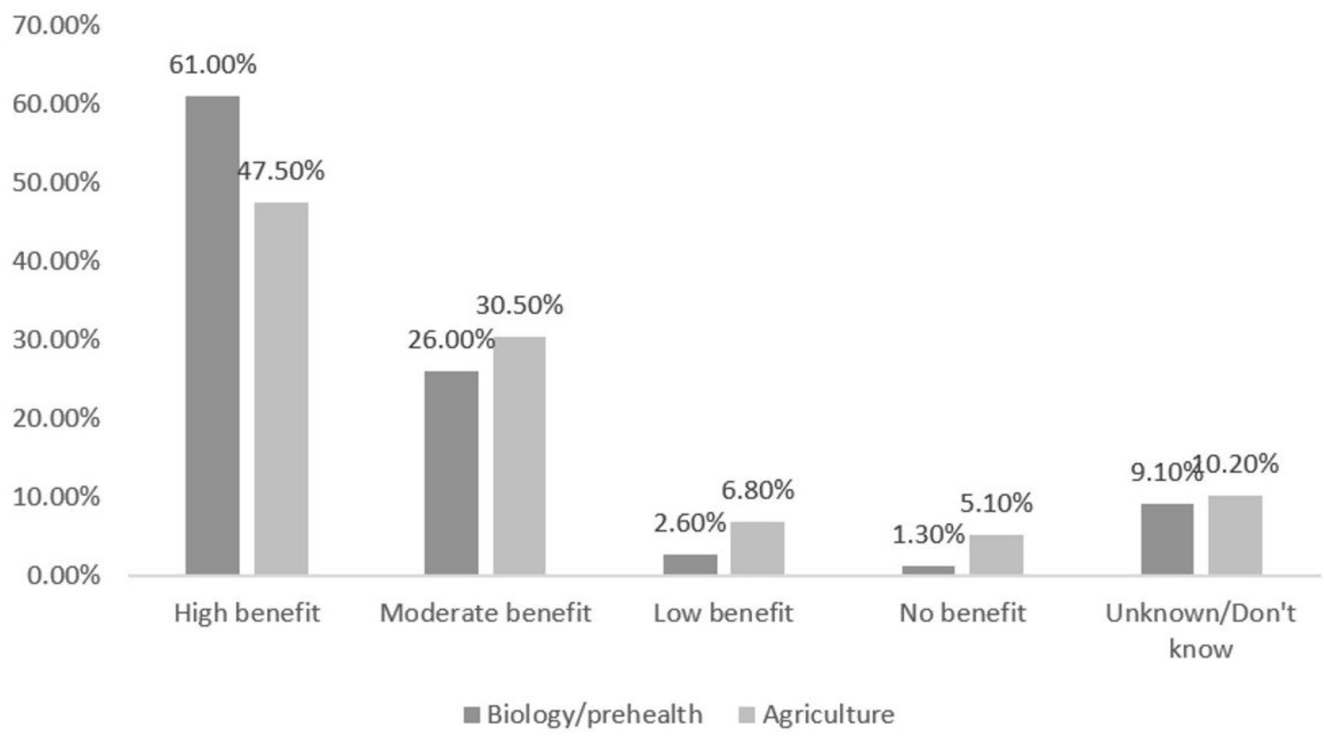

FIG 2 Comparison of frequency of responses assessing the level of perceived benefit of antibiotic resistance education between Biology/Pre-Health and Agriculture undergraduates. Undergraduate students in Biology/pre-health and Agriculture programs were assessed on their perceived benefits of antibiotic-resistance education using Question I from Section IV of the survey in Appendix B. Students rated their level of agreement or disagreement with statements about the value of further education on antibiotic resistance stewardship using a Likert scale. In this scale, "high benefit" indicated a strong belief in the substantial benefits of such education, "moderate benefit" indicated a belief that education is somewhat beneficial, and "low benefit" indicated that respondents felt the benefits were limited or not significant.

between Biology/pre-health and Agriculture undergraduate students showed that both knowledge and the interest in additional education on antibiotic resistance increased as students move up in class classification.

Using the estimated knowledge of a senior undergraduate student in Biology and Agriculture majors as the baseline for the ordinal logistics regression analysis, the knowledge of antibiotics increases as students move up in class classification. The results suggested juniors and seniors (0.824, P-value < 0.05) being more knowledgeable of antibiotics and the meaning of antibiotic resistance than freshman (2.170, P-value < 0.05) and sophomores (1.895, P-value < 0.05) undergraduate students regardless of the academic majors. The difference in knowledge is statistically significant based on the class classification. When assessing the level of perception, regardless of the academic majors, juniors (3.477, $P > 0.05$) have a higher positive perception of the benefit of antibiotic resistance education than sophomore (0.725, $P > 0.05$); however, freshmen (0.511, $P > 0.05$) seem to have a slightly higher positive perception of benefit of antibiotic resistance education than sophomore students (0.725, $P > 0.05$). The differences are small between class classifications, and there is no statistically significant difference between class classification.

The results of the χ^2 analysis revealed a significant association between academic major and the level of perceived threat of antibiotic resistance X^2 (4, $N = 136$) = 15.067, $P < 0.05$ (see Fig. 3).

The frequency of responses of questions assessing how Biology/pre-health and Agriculture undergraduate students perceived antibiotic resistance as a threat is shown in Table S6 in Appendix D. The questions are all related to assessing the level of perceived

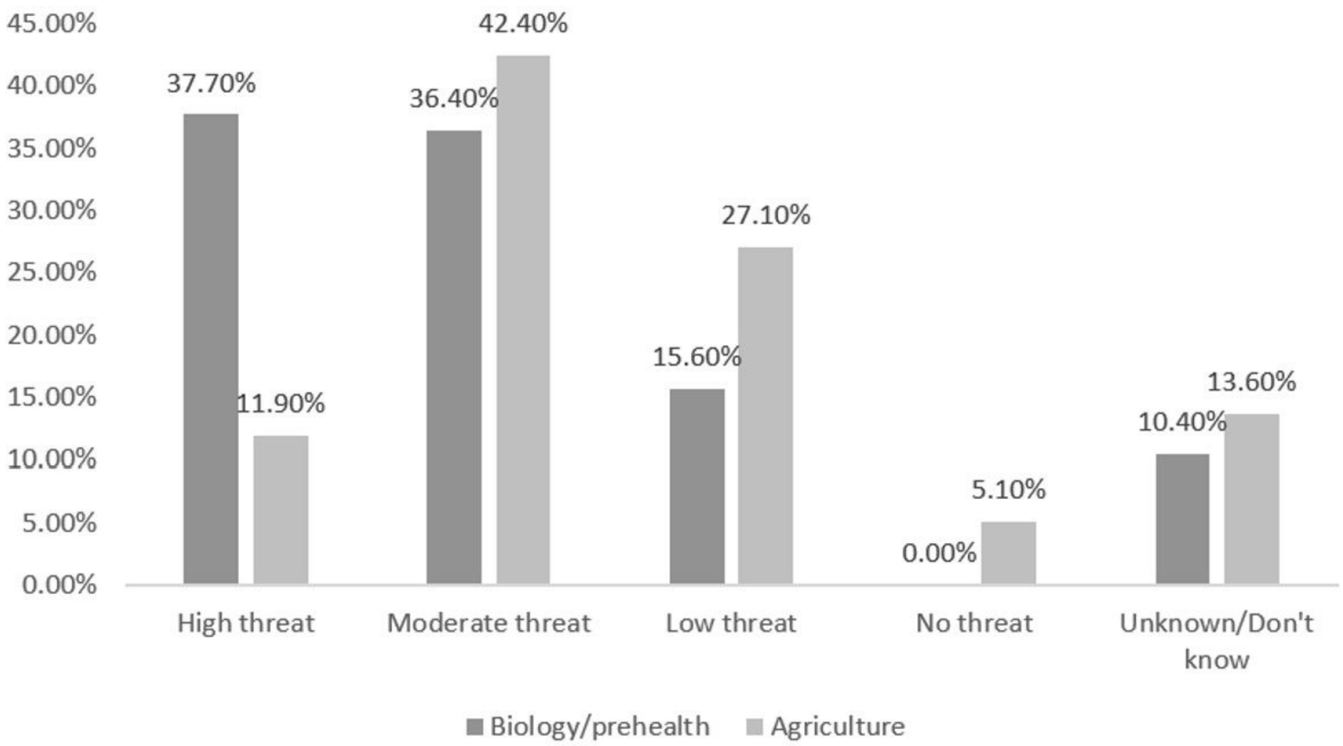

FIG 3 Comparison of frequency of responses assessing the level of perceived threat of antibiotic resistance between Biology/Pre-Health and Agriculture undergraduates. Undergraduate students in Biology/pre-health and Agriculture programs were assessed on their perceived threat of antibiotic resistance using question I from section III of the survey in Appendix B. Students rated their perceived threat of antibiotic resistance using a Likert scale. In this scale, "high threat" indicated that respondents perceived antibiotic resistance as a very significant threat, "moderate threat" indicated that respondents viewed it as a notable threat, though not as severe, and "low threat" indicated that respondents perceived it as a minor concern.

threat as well as the impact of antibiotic resistance based on the academic major. The results of the analysis suggest when it comes to the danger of antibiotic use globally and in farming, the perception of threat between the two groups of students differ statistically, but as shown in Table 6 (see Appendix D), the perception of the threat of antibiotic resistance in term of efficacy in treatment and how it will affect their families are not statistically different between the two majors.

The results of the ordinal logistics regression analysis to investigate the potential relationship between class classifications and the perceived level of threat of antibiotic resistance showed that juniors (0.804, $P < 0.05$) perceived antibiotic resistance more as a threat than sophomores students (1.389, $P < 0.05$). However, there is a gap between freshmen and sophomore where in this instance, freshmen view antibiotic resistance more as a threat than sophomores (0.862, $P > 0.05$). This result is not statistically significant. Overall, regardless of the academic major, there was a significantly higher probability juniors, and seniors have a higher perception of the threat of antibiotic resistance than freshman and sophomore students. The results are statistically significant suggesting that class classification is indeed a possible predictor for evaluating the level of perceived threat of antibiotic resistance between Biology/pre-health and Agriculture undergraduate students.

As this study suggested that class classification could potentially influence the perception and knowledge of these particular topics, additional χ^2 analysis was conducted to evaluate whether particularly seniors of both majors differed significantly in their overall knowledge of antibiotics, perception of antibiotic resistance as a threat and recognition of the benefits of antibiotic education. A total of 59 students were identified as seniors. Thirty students were identified a Biology seniors, and 28 students were identified as Agriculture seniors. The results of the χ^2 analysis revealed a significant difference between Biology seniors and Agriculture seniors on their overall knowledge of antibiotic and antibiotic resistance [X^2 (2, $N = 59$) = 8.351, $P < 0.05$], on their perceived benefits of antibiotic education [X^2 (4, $N = 59$) = 12.574, $P < 0.05$], and on their perceived threat of antibiotic resistance. The distributions of answers among seniors are depicted in Fig. 4 to 6.

DISCUSSION

Based on this study, when it comes to knowledge of antibiotic resistance between Biology/pre-health undergraduate students and Agriculture undergraduate students, there is minimal to no significant difference in knowledge between the two groups. Both groups of students seem to be knowledgeable as to what antibiotics do and the role of antibiotic resistance (see Fig. 1). Based on this study, there was no statistically significant difference in the perceived benefit of antibiotic resistance education for future prescribers (see Fig. 2). Both groups of students saw a benefit in the education of antibiotic resistance. When assessing if they perceived a benefit of education on antibiotic resistance at the undergraduate level, both Biology/pre-health undergraduate students and Agriculture undergraduate students strongly agreed that they can contribute to the work being done to control antibiotic resistance. They also strongly agreed that education and training on the appropriate use of antibiotics at the undergraduate level were beneficial. However, there was a statistically significant difference in the perceived threat of antibiotic resistance not only globally but also to human health between Biology/pre-health and Agriculture undergraduate students. The majority of Biology/pre-health undergraduate students rated the perceived threat of antibiotic resistance as high or moderate, whereas the majority of Agriculture undergraduate students rated the threat of antibiotic resistance as moderate or low (see Fig. 3). This suggests that Biology/pre-health students are more aware of the damage antibiotic resistance can cause in disease treatments and individual health, as those concepts are more of a focus in the courses Biology/pre-health students take. Agriculture students seem to be less interested in the threat of antibiotic resistance in human health. The perception of threat between both groups of students differs statistically when it comes to the

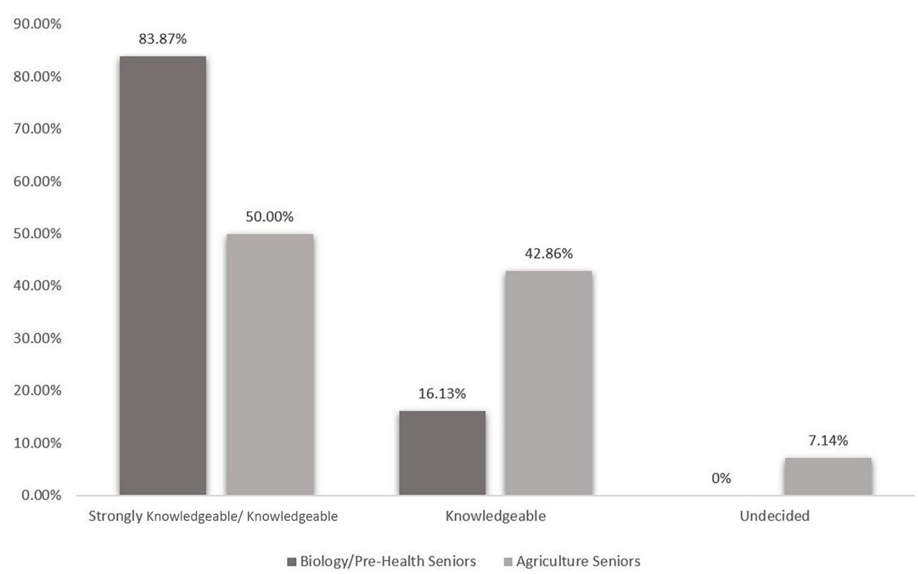

FIG 4 Comparison of frequency of responses assessing the overall knowledge of antibiotic and antibiotic resistance between Biology/Pre-Health seniors and Agriculture seniors. Undergraduate senior students in Biology/pre-health and Agriculture programs were assessed on their overall knowledge of antibiotic resistance using question I from section II of the survey in appendix B. Students rated their confidence in and depth of understanding of antibiotic resistance using a Likert scale. In this scale, “strongly knowledgeable” indicated a high level of proficiency in understanding, applying, and analyzing the concept of antibiotic resistance, while “somewhat knowledgeable” indicated a foundational understanding of the topic.

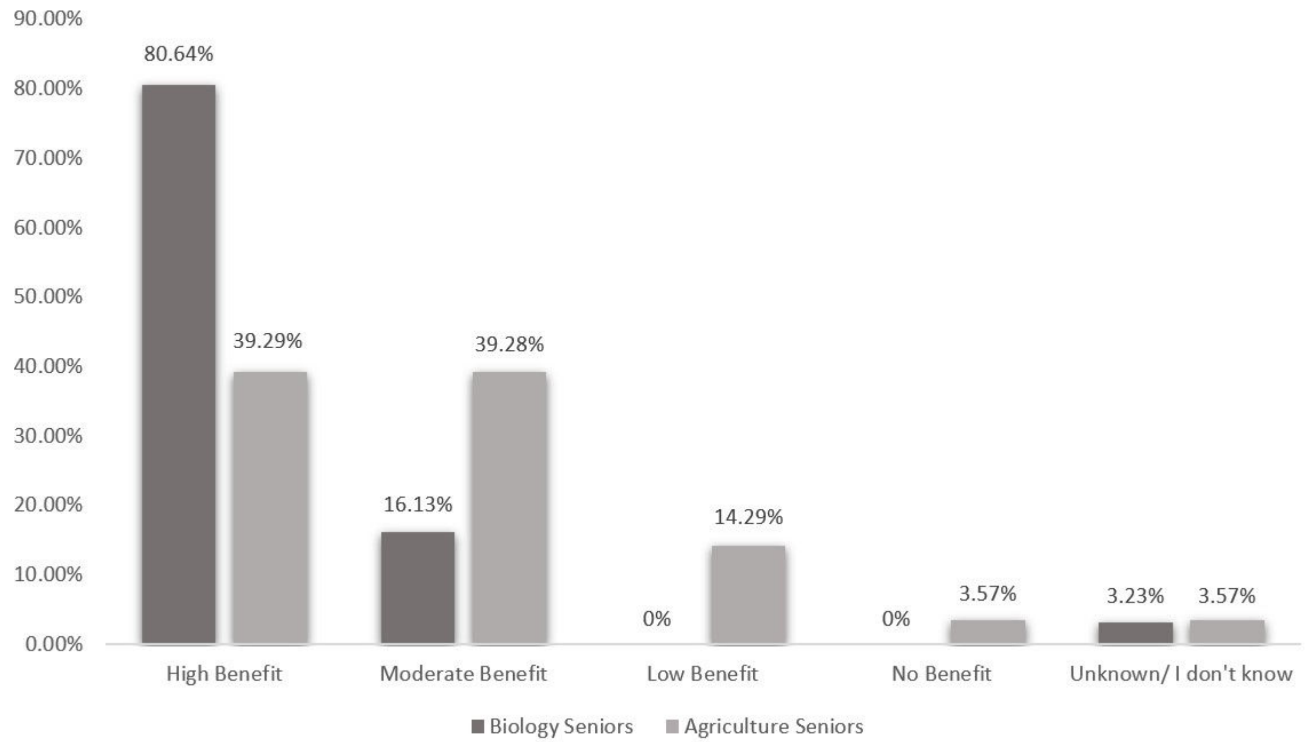

FIG 5 Comparison of frequency of responses assessing the overall perceived benefits of antibiotic resistance education between Biology/Pre-Health seniors and Agriculture seniors. Undergraduate senior students in Biology/pre-health and Agriculture programs were assessed on their overall knowledge of antibiotic resistance using question I from section II of the survey in appendix B. Students rated their confidence in and depth of understanding of antibiotic resistance using a Likert scale. In this scale, "strongly knowledgeable" indicated a high level of proficiency in understanding, applying, and analyzing the concept of antibiotic resistance, while "somewhat knowledgeable" indicated a foundational understanding of the topic.

health damage that can be caused by the frequent use of antibiotics in farming. The Biology/pre-health undergraduate students tended to strongly agree that antibiotic resistance is a threat to their health and their family's health and a major health issue globally. By contrast, Agriculture undergraduate students tended to view the threat of antibiotic resistance moderately, especially when it comes to the threat of the use of antibiotics in farming in relation to the danger to human health.

The logistic regression analysis revealed that class classifications may influence perceptions and knowledge regarding antibiotic resistance, the perceived threat of antibiotic resistance, and the overall benefit of antibiotic resistance education. When comparing these variables among seniors from both majors, the results indicated that Biology seniors exhibit greater knowledge of antibiotic resistance, perceive it as a greater threat, and recognize the benefits of antibiotic resistance education compared to Agriculture senior students. Consequently, these findings suggest that differences in curriculum between the majors can directly impact the knowledge and perception of the variables analyzed in this study.

These results are not surprising for Fort Hays State University. Although the Microbiology courses offered at this institution follow the recommendation guidelines of ASM, the amount of information covering antibiotic resistance among Biology/pre-health and Agriculture undergraduate students differs not only at FHSU but also in most 4-year academic institutions (20). Particularly at FHSU, the Pre-Health program and some sections of the Animal Sciences curriculum emphasize biological concepts in disease, epidemiology, and disease prevention, while the Agriculture curriculum emphasizes animal health, focusing primarily on socioeconomic values and mass animal production. Consequently, the differences in curriculum highlighted in Table 2 would influence the survey responses. Notably, variations emerge in how these two groups perceive the

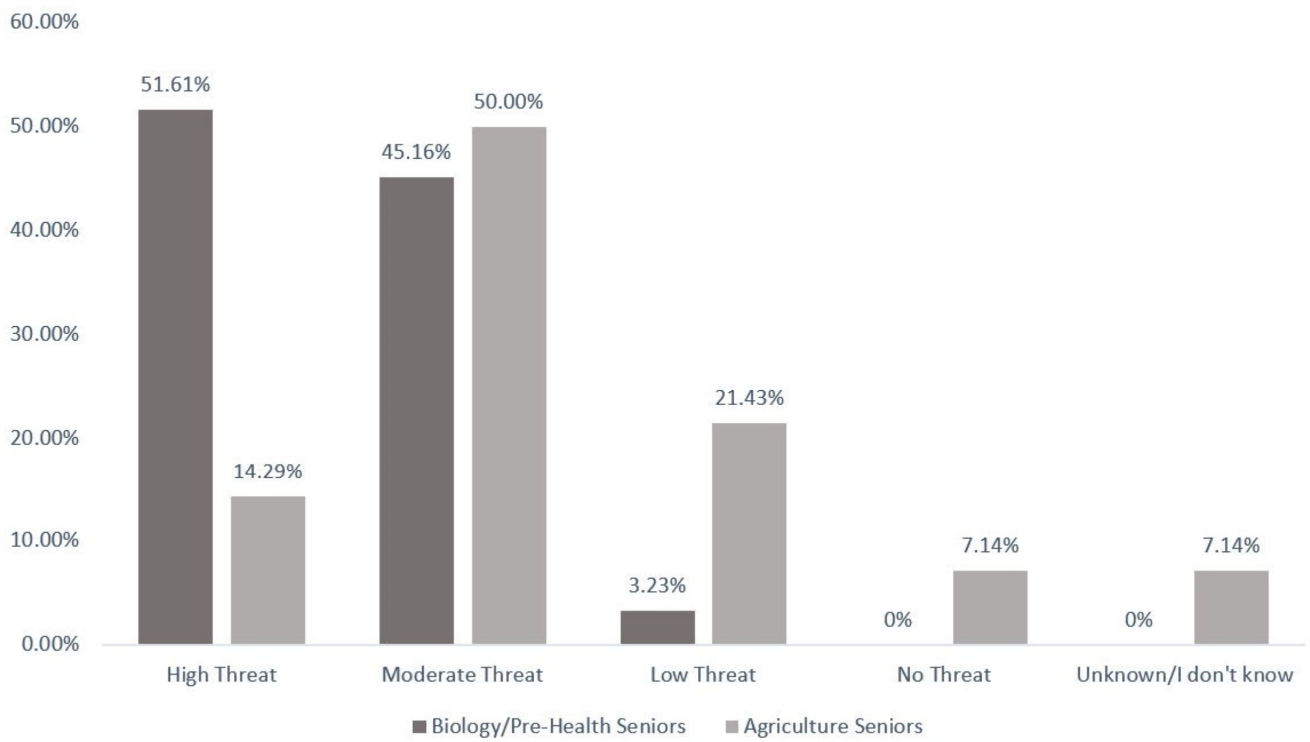

FIG 6 Comparison of frequency of responses assessing the overall perceived threat of antibiotic resistance between Biology/Pre-Health seniors and Agriculture seniors. Undergraduate senior students in Biology/pre-health and Agriculture programs were assessed on their perceived threat of antibiotic resistance using question I from section III of the survey in appendix B. Students rated their perception of the threat posed by antibiotic resistance using a Likert scale. In this scale, "high threat" indicated that respondents perceived antibiotic resistance as a very significant threat, "moderate threat" indicated that respondents viewed it as a notable threat, though not as severe, and "low threat" indicated that respondents perceived it as a minor concern.

frequent use of antibiotics as a risk, particularly in human medicine (20). Biology students are exposed to and tend to acknowledge the link between frequent use of antibiotics and patient health, whereas Agriculture students have been less exposed to the risk of the frequent use of antibiotics on an individual's health (21). A part of this difference between the two groups may also be attributed to the lack of evidence of the degree and relative impact on the dissemination of antibiotic resistance on human health (21).

The findings relate to Aslam et al. (22) who reported that ASP guidelines have not been successfully implemented in agriculture settings due to the lack of reliable data about the quantity and patterns use of antibiotics in relation to threat. Hence, most Agriculture students do not perceive antibiotic resistance as a threat. This perception may be attributed to the fact that there is no direct link between the frequent use of antibiotics and livestock health. Most antibiotic-resistant pathogens are human pathogens, such as *Staphylococcus aureus*, *Klebsiella pneumoniae*, and nontyphoid *Salmonella* and *Mycobacterium tuberculosis*, therefore do not apply to animal health directly.

Ample active learning pedagogies on antibiotics and their role in society are emphasized in the curriculum for Biology/pre-health nationwide (23). Courses, such as Immunology, Microbiology of Pathogens, and Virology, are courses examples in which lecture topics highlight the importance of antimicrobial properties and functions at Fort Hays State University. With enough repetition on the topic, it is easier for one academic group to be more aware of the importance of antibiotics and the threat of antibiotic resistance relative to a patient's treatment course.

Hope is not lost. Even though Agriculture students perceive that they already have a good grasp of knowledge on antibiotic resistance, they do not perceive antibiotic resistance as a threat, and they do want to have more information about the topic. For many years, public health organizations have been advocating for the implementation of strategies that allow the next generation of antibiotic prescribers in medicine and agriculture to be better prepared for the appropriate use of antibiotics and other antimicrobials and to combat antimicrobial resistance (24). The undergraduate training track is the time when knowledge, attitudes, and behaviors of future prescribers are shaped. Education about prudent antibiotic prescribing and stewardship could be significantly effective in minimizing antibiotic resistance (13). At a time when resistance is being acknowledged as a serious public health problem, this small study shows that, although undergraduates in Agriculture perceived antibiotic resistance as less threatening than undergraduates in Biology/pre-health, both undergraduate groups are knowledgeable of the problem and would like more academic education on the issue. This finding creates a good foundation for initiating curriculum development to meet ASP goals and objectives. The divergence in courses completed by the different groups warrants analysis, as it can shed light on how specific classes may influence survey responses. This could provide valuable insights into the knowledge and perceptions of the threat posed by antibiotics.

This is the first study to assess and compare perceptions and knowledge of antibiotic resistance and stewardship among undergraduate students majoring in Biology/pre-health and Agriculture in Western Kansas. Given the importance of antibiotic and other antimicrobial resistance worldwide and the ambiguous use of antibiotics in both medicinal and agricultural purposes, the evaluation of knowledge and perception of antibiotic resistance can help guide the development of optimal training in antibiotic practices in future prescribers at the undergraduate level (4). Currently, little is known about how knowledgeable Agriculture undergraduate students are on the topic of antibiotic resistance, and little is known about how they perceived this threat and how they perceived the benefit of antibiotic resistance education. Consequently, this study presents useful data at the undergraduate level. The ultimate question is when education of antibiotic and other antimicrobial stewardship should start. As the importance of undergraduate training in the prudent prescribing of antibiotics has become increasingly recognized, a robust and transparent framework for curriculum development at all stages of undergraduate education should be the goal for both Agriculture and Biology/pre-health courses (25). Recommendations on the development of learning outcomes should be re-examined to create a foundation and transfer of basic antibiotic resistance science knowledge through the different class classifications. If training starts early in the curriculum of undergraduates, postgraduate education could then focus on the implementation and measurement of practice, with additional supportive and restrictive measures (25).

Still, further studies on the assessment of knowledge and attitudes of Agriculture undergraduate students on antibiotic resistance and stewardship should be further carried out to get a clear understanding of the gap that can exist between Biology/pre-health student and Agriculture students. While the primary goal of this study was to investigate if differences in perceptions and knowledge of antibiotic resistance between Agriculture and Biology students existed at FHSU, extending the scope of this research to encompass surveys from multiple institutions or conducting longitudinal surveys over multiple years at FHSU could offer a more comprehensive understanding of trends in antibiotic resistance perceptions among undergraduate students. Additionally, exploring the influence of other sociodemographic factors such as gender and race could provide valuable insights for future studies, especially after establishing significant distinctions between the two majors.

I also recommend further studies to consider the possible correlation between undergraduate training and becoming good stewards of antibiotic prudent practices. As the demand for antibiotic education increases, focusing on an adapted undergraduate curriculum for pre-health as well as Agriculture that teaches all the necessary principles of microbiology and infectious diseases with an important emphasis on the principles of prudent antibiotic stewardship can help the dissemination of antibiotic resistance and advocate for the prudent use of antibiotic both in the medical and agriculture fields. Despite what we know and understand about antibiotic resistance, much is still unknown about educational approaches to antibiotic and other antimicrobial resistance stewardship (26). As Silverberg (13) stated, there has been no evaluation of the best practice for teaching antibiotic resistance stewardship at the undergraduate level. Still, knowing our undergraduate students, particularly in the health and agriculture fields, are interested in knowing more about stewardship, there is perhaps a possibility to develop novel and optimum learning outcomes and training courses to foster a culture of antibiotic stewardship at the undergraduate level.

This study had some limitations that could affect the generalization of the findings to other contexts (27). The study relied solely on data from the survey that was distributed to Biology/pre-health and Agriculture undergraduate students at a single university. The findings are limited to one institution in western Kansas and do not necessarily reflect the perceptions of students at other institutions. It is worth noting that the survey did not distinguish between the different degree options for either major. Pre-vet students could pursue majors in Agriculture or Biology. Although the results presented above do not account for specific degree options within each major other than Biology/pre-health, it is crucial to emphasize that the curricula and degree outcomes of foundation courses appeared consistent for both Agriculture/pre-vet students and Biology/pre-health students. However, given the similar classes shared by some tracks of Agriculture major, this would be important to consider for the future. Moreover, the survey did not inquire about prior core coursework. Ideally, all respondents categorized as sophomores and above Biology/pre-health and Agriculture/pre-vet would have completed Principles of Biology and Microbiology or other related courses covering to some extent the topic. On the contrary, for all other Agriculture majors apart from pre-vet, Microbiology is neither a requirement nor an elective. Thus, we can only assume that the aforementioned assumptions are accurate. This could potentially serve as a limitation to consider for future surveys.

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ADDITIONAL FILES

The following material is available online.

Supplemental Material

Appendixes A through D (S1 through S4) (jmbe00069-24-S0001.docx). Research questions and hypothesis; survey; coding analysis, Table S4a, Table S4b, Table S4c.

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