KNOWLEDGE OF ANTIMICROBIAL RESISTANCE AND ANTIBIOTIC USE AMONG STUDENTS IN A HEALTH OCCUPATION PROGRAM

by

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Abstract

The discovery of antibiotics was a revolution in history of medicine and resulted in many lives being saved. We are at risk of losing this advantage due to antimicrobial resistance (AMR). Students in health occupation programs need basic knowledge of antibiotic use and AMR if they are to be antimicrobial stewards. This study examined nursing students' knowledge of antibiotic use and AMR and stewardship using a cross-sectional, descriptive-correlational design. Response rate to the online survey was 8% (N = 25). Associations between knowledge of antibiotic use and AMR and respondents' perceptions of adequacy of antibiotic education as well as importance of this knowledge for their practice were examined. Findings suggest respondents' knowledge of antibiotic use (M = 90.7%, SD = 9.4%) was higher than their knowledge of AMR (72.3%, SD = 12.4%). While all respondents reported they had heard about antibiotic resistance, none reported familiarity with the term antibiotic stewardship.

Dedication

This thesis is dedicated to my family especially my sisters: Shukrallah, Halimah, Fatimah and Nafisah.

Acknowledgements

I appreciate the contributions of my supervisors and instructors for the constructive feedback and criticism they provided to guide my knowledge and skills to become better in crafting my ideas for this thesis.

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List of Abbreviations

AMR	Antimicrobial Resistance
BN	Bachelor of Nursing
CDC	Centers for Disease Control and Prevention
HCPs	Healthcare Professionals
PHAC	Public Health Agency of Canada
TCPS	Tri-Council Policy Statement
UNB	University of New Brunswick
UNBF	University of New Brunswick Fredericton
UNBSJ	University of New Brunswick Saint John

Chapter 1. Introduction

Students in most health occupation programs are required to complete courses in microbiology and pharmacology. Knowledge of microorganisms, such as bacteria, viruses, fungi, and parasites, is important as microorganisms are responsible for many diseases. In Canada, infectious diseases have resulted in approximately 4,000 deaths annually between 2016 and 2020 (Statistics Canada, 2022). Although advances in science have resulted in the development of antimicrobials (antibiotics, antivirals, antifungals, and antiparasitics), their effectiveness may decrease over time due to changes that occur naturally in many microorganisms (Aslam et al., 2018). Antimicrobial resistance (AMR) occurs as a result of an adaptive process in some microorganisms that renders medications used to treat infections ineffective (Prestinaci et al., 2015). In this chapter, AMR is discussed in terms of its importance, factors contributing to its development, and actions that can be taken to slow its development.

Antimicrobial Resistance and Its Importance

The discovery of antibiotics was a revolutionary moment in the history of medicine and has resulted in many lives being saved (Aslam et al., 2018). Unfortunately, we are at risk of losing this advantage because of the increasing incidence of AMR (Public Health Agency of Canada [PHAC], 2014). AMR is a serious public health problem because as antimicrobials lose their effectiveness, our ability to treat infection decreases which can increase morbidity and mortality (World Health Organization

[WHO], 2021). AMR can also increase the cost of infection management as the drugs required to combat these resistant infections tend to be more expensive to administer and monitor (PHAC, 2014). For example, polymyxin antibiotics which are considered the last line of defence against bacterial infections require a long duration of treatment with ongoing monitoring for toxicity. In addition, with fewer antibiotics currently under research and development relative to other medications, it is imperative to maintain the effectiveness of available antibiotics by addressing factors contributing to the development of AMR (Aslam et al., 2018; PHAC, 2014).

Factors Contributing to Antimicrobial Resistance and Preventative Actions

Although AMR occurs naturally, the actions of humans can contribute to its development. The major contributing factor to AMR development is the misuse or overuse of antimicrobials, especially antibiotics (WHO, 2021). It is estimated that of the 23 million antibiotic prescriptions written annually in Canada, between 30 and 50% are unnecessary (Fleming-Dutra et al., 2016; Public Health Agency of Canada [PHAC], 2016; Schwartz et al., 2020). For example, infections such as colds and influenza are self-limiting and usually do not require antimicrobials. Despite this, many people seek healthcare when they experience cold and influenza symptoms and expect to receive an antibiotic prescription (Public Health Agency of Canada [PHAC], 2017). To avoid patient dissatisfaction, some healthcare professionals (HCPs) may opt to write a prescription rather than take the time to educate patients on AMR. The inappropriate use of antimicrobials is not limited to medicine but also occurs in agriculture. Antibiotics are

used in agriculture to treat sick animals and promote their growth as well as to increase crop production; however, this practice has negative consequences as it can indirectly transmit resistant pathogens to humans (Bello-López et al., 2019; Mann et al., 2021; Thanner et al., 2016; Venter et al., 2017).

Inadequacies in implementing measures to prevent and control infections is another contributing factor in AMR development (PHAC, 2017; WHO, 2021). Key infection prevention and control measures include hand cleansing and respiratory hygiene (also known as cough etiquette), environmental hygiene, and vaccination (PHAC, 2017). Ideally, one should wash their hands with soap and water or use hand sanitizers with 60% to 95% alcohol for at least 20 seconds (Todd et al., 2010; Wolfe et al., 2016). Cough etiquette involves covering the mouth and nose with a tissue followed by hand cleansing (Centers for Disease Control and Prevention [CDC], 2016). Coughing in the elbow is an alternative when a tissue is not available (CDC, 2016). Environmental hygiene refers to practices to improve the conditions or surroundings in which people live that can affect their health and includes the availability of clean water, proper disposal of human and animal waste, and the safe handling and storage of food (European Environment Agency, 1993). Vaccination involves stimulation of the body's immune response to a specific microorganism which enhances the ability to fight future infections thereby reducing the need for antimicrobials (Baur et al., 2017; Mao & Chao, 2020).

A third factor contributing to AMR is limited access to or use of diagnostic tests that can rapidly and accurately identify the microorganism responsible for the infection

(Castro-Sánchez et al., 2016; PHAC, 2014). The availability of rapid and accurate diagnostic tests can help direct therapy targeting the specific infecting microorganism (Minejima & Wong-Beringer, 2016). Without diagnostic tests that will identify the specific microorganism causing an infection, inappropriate antimicrobials or broad-spectrum antimicrobials may be prescribed (Hsieh et al., 2022). This misuse of antimicrobials can also disrupt the body's normal beneficial microflora, leading to opportunistic infections; an example is *Clostridioides difficile* associated diarrhea.

Antimicrobial Stewardship

Antimicrobial stewardship is a term coined to describe actions to optimize the proper use of antimicrobials and reduce AMR development (Cunha, 2018; Dyar et al., 2017). All healthcare providers have a role to play in antimicrobial stewardship. To be an antimicrobial steward, healthcare providers need to critically evaluate the need for antimicrobial therapy and ensure its proper use (right agent, right dosage, and right timing), implement appropriate infection prevention and control measures, and educate patients about AMR and measures to reduce its occurrence (Doron & Davidson, 2011; Dyar et al., 2017).

Problem Statement and Significance of Research

To be antimicrobial stewards, students in all health occupation programs need to acquire basic knowledge of AMR, factors contributing to AMR, and actions they can take in their future practice to reduce AMR development. In the next chapter, the research that has been conducted to examine the knowledge level of AMR and antibiotic use among

students in health occupation programs is reviewed. Specific attention is given to the instruments developed to measure AMR knowledge and the content addressed. Findings from this review of the literature provide a foundation for an investigation of the knowledge level of students currently completing a Bachelor of Nursing (BN) program.

Chapter 2. Literature Review

All healthcare professionals, not merely those with prescribing privileges, have a role to play in stewarding the proper use of antimicrobials and reducing the occurrence of AMR. To assume this role, it is essential that students in health occupation programs acquire knowledge of the principles of antimicrobial stewardship. A literature review was conducted to retrieve and synthesize research studies investigating the knowledge of AMR and antibiotic use among students in health occupation programs.

Search Strategy

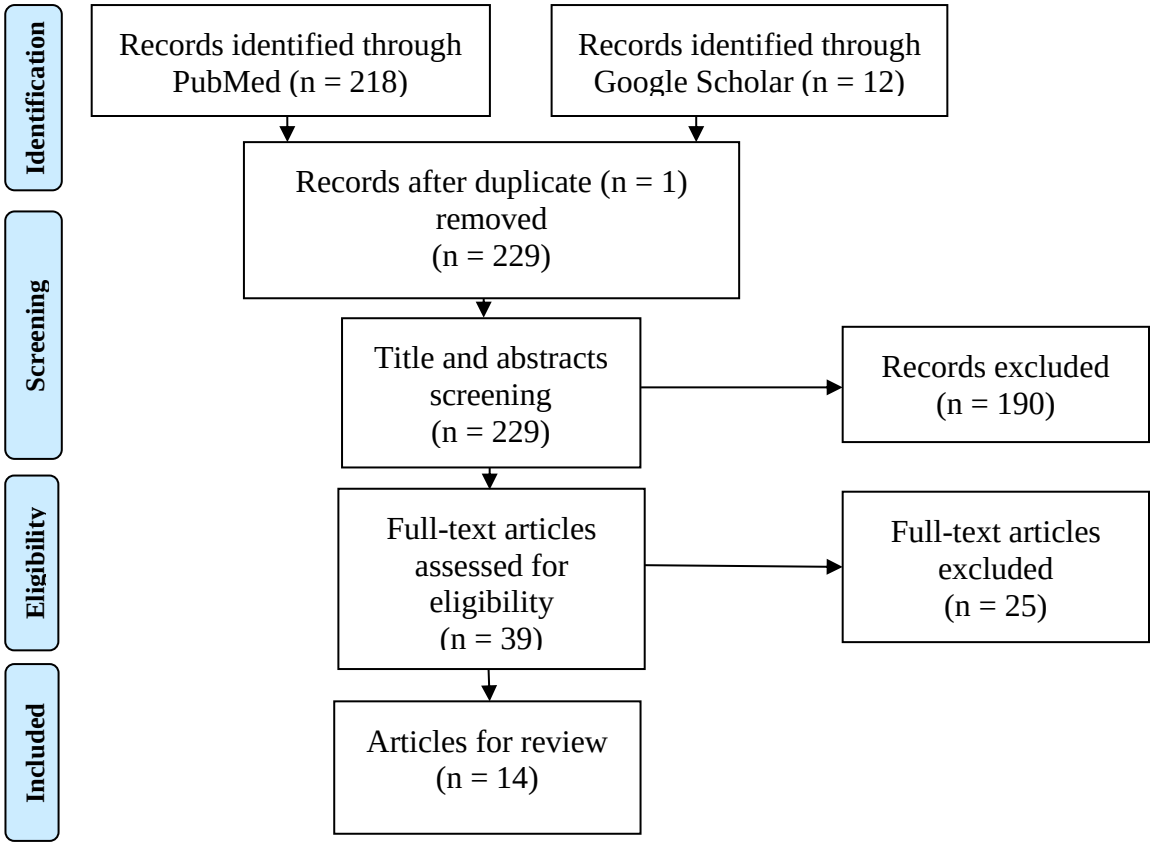
A search of the PubMed bibliographic database was conducted in August 2020 to retrieve research articles examining knowledge of AMR and antibiotic use among students in health occupation programs that were published in English. A date limit was not applied to the search strategy. Using PubMed's automatic term mapping feature which searches British and American spellings, singular and plural word forms, and other synonyms (Nahin, 2003), the database was searched for the terms 'antimicrobial resistance' and 'antibiotic use'. After searching each term individually, the searches were combined using the Boolean operator 'OR' to retrieve citations with either term. Next, a search was conducted using the Medical Subject Heading (MeSH) 'students, health occupations'. The default option of exploding the MeSH was used so MeSH terms for specific occupational groups that were indexed below were also included in the search (See Appendix A). Results of this search were combined with the first search using the Boolean operator 'AND' to narrow the retrieved citations to the population of interest

which resulted in 218 citations. The search was repeated using Google Scholar and an additional 12 citations were retrieved for a total of 230. The retrieved citations were exported to Mendeley, a reference manager software. After duplicates were removed, 229 citations remained.

The titles and abstracts of the 229 citations were screened to determine their relevance to the proposed study. To be included in the full review, citations had to be for a research study examining the knowledge of AMR and/or antibiotic use among students in health occupation programs. This screening resulted in the exclusion of 190 citations (See Figure 1). An additional 25 studies were excluded after the full-text review because they were conducted in countries where antibiotics can be obtained without a prescription which could affect utilization patterns (Prestinaci et al., 2015). A total of 14 research articles were retained and synthesized.

Figure 1

Search Strategy Flow Diagram



Summary of Retrieved Studies

The publication years of the 14 retrieved articles ranged from 2004 to 2019 with 12 published during the last decade (see Table 1). Eight of the studies were conducted in Europe (Dyar et al., 2013; Dyar et al., 2014; Dyar et al., 2018; Inácio et al., 2017; Rusic et al., 2018; Scaioli et al., 2015; Struzycka et al., 2019; Wright & Jain, 2004). Two studies were conducted in Australia (Sakeena et al., 2019; Weier et al., 2017), with one involving a comparison cohort in Sri-Lanka (Sakeena et al., 2019). The remaining four

studies were conducted in the USA (Ibia et al., 2005; Justo et al., 2014; Minen et al., 2010; Mohajer et al., 2017).

Eight of the retrieved studies were purely descriptive in nature. Three were descriptive-comparative (Justo et al., 2014; Sakeena et al., 2019; Weier et al., 2017) and the remaining three were descriptive-correlational (Ibia et al., 2005; Mohajer et al., 2017; Scaioli et al., 2015). All of the studies were cross-sectional, except one which was longitudinal (Mohajer et al., 2017). The sample size of the retrieved studies ranged from 52 to 1,050 with a median of 321 participants. Ten of the studies reported response rates which ranged from 8.3% (Sakeena et al., 2019) to 100% (Scaioli et al., 2015; Struzycka et al., 2019) with a median response rate of 40%. Ten studies involved students from a single health occupation while the remaining four included students from more than one health occupation. Not surprisingly, medical students were the most commonly investigated group involved in 10 of the studies (Dyar et al., 2013; Dyar et al., 2014; Dyar et al., 2018; Ibia et al., 2005; Minen et al., 2010; Mohajer et al., 2017; Rusic et al., 2018; Scaioli et al., 2015; Weier et al., 2017; Wright & Jain, 2004). Six studies investigated pharmacy students (Dyar et al., 2018; Inácio et al., 2017; Justo et al., 2014; Mohajer et al., 2017; Rusic et al., 2018; Sakeena et al., 2019), three included dentistry students (Dyar et al., 2018; Scaioli et al., 2015; Struzycka et al., 2019) and two studies investigated nursing students (Dyar et al., 2018; Scaioli et al., 2015). Eight of the retrieved studies limited their sample to students in their last two years of study (Dyar et

al., 2013; Dyar et al., 2014; Ibia et al., 2005; Justo et al., 2014; Rusic et al., 2018; Struzycka et al., 2019; Weier et al., 2017; Wright & Jain, 2004).

Survey Instruments

In 8 of the 14 studies, an instrument was specifically developed to measure students' knowledge (Dyar et al., 2013; Ibia et al., 2005; Inácio et al., 2017; Mohajer et al., 2017; Rusic et al., 2018; Struzycka et al., 2019; Weier et al., 2017; Wright & Jain, 2004). The measurement instrument developed by Dyar et al. (2013) was used in two subsequent studies (Dyar et al., 2014; Dyar et al., 2018), with a modified version used in 2018. The remaining four studies (Justo et al., 2014; Minen et al., 2010; Sakeena et al., 2019; Scaioli et al., 2015) utilized instruments that had been previously used in studies conducted by other research groups. Copies of the survey instruments were appended or provided as supplementary materials in ten of the retrieved articles (Dyar et al., 2013; Dyar et al., 2014; Dyar et al., 2018; Ibia et al., 2005; Inácio et al., 2017; Justo et al., 2014; Mohajer et al., 2017; Sakeena et al., 2019; Scaioli et al., 2015; Weier et al., 2017). Because Dyar and his colleagues used the same survey in two studies, nine unique surveys were available for critique.

An examination of the retrieved surveys revealed that various approaches have been used to measure knowledge. In four studies, the knowledge of AMR and antibiotic use was measured using clinical cases/vignettes and participants were asked to select the appropriate treatment option (Ibia et al., 2005; Justo et al., 2014; Mohajer et al., 2017; Weier et al., 2017). Ibia et al. (2005) based the correct responses on the Centers for

Disease Control and Prevention guidelines while Weier et al. (2017) used the Australian therapeutic guidelines. The resources used to determine best response were not identified by Justo et al. (2014) and Mohajer et al. (2017). In three studies, knowledge was examined by having respondents answer questions with dichotomized responses (Yes/No, True/False, Agree/Disagree; Dyar et al., 2018; Inácio et al., 2017; Sakeena et al., 2019). Six studies utilized Likert scale statements and respondents indicated their agreement with each statement, and their responses were dichotomized during analysis (Dyar et al., 2013; Dyar et al., 2014; Justo et al., 2014; Minen et al., 2010; Rusic et al., 2018; Scaioli et al., 2015).

The number of items used to measure knowledge in the surveys ranged from 8 to 29 (Median = 12). The knowledge content addressed in the 9 retrieved surveys was examined to identify commonalities. Knowledge content was grouped into 8 themes: (a) behavioural factors contributing to AMR, (b) indications for antibiotic use, (c) antibiotic side effects, (d) what constitutes AMR, (e) appropriateness of prophylactic antibiotic use, (f) antibiotics name recognition, (g) physiologic mechanism of AMR, and (h) organisms associated with AMR (see Table 2). The number of themes addressed in the surveys ranged from 2 to 7. The theme that was most consistently addressed was ‘behavioural factors contributing to AMR’ with items pertaining to this theme appearing in all surveys except for the one developed by Mohajer et al. (2017). The survey that contained items addressing the most themes (7 of the 8) was the one developed by Inacio et al. (2017).

Items dealing with “organisms associated with AMR” were not included in the survey by Inacio et al. (2017).

In addition to knowledge of AMR and antibiotic use, other concepts were addressed in some of the surveys. Attitudes (beliefs) toward antibiotic use and AMR development were examined in three surveys (Dyar et al., 2018; Justo et al., 2014; Weier et al., 2017). For example, Dyar et al. (2018) had respondents rate the relative importance of various contributors (e.g., over prescribing of antibiotics) to the development of AMR. Sources of antibiotic knowledge (e.g., grand rounds, lectures, rotations) were investigated in two surveys (Ibia et al., 2005; Justo et al., 2014). The adequacy of education/training on the proper use of antibiotics as well as students’ confidence in their ability to make appropriate treatment decision were examined in four surveys (Dyar et al., 2013; Inácio et al., 2017; Justo et al., 2014; Weier et al., 2017). However, analysis to examine the associations among these concepts and students’ knowledge of AMR and antibiotic use were not conducted in any of the studies.

Summary

The inconsistencies evident in the conceptualization and measurement of knowledge of AMR and antibiotic use made it difficult to synthesize the study findings in order to determine the knowledge level of students in health occupational programs. Because none of the 14 retrieved studies were conducted in Canada, the knowledge level of Canadian students is currently unknown. Given the importance of antimicrobial

stewardship, research is needed to address this gap. Findings from this research may assist educators in curriculum development.

Table 1

Summary of Studies Investigating Health Occupation Students' Knowledge of AMR and Antibiotic use (N = 14; ordered by year study completed)

Author, Year (Country)	Study Design	N (RR)	Student Groups	Survey Description
Wright & Jain, 2004 **(UK)**	Descriptive	52 (NR)	Medical, final year	- Number of items not stated - Identify generic name for 6 antibiotics - List 3 bacteria linked to antibiotic resistance - List 3 reasons why patients may not respond to antibiotic treatment - Estimate of hospitalized patients receiving antibiotics
Ibia et al., 2005 **(USA)**	Descriptive-correlational	934 (46%)	Medical, senior year	- 20-item knowledge of antibiotic use for upper respiratory tract infections survey (copy attached to article) - Compliance with CDC principles for management of 6 pediatric vignettes on upper respiratory tract infections - Vignettes on diagnostic choices, duration of symptoms, and influence of day care attendance - Familiarity with CDC principles and sources of knowledge - Perceived solution to antibiotic resistance

Author, Year (Country)	Study Design	N (RR)	Student Groups	Survey Description
				- Assessed relationship between sources of knowledge and compliance to CDC principles
Minen et al., 2010 **(USA)**	Descriptive	304 (30%)	Medical, year 1 to 4	- 35-item knowledge, attitude, and beliefs survey (Srinivasan et al., 2004) - Importance of knowledge of antibiotics - Sources of knowledge - Perception of overuse of antibiotics - Perception of need for additional education on antibiotic - Feedback and education on antibiotic selection - List organism presenting greatest resistance challenge
Dyar et al., 2013 **(France)**	Descriptive	60 (20%)	Medical, penultimate and final year	- 41-item knowledge, attitudes, beliefs, and practices survey (copy attached to article) - Knowledge of antibiotic prescribing, antibiotic usage, and resistance - Knowledge of prevalence of antibiotic resistance and misuse - Understanding of core antibiotic stewardship principles - Perception of antimicrobial resistance - Confidence in antibiotic prescribing - Education on antibiotic use - Contributors to resistance

Author, Year (Country)	Study Design	N (RR)	Student Groups	Survey Description
Dyar et al., 2014 **(Europe)**	Descriptive	338 (35%)	Medical, final year	- 41-item knowledge, attitudes, beliefs and practices survey (copy attached to article; see Dyar et al., 2013)
Justo et al., 2014 **(USA)**	Descriptive-comparative	579 (40%)	Pharmacy, final year	- 26-item survey adapted from one used for medical students (copy attached to article; Abbo et al., 2013) - Attitudes about antimicrobials and AMR - Awareness of AMR - Sources of and resources for antimicrobial education - Confidence in antimicrobial recommendations - Knowledge of antimicrobial use and resistance (8 clinical vignettes) - Perception of quality of education on antimicrobial use - Compares knowledge across USA schools
Scaioli et al., 2015 **(Italy)**	Descriptive-correlational	1050 (100%)	Health occupations, all years	- 31-item knowledge and attitude survey with 5 sections (copy attached to article; Huang et al., 2013) - Knowledge about antibiotics and adverse reaction - Awareness of antibiotic resistance - Attitudes and behaviors about antibiotic use - Consumption of antibiotics in previous year - Assessed relationship between antibiotic consumption and gender

Author, Year (Country)	Study Design	N (RR)	Student Groups	Survey Description
				- Assessed relationship between living with a healthcare professional and taking antibiotic without prescription - Assessed relationship between attitudes of antibiotic use and demographic variables (age, gender, nationality, degree program, relative/s in healthcare)
Weier et al., 2017 **(AU)**	Descriptive-comparative	191 (NR)	Medical, final year	- 40-item knowledge and confidence survey (copy attached to article) - Education on prescribing and infectious disease - Education satisfaction on infectious disease - Confidence in antibiotic prescribing - Knowledge of antimicrobial prescribing guidelines - Attitudes towards antimicrobial prescribing - Perceptions of AMR - Knowledge of antimicrobial prescribing (clinical cases) - Compares knowledge of infectious disease with cardiovascular disease
Inácio et al., 2017 **(UK)**	Descriptive	583 (32%)	Pharmacy, year 1 to 4	- 51-item knowledge and awareness survey (copy attached to article) - Knowledge of antibiotic use and antibiotic resistance - Perception of education received on antibiotics - Awareness of antibiotic stewardship

Author, Year (Country)	Study Design	N (RR)	Student Groups	Survey Description
Mohajer et al., 2017 **(USA)**	Descriptive-correlational	146 (NR)	Medical, pharmacy and medical residents NR	- 12-item questions (copy attached to article) - Knowledge at baseline, post-intervention and at 2-month follow-up - Knowledge on diagnosis and management of respiratory infections - Questions based on national guidelines - Assessed relationship between online education module and knowledge
Dyar et al., 2018 **(UK)**	Descriptive	255 (NR)	Medical, pharmacy, nursing, physician associate, dentistry, and veterinary students all years	- 25-item knowledge, attitudes, and behavior survey (copy attached to article) - Knowledge of antibiotic use and resistance - Attitudes towards antibiotic use and resistance - Practices towards antibiotic use and resistance - Awareness of antibiotic stewardship - Perceived importance of antibiotic resistance - Need for additional education on antibiotic use and resistance
Rusic et al., 2018 **(Croatia)**	Descriptive	161 (64%)	Medical and pharmacy,	- 50-item knowledge and attitude survey in 7 sections - Tested on dosing, treatment duration, efficacy, and treatment choice - Sources used for antimicrobial use and resistance knowledge - Knowledge of possible contributors to AMR

Author, Year (Country)	Study Design	N (RR)	Student Groups	Survey Description
			penultimate and final year	- Self-estimated readiness on tackling AMR - Education and education satisfaction on antimicrobials and resistance - Personal experience relevant to AMR - Attitudes and behavior on antimicrobials and AMR
Struzycka et al., 2019 **(Poland)**	Descriptive	752 (100%)	Dentistry, final year	- 28-item knowledge and attitude survey - Awareness of antibiotic prescribing and AMR - Attitude towards antibiotics - Indication for antibiotic therapy - Compliance of antibiotic prescription with therapeutic guidelines - Sources of knowledge on antibiotics and AMR
Sakeena et al., 2019 **(AU & Sri-Lanka)**	Descriptive-comparative	942 (8.3% and 63%)	Pharmacy, year 1 to 4	- 46-item antibiotic resistance survey (WHO, 2015) - Personal use of antibiotics, obtaining antibiotics, counselling during purchase - Tested on duration of antibiotic therapy, sharing antibiotics, symptoms justifying antibiotic use, and appropriate use of antibiotics - Compares knowledge of Australian pharmacy students to Sri-Lanka

Legend: AMR, antimicrobial resistance; AU, Australia; N, sample size; NR, not reported; RR, response rate; USA, United States of America; UK, United Kingdom

Table 2

Summary of Surveys with Themes on the Knowledge of AMR and Antibiotic use (Number of Surveys = 9; ordered by year study completed)

	First authors								
Themes	**Ibia**	**Dyar***	**Justo**	**Scaioli**	**Weier**	**Inacio**	**Mohajer**	**Dyar⌘**	**Sakeena**
Behavioural factors contributing to AMR	✓	✓	✓	✓	✓	✓		✓	✓
Indications for antibiotic use	✓			✓		✓	✓	✓	✓
Antibiotic side effects			✓	✓	✓	✓	✓	✓	
What constitutes AMR				✓		✓		✓	✓
Appropriateness of antibiotic prophylaxis			✓		✓	✓			
Physiological mechanism of AMR			✓			✓			
Antibiotic name recognition				✓		✓			
Organisms associated with AMR		✓							

*Survey used in Dyar et al. (2013; 2014) and ⌘Dyar et al., (2018)

Chapter 3. The Method

The purpose of this cross-sectional, descriptive-correlational study was to investigate the knowledge of AMR and antibiotic use among students enrolled in a health occupation program. Three research objectives were addressed in the study:

1. To describe the knowledge of AMR and antibiotic use among students enrolled in a health occupation program.
2. To examine correlations among students' knowledge of AMR and antibiotic use and their perceptions of the adequacy of antibiotic education in their program as well as the importance of this knowledge for their future practice.
3. To determine the amount of variability in students' knowledge of AMR and antibiotic use that can be explained by their perceptions of the adequacy of antibiotic education in their program and the importance of this knowledge for their future practice.

Population and Sample

Although the population of interest was students in all health occupation programs, the accessible population for the study was students enrolled in an undergraduate nursing program at the University of New Brunswick (UNB). Criteria for inclusion in the study was successful completion of courses in clinical microbiology and pharmacotherapeutics. To complete the survey, respondents had to be English speaking and have access to a computer/mobile device with internet connection.

Survey Instrument

For the study, a modified version of the "Knowledge and Awareness of Antibiotic use, Antimicrobial Resistance and Stewardship" survey was used. The survey was developed by Inacio et al. (2017) for pharmacy students and used in a subsequent study of nursing students conducted by Rábano-Blanco et al. (2019). The original survey consists of five sections. The first section captures demographic characteristics of respondents such as gender, age group, year of study, and anticipated practice area. The second section includes 12 items measuring knowledge of antibiotic use. The third section is comprised of 4 items examining students' awareness of antibiotic resistance and stewardship as well as 17 items on their knowledge of this topic. The fourth section contains 7 items that measure students' perceptions of the adequacy of antibiotic education in their program as well as 2 items on their perception of the importance of this knowledge for their future practice. The final section is an open-ended question that allows students to provide additional information, suggestions, and opinions about the topics of the survey.

To evaluate the clarity of the survey items and their appropriateness for the current study, the survey was reviewed by the thesis supervisors as well as instructors teaching clinical microbiology and pharmacotherapeutics to undergraduate nursing students (Senior Teaching Associate, Nancy Doiron-Maillet; Dr. Katherine Barclay; and Dr. Sarah Rigley MacDonald). Based on their feedback, the following modifications were made. First, two knowledge items addressing the physiological mechanisms by which bacteria develop resistance to antibiotics were removed since this content is not currently covered

in the clinical microbiology course (Dr. Rigley MacDonald, personal communication, March 25th, 2021). In addition, in the knowledge section of the survey, cefuroxime was substituted for cefotaxime, which is no longer commonly used in Canada (Senior Teaching Associate, Doiron-Maillet, personal communication, March 8th, 2021). The word *killing* in item 12 was changed to *destroying* to encompass both bactericidal and bacteriostatic antibiotics (Senior Teaching Associate, Doiron-Maillet, personal communication, March 8th, 2021). The response options of two items addressing students' perceptions of the importance of knowledge of antibiotics and of microbial and infection control for their future practice were changed from dichotomous (Yes/No) to a 10-point numerical rating scale to increase the variability in responses. The revised version of the survey consists of 48 items (see Appendix B).

Study Protocol

The survey was administered electronically via Microsoft Forms to provide respondents with access without creating a user account other than their university account. The survey was created so it could only be completed once and responses were anonymous. Microsoft Forms was set up to assign a unique serial number (pseudo-identifier) that reflects the order the surveys were submitted. Respondents' name or other personal information that could be used to identify specific individuals were not collected. An email inviting study participation was circulated through the BN program administrative offices to all students in the 3rd and 4th year of the basic BN program, and the 2nd year of the Advanced Standing BN program. The email was used to introduce the study, outline what participation involved, and provide a link to the survey. Following

this initial e-contact, e-reminders were circulated with the help of the BN program administrative assistants after 3 and 10 days to promote participation (See Appendix D). Initially, the plan was to deactivate the survey after 14 days of the initial contact with potential respondents. However, due to a lower than anticipated response rate, additional measures were implemented. A brief video inviting students to complete the survey was created and attached to the second e-reminder. In addition, I contacted the program directors to seek their suggestions for increasing participation. Based on their feedback, I joined a synchronous class on MS Teams to discuss the study with 3rd year students. An instructor also agreed to forward the e-invitation to 4th year students. The deadline for completion of the survey was extended by 10 days. After the survey was deactivated on MS Forms, responses were exported as a Microsoft Excel file and uploaded to the Statistical Package for Social Sciences (SPSS version 27).

Statistical Analysis

A preliminary check of the data was conducted to assess completeness as well as the presence of extreme or nonsensical values. Numerical descriptive statistics were generated for each of the survey items. Items were examined for the presence of missing data which could impact the computation of summative scores. For each of the 27 knowledge items, a new variable was created indicating whether the item was answered correctly. A value of 1 was assigned for "correct" responses and a value of 0 for "incorrect", "not sure", or missing responses. For each of the 7 items capturing respondents' perceptions of the adequacy of antibiotic education, a new variable was created with dichotomized responses. A value of 1 was assigned for "agree" responses

and a value of 0 for “disagree”, “not sure”, or missing responses. The internal consistency (homogeneity) of the responses to the newly created (dichotomized) knowledge and perception items were examined using Cronbach’s alpha. A Cronbach’s alpha of .70 or higher is typically used to indicate an acceptable level of internal consistency (Field, 2018). An examination of the descriptive statistics for the items and inter-item correlations was conducted to identify problematic items when an acceptable level of internal consistency was not obtained. New variables were created for each section (knowledge of antibiotic use; knowledge of antibiotic resistance and stewardship; combined knowledge of antibiotic use and AMR; perception of adequacy of antibiotic education and importance of knowledge for practice) by summing items. The summative scores for each section were converted into percentages.

Statistics of central tendency, variability, and shape were computed to describe characteristics of the respondents, their knowledge of AMR and antibiotic use, and perceptions of the adequacy of antibiotic education in their program as well as importance of this knowledge for their future practice. Decisions of the appropriate statistics were based on the variables’ level of measurement and characteristics of the data collected. An assessment was conducted to determine if the assumptions underlining regression analysis were satisfied. Bivariate Pearson’s correlations were conducted to examine the associations among the variables. Multiple linear regression analysis was used to determine the amount of variability in students’ knowledge of AMR and antibiotic use that can be explained by their perceptions of adequacy of antibiotic education in their program and importance of this knowledge. For all statistical tests,

alpha was set at .05 and a two-tail test was conducted. Responses to the open-ended question were reviewed to determine if they provided insights that would assist with the interpretation of the results of the quantitative analysis.

Ethical Consideration

Development of the proposed study was guided by the core principles of respect for persons, concern for welfare, and justice as outlined in the *Tri-Council Policy Statement: Ethical Conduct of Research Involving Humans – TCPS 2* (2018). Prior to commencement of the study, the proposal was reviewed by the UNB Research Ethics Board and is on file as UNB REB File #043-2021. Potential respondents were provided with a description of the study purpose and what participation involved. They were also informed that participation was voluntary, would have no impact on their grades and that their responses to the survey would be anonymous (see Appendix C). Given there is minimal risk associated with the study, written consent was not obtained. A disclaimer appeared at the end of the survey indicating that clicking the submit button implied informed consent to use the data for research purposes. Students were advised that although they would not benefit directly from participating in this study, findings may assist in curriculum development that may benefit future students. Data collected were saved on the UNB password protected and multi-factor authentication server and accessible only to the principal investigator and the thesis supervisors. Following completion of the Master of Applied Health Services Research Program and dissemination of findings, I will transfer the data files for safe keeping to my supervisors.

The data file, which contains no information that could be used to identify specific individuals, will be permanently deleted after 7 years.

Chapter 4. Findings

Accessible Population and Sample

Based on estimates provided by the administrative assistant for the various programs, 321 students received the e-invitations. A total of 27 surveys were submitted during the data collection period. Twelve (44%) submissions were received following the initial e-invitation. The first e-reminder resulted in nine additional submissions while the second e-reminder yielded three. The final contact with potential respondents resulted in three submissions. The overall response rate for the survey was 8%. Only 25 submissions met the inclusion criteria of successful completion of courses in clinical microbiology and pharmaco-therapeutics and were included in the analysis. The median time for completion of the survey was 5.6 minutes (Range = 1.3 to 50.1 minutes). Only two respondents took more than 8 minutes to submit the survey.

Of the 25 submissions, 12 (48%) were completed by students enrolled in the 3rd year of the BN program, 8 (32%) in the 4th year, and 5 (20%) in the 2nd year of the Advanced Standing program. The majority of respondents were between 20 to 25 years of age (76%) and self-identified as female (96%). When asked to indicate where they would like to practice after graduation, the majority indicated an area typically associated with acute care (e.g., surgical-medical, emergency, obstetric-gynecologic; see Table 3). Twenty-one (84%) reported having a family member or close friend who worked in a health-related field.

Awareness of Antibiotic Resistance and Stewardship

While all respondents reported they had heard about antibiotic resistance, only 22 (88%) reported that this issue had been discussed in their program of study. None of the respondents reported familiarity with the term antibiotic stewardship.

Table 3

Demographic Characteristics of Respondents (N = 25)

Characteristics	Response Options	n (valid %)
Age in years	< 20	0 (0.0%)
	20 to 25	19 (76.0%)
	> 25	6 (24.0%)
Gender	Male	1 (4.0%)
	Female	24 (96.0%)
	Other	0 (0.0%)
Future practice area	Surgical-medical nursing	7 (28.0%)
	Emergency nursing	5 (20.0%)
	Community nursing	2 (8.0%)
	Pediatric nursing	2 (8.0%)
	Obstetric-gynecologic nursing	2 (8.0%)
	Mental health nursing	1 (4.0%)
	Teaching	1 (4.0%)
	Other	1 (4.0%)
	Occupational nursing	0 (0.0%)
	Geriatric nursing	0 (0.0%)
	Undecided	4 (16.0%)
Family member or close friend in a health-related field		21 (84.0%)
Has heard about antibiotic resistance		25 (100.0%)
Discussed problem of antibiotic resistance in BN program		22 (88.0%)

Had heard about antibiotic stewardship	0 (0.0%)

Knowledge of Antibiotic Use

The 12 items measuring Knowledge of Antibiotic Use with the number and percentage of respondents answering them correctly is presented in Table 4. Three items were answered correctly by all respondents. Although all respondents correctly agreed that amoxicillin is an antibiotic and aspirin is not, only 56% correctly identified cefuroxime as a cephalosporin (an antibiotic class). While all respondents were correct as they disagreed that colds and coughs should always be treated with antibiotics for patients/clients to recover more quickly, only 88% were correct that antibiotic are not useful for viral infections. In addition, only 84% were correct that antibiotics cannot treat influenza and that the use of antibiotics to reduce any kind of pain and inflammation is inappropriate. Majority of respondents (96%) answered the following knowledge items correctly: (a) antibiotics may be stopped as soon as patients/clients start feeling better (disagree), (b) antibiotics should always be prescribed as preventive measure to fight against future infections (disagree), (c) antibiotics can cause allergic reactions (agree), and (d) antibiotics are useful for bacterial infections (agree). Finally, 92% were correct that secondary bacterial infections can be caused by antibiotics destroying good bacteria found in the body.

A Cronbach's alpha of .35 was obtained for the 12 Knowledge of Antibiotic Use items. The three items that were answered correctly by all respondents were not used in the determination of Cronbach's alpha because they had zero variance. Examination of

the inter-item correlations revealed that 24 of the 36 (66.7%) correlations were negative with coefficients ranging from -.18 to -.04. Fifteen of the twenty-four negative correlations (62.2%) involved two items (antibiotic are useful for bacterial infections; and antibiotics may be stopped as soon as patients/clients starts feeling better). Due to exploratory nature of the study and that the items were developed to measure knowledge of antibiotic use and were deemed by content experts to be appropriate and relevant, a new variable was computed to reflect the percentage of correct responses for the 12 items. The mean was 90.7% (SD = 9.4%) with scores ranging from 66.7% to 100.0%. Eighty-eight percent (n = 22) of respondents had a score of 80% and higher while 36% (n = 9) answered all items correctly.

Table 4

Number (%) of Correct Responses to Knowledge of Antibiotic Use Items (N =25)

Knowledge items	**Correct response**	**Number (%)**
Amoxicillin is an antibiotic	Agree	25 (100.0%)
Aspirin is an antibiotic	Disagree	25 (100.0%)
Colds and coughs should always be treated with antibiotics as patients/clients will recover more quickly	Disagree	25 (100.0%)
Antibiotics may be stopped as soon as patients/clients starts feeling better	Disagree	24 (96.0%)
Antibiotics should always be prescribed as preventive measure to fight against future infections	Disagree	24 (96.0%)
Antibiotics can cause allergic reactions	Agree	24 (96.0%)
Antibiotics are useful for bacterial infections	Agree	24 (96.0%)

Antibiotics can cause secondary infections after destroying good bacteria present in our body	Agree	23 (92.0%)
Antibiotics are useful for viral infections	Disagree	22 (88.0%)
Antibiotic are indicated to reduce any kind of pain and inflammation	Disagree	21 (84.0%)
Antibiotics cannot treat influenza	Agree	21 (84.0%)
Cefuroxime is a cephalosporin	Agree	14 (56.0%)

Knowledge of Antibiotic Resistance and Stewardship

The 15 items measuring Knowledge of Antibiotic Resistance and Stewardship with the number and percentage of respondents answering them correctly is shown in Table 5. All respondents correctly agreed with three items: (a) antibiotic resistance could be a greater clinical problem in my future career; (b) teaching healthcare students about antibiotics may help reduce the occurrence of antibiotic resistance; and (c) improving techniques for bacterial diagnostics will improve efforts to combat antibiotic resistance. The majority (96%) correctly agreed that inappropriate use of antibiotics causes antibiotic resistance, but only 60% understood that exposure to antibiotics is a principal risk factor for the development of antibiotic resistance and only 40% understood that even appropriate use contributes to the problem. Sixty-four percent were aware that the use of antibiotics in livestock production also contributes to antibiotic resistance. Although 84% correctly agreed that using narrow-spectrum therapy after identification and susceptibility testing helps minimize antibiotic resistance, only 68% correctly agreed that prescribing broad-spectrum antibiotic increases resistance. Interestingly, only 84% correctly agreed that infection control practices, such as hand hygiene, helps control antibiotic resistance

and only 72% correctly agreed that poor infection control practices by healthcare professionals can cause the spread of antibiotic resistance microorganism. Ninety-two percent correctly agreed that antibiotic resistance occurs when a bacterium loses its sensitivity to an antibiotic; however, only 8% correctly disagreed that antibiotic stewardship is a phenomenon for which a bacterium gains resistance to an antibiotic, which is the definition of antibiotic resistance. Eighty percent correctly agreed that antibiotics are overused nationally and internationally in healthcare while only 36% correctly disagreed that today's research in developing new antibiotics will be sufficient to meet future needs.

A Cronbach's alpha of .45 was obtained for the 15 Knowledge of Antibiotic Resistance and Stewardship items. Examination of the inter-item correlations revealed the 25 of the 66 (37.9%) correlations were negative with coefficients ranging from -.58 to -.03. Sixty percent of the negative coefficients were a result of two items (poor infection control practices by HCPs can cause spread of antibiotic resistance; and improved hand hygiene helps to control antibiotic resistance). The strongest negative correlations of -.58 was between the items "poor infection control practices by HCPs can cause spread of antibiotic resistance and "today's research in developing new antibiotics will be sufficient to meet future needs". Once again, because the items were deemed to have content validity, a new variable was computed by summing all 15 items and converting to a percentage of correct responses. The mean was 72.3% (SD = 12.4%) with scores ranging from 46.7% to 93.3%. Forty-four percent of respondents (n=11) had a score of 80% and higher.

Table 5

Number (%) of Correct Responses to Knowledge of AMR and Stewardship Items (N =25)

Knowledge items	**Correct response**	**Number (%)**
Antibiotic resistance could be a greater clinical problem in my future career	Agree	25 (100.0%)
Teaching healthcare students about the proper usage of antibiotics may help reduce the occurrence of antibiotic resistance	Agree	25 (100.0%)
Improving techniques for bacterial diagnostics will improve efforts to combat antibiotic resistance	Agree	25 (100.0%)
Inappropriate use of antibiotics causes antibiotic resistance	Agree	24 (96.0%)
Antibiotic resistance happens when a bacterium loses its sensitivity to an antibiotic	Agree	23 (92.0%)
Improving hand hygiene helps control antibiotic resistance	Agree	21 (84.0%)
Antibiotic resistance can be minimized by using narrow-spectrum therapy after identification and susceptibility testing	Agree	21 (84.0%)
Antibiotics are overused nationally and internationally in healthcare	Agree	20 (80.0%)
Poor infection control practices by HCP can cause spread of antibiotic resistance	Agree	18 (72.0%)
Prescribing broad-spectrum antibiotics increases antibiotic resistance	Agree	17 (68.0%)
Exposure to antibiotics appears to be the principal risk factor for the development of antibiotic resistance bacteria	Agree	15 (60.0%)
Use of antibiotics in livestock production and agriculture contributes to antibiotic resistance	Agree	16 (64.0%)

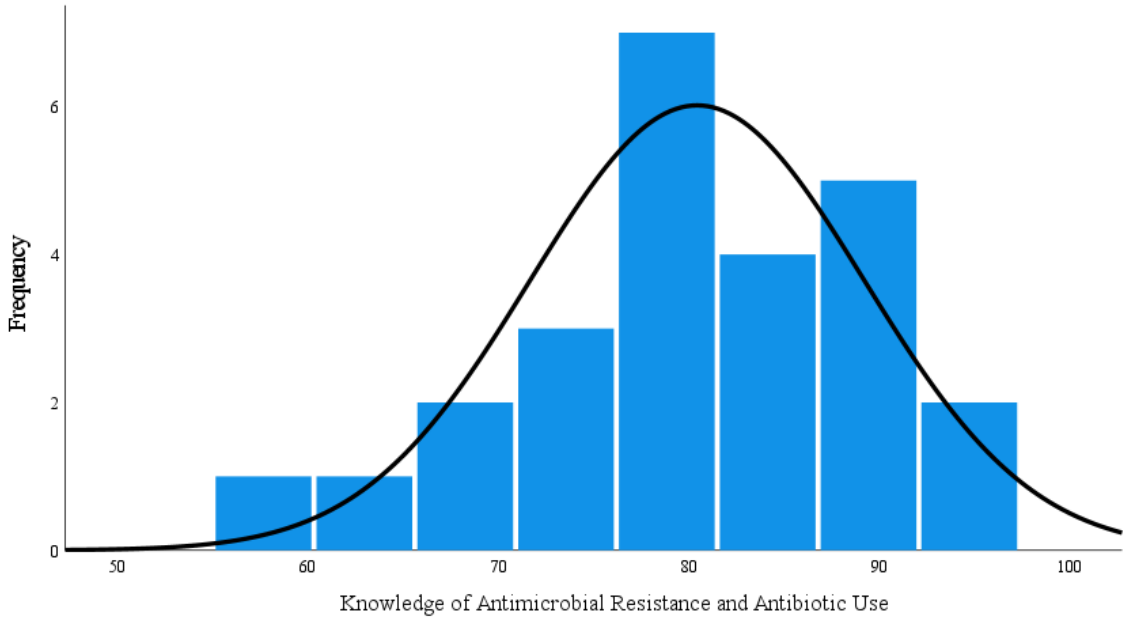
Appropriate use of antibiotics can cause antibiotic resistance	Agree	10 (40.0%)
Today's research in developing new antibiotics will be sufficient to meet future needs	Disagree	9 (36.0%)
Antibiotic stewardship is a phenomenon for which a bacterium gains resistance to an antibiotic	Disagree	2 (8.0%)

Knowledge of AMR and Antibiotic Use

The 27 items measuring Knowledge of AMR and Antibiotic Use yielded a Cronbach's alpha of .50. A new variable indicating the percentage of correct responses for the 27 items had a mean 80.4% (SD = 8.8%) with scores ranging from 59.3% to 92.6%. Fifty-six percent of respondents (n=14) had a score of 80% and higher. A histogram of the Knowledge of AMR and Antibiotic Use scores depicts that the distribution of scores approximates a normal bell-shaped curve (see Figure 2). Standardized skewness and kurtosis were calculated to be -1.54 and 0.11, respectively. In addition, a test of normality using Kolmogorov-Smirnov test revealed the distribution of scores did not deviate significantly from normal, statistic (25) = 0.15, p = .18.

Figure 2

Histogram: Distribution of Scores for Knowledge of AMR and Antibiotic Use (N = 25)



Perceptions of Adequacy of Antibiotic Education

The 7 items measuring respondents' Perceptions of Adequacy of Antibiotic Education with the number and percentage of respondents reporting sufficient education is presented in Table 6. Seventy-six percent of respondents reported having received adequate knowledge of proper antibiotic use, whereas only 12% reported being able to identify the best antibiotic for a specific infection. Sixty-four percent reported having sufficient education to handle clients/patients who demand antibiotic therapy when it is not indicated.

A Cronbach's alpha of .59 was obtained for the 7 Perceptions of Adequacy of Antibiotic Education items. Examination of the inter-item correlations revealed 3 of the 21 (9.5%) coefficients are negatives which ranged from -.09 to -.01. A new variable was computed indicating the percentage of responses for the 7 items denoting perceived adequacy of antibiotic education which has a mean of 42.9% (SD = 23.0%) and scores ranging from 0% to 100.0%. A histogram of the Perceptions of Adequacy of Antibiotic Education scores depicts a normal distribution (see Figure 3). Standardized skewness and kurtosis were calculated to be 0.85 and 0.18, respectively. The Kolmogorov-Smirnov normality test also suggested the distribution of perception scores were not statistically significantly different from a normal distribution, statistic (25) = 0.17, p = .052.

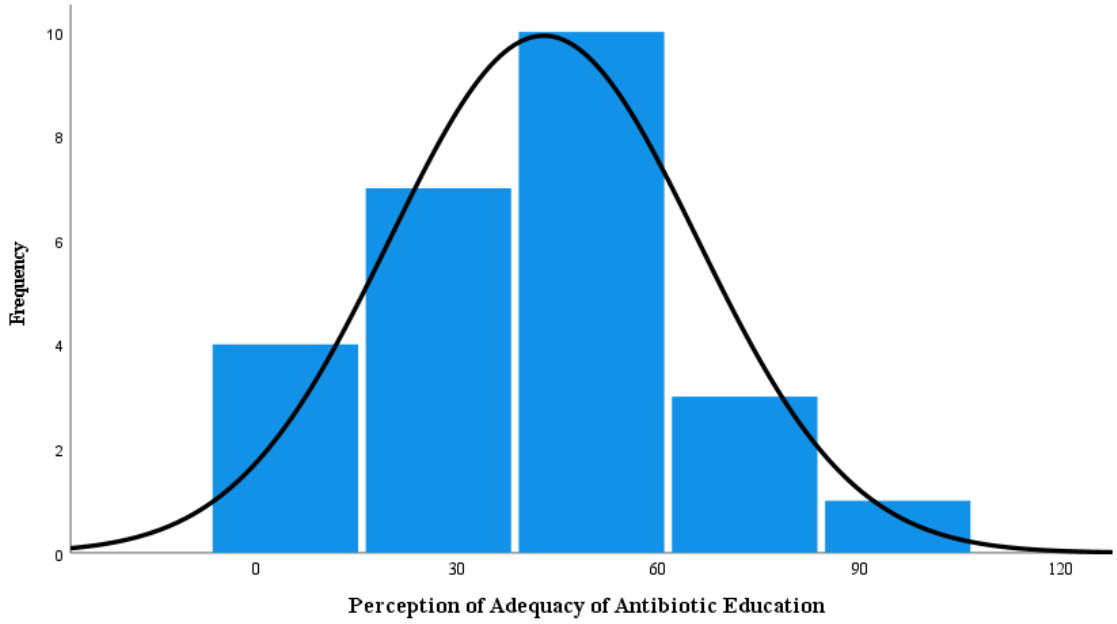
Table 6

Number (%) of Responses Indicating Perceived Adequacy of Antibiotic Education (N = 25)

Perception items	**Anticipated Response**	**Number (%)**
I have had sufficient education regarding appropriate use of antibiotics	Agree	19 (76.0%)
I have had sufficient education to understand the mechanisms of antibiotic resistance	Agree	18 (72.0%)
I have had sufficient education to handle a patient/client who demands antibiotics therapy when it is not indicated	Agree	16 (64.0%)
I have had sufficient education to identify an appropriate regimen (dose, route, and frequency) of antibiotic therapy	Agree	10 (40.0%)
I have had sufficient education to identify the best antibiotic for a specific infection	Agree	3 (12.0%)
I would like more education on antibiotic use, resistance, and stewardship	Disagree	2 (8.0%)
I would like more education on microbiology and infection control	Disagree	7 (28.0%)

Figure 3

Histogram: Distribution of Scores for Perceptions of Adequacy of Antibiotic Education (N = 25)



Perceptions of Importance of Knowledge of Antibiotics and Infection Control

Sixty percent of respondents rated the importance of knowledge of antibiotics for their future practice as 9 or 10 on a numerical rating scale with 1 being 'not important' and 10 being 'very important'. When asked to rate the importance of knowledge of microbial and infection control, 72% gave a rating of 9 or 10. A Cronbach's alpha of .90 was obtained for the 2 items on perceptions of importance. A new variable using summative score was computed with a mean of 18 out of 20 (SD = 2) and scores ranging from 14 to 20. Due to the nature of the distribution, the scores were recoded into three groups to indicate low (value 14 to 17), moderate (value 18 and 19), and high (value 20) importance.

Associations between Knowledge and Perceptions

The correlations among respondents' scores for knowledge and perceptions are presented in Table 7. Given how the variables were created, strong positive associations were observed between scores for the 12- and the 15-item sections and scores for the combined Knowledge of AMR and Antibiotic Use. The strongest correlation was between the Knowledge of Antibiotic Resistance and Stewardship and the combined scores (r = .89, p < .001) which may be due to more variability in the scores for Knowledge of Antibiotic Resistance and Stewardship. None of the correlations between the knowledge and perception variables attained statistical significance. However, the negative weak correlation between the Perceptions of Adequacy of Antibiotic Education and the Knowledge of AMR and Antibiotic Use (r = -.284, p = .17; see Figure 4) is noteworthy as it suggests respondents with higher scores on perceptions of adequacy tend

to have lower scores on the knowledge test. Likewise, the Perception of the Importance of Knowledge is negatively correlated with the combined knowledge scores, but the correlation is small, r = -.162. Lastly, a weak positive association was observed between the perceptions of adequacy of education and importance of antibiotic knowledge (r = .329) but was not statistically significant.

Table 7

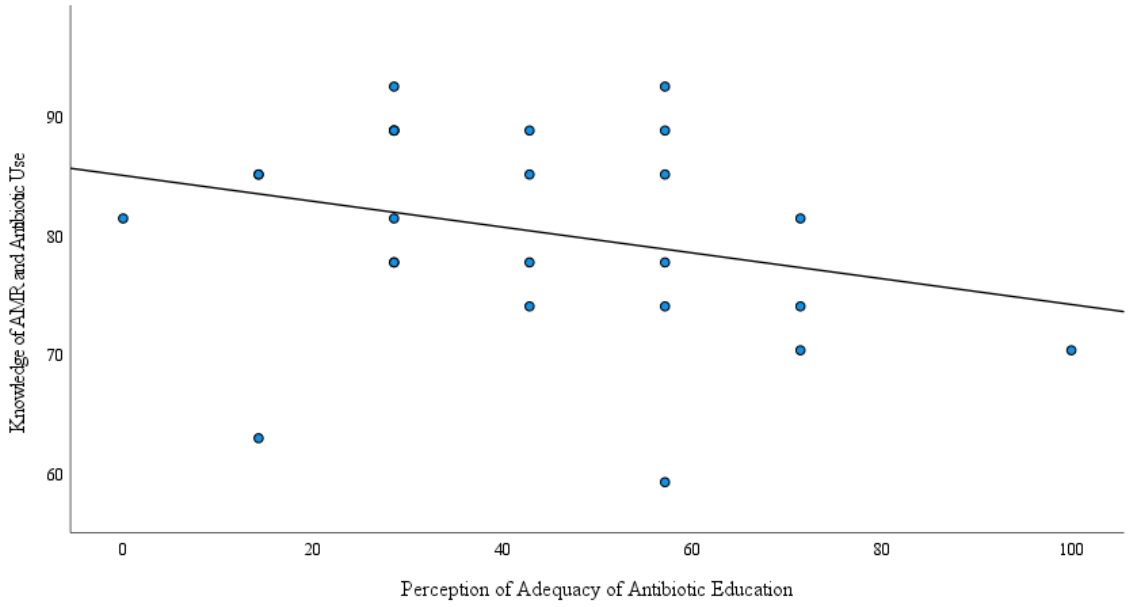
Correlation Matrix: Associations between Knowledge and Perceptions (N = 25)

	1	2	3	4
1. Knowledge of AMR and Antibiotic Use	1.00			
2. Knowledge of Antibiotic Use	.640 (.001)	1.00		
3. Knowledge of Antibiotic Resistance and Stewardship	.885 (<.001)	.208 (.318)	1.00	
4. Perceptions of Adequacy of Antibiotic Education	-.284 (.169)	-.161 (.443)	-.264 (.202)	1.00
5. Perceptions of Importance of Knowledge	-.162 (.438)	-.341 (.096)	.000 (1.00)	.329 (.108)

p-values in parentheses

Figure 4

Scatterplot: Association between Knowledge of AMR and Antibiotic Use and Perceptions of Adequacy of Antibiotic Education (N = 25)



Estimated Sample Size to Achieve Statistical Power

Given the lower than anticipated response rate, a post hoc power calculation was conducted using SPSS Power Analysis to determine the number of respondents that would be required to obtain statistically significant results. With an assumed power of .80, alpha preset at .05, and a correlation of .284, the estimated number of respondents to attain statistically significant results was 95. This estimated sample size was confirmed using G*Power version 3.1.9.7.

Explaining Variability in Students' Knowledge

A multiple linear regression was conducted to determine the amount of variance in students' Knowledge of AMR and Antibiotic Use that could be explained by their scores for the Perceptions of Adequacy of Antibiotic Education and the Perceptions of the Importance of Antibiotic Knowledge. Although the set of independent variables did not make a statistically significant contribution, they explained approximately 8.6% of the variance in knowledge, $R^2_{\text{unadjusted}} = .086$, $F_{(2, 22)} = 1.04$, $p = .37$. Given the result were not statistically significant, the unique contribution of each independent variable was not examined.

Respondents' Opinions on Topics Addressed in the Survey

When asked to provide additional information, suggestions, or opinions about the topics addressed in the survey, only two respondents opted to provide comments. Although this was insufficient to conduct qualitative analysis, both comments suggest the students perceived the courses in microbiology and pharmacotherapeutics to be valuable to their future practice. One respondent stated:

> The microbiology course taught to my class was not well geared towards nurses. A lot of this may have been becuase [sic] it was early during COVID and online classes were new. But al [sic] the lectures wer [sic] recorded years ago, and for example, when discussing Coronaviruses [sic], the only info was on SARS-Cov 1, and nothing else.
>
> (Male, 4th year BN, 82% combined Knowledge score)

The other respondent focused on the importance of antibiotic education saying:

> I realize as nurses we do not prescribe antibiotics, we often just follow MD orders, but we do administer and provide patient education so it is important to know.
>
> (Female, 3rd year BN, 89% combined Knowledge score)

Chapter 5. Discussion

This is the only study, to my knowledge, that has investigated the knowledge of AMR and antibiotic use among students in a health occupation program in Canada as well as their perceptions of the importance of this knowledge for their practice and the adequacy of education on these topics. Knowledge of AMR and measures to inhibit its development is important as inadequate knowledge could jeopardize our ability to prevent and treat infections. Studies conducted in other countries have indicated that students in health occupational programs have gaps in their knowledge about AMR and antibiotic use (Abbo et al., 2013; Dyar et al., 2018); however, it is unknown if such gaps exist among students in Canada. Findings from this study suggest that further investigation is warranted to assess the knowledge of antimicrobial resistance and stewardship of students in health occupation programs in Canada. Findings may be of interest to educators and those responsible for curriculum development.

Factors Affecting Survey Response Rate

Despite the implementation of measures aimed at encouraging participation which included sending an e-invitation and e-reminder with a link to a video introducing the primary investigator, speaking directly to students during online synchronous classes, distributing the survey during a period that was deemed to be less busy (i.e., after the rush of the first week of term but before assignments became due), as well as providing access to the survey over a 3-week period, the response rate for this study was lower than anticipated (8%). Considerable variability is evident in the response rates reported for previous investigations of students' knowledge of AMR and antibiotic use. In my review

of the literature, the 11 studies that reported response rates had rates ranging from 8.3% to 100% with a median rate of 40%. These rates are similar to those reported in a systematic review of 23 studies investigating medical students' knowledge of AMR and antibiotic use which ranged from 6% to 100% (Nogueira-Uzal et al., 2020).

A number of factors may have contributed to the response rates reported in the various studies. The duration that a survey is available may affect the response rate. In two studies that reported higher response rates, the surveys were available for a period of two months (100% response rate in Struzycka et al., 2019; 64% response rate in Rusic et al., 2018). The method used to deliver the survey may also have an effect on the response rate. A study involving Australian and Sri Lankan pharmacy students reported a 63% response rate for Sri Lankan students who completed a paper-based survey but only a 8.3% response rate for Australian students who completed an online survey (Sakeena et al., 2019). However, it is also possible that the observed difference in the response rates for the two groups of students may be due to social-cultural factors such as attitudes towards education and research. How the survey is introduced to potential respondents may also affect the response rate. Although my survey was distributed by administrative assistants for the nursing program, it was not directly endorsed by faculty members which could have impacted students' attention to the e-invitation. Scaioli et al. (2015) invited students to participate in a class activity facilitated by two faculty members which yielded a 100% response rate. However, it is possible that this high response rate was due to the survey being conducted during class time. This was not possible in my study due to restrictions imposed by the COVID-19 pandemic which included the use of alternative

delivery method of teaching and learning (i.e., online classes). In addition, the 4th year BN students were completing a concentrated clinical preceptorship and had no structured classes. A final factor that may affect response rates is the use of incentives such as a voucher for a free coffee. As an unfunded master student, I was unable to offer an incentive to encourage participation.

Knowledge of Antibiotic Use and Antimicrobial Resistance and Stewardship

Respondents to my survey appeared to have a fairly good knowledge of antibiotic use (M = 90.7%; SD = 9.4%), however their knowledge of antimicrobial resistance and stewardship was considerably lower (M = 72.3%; SD = 12.4%). Overall, only 56% of respondents attained a combined knowledge score of 80% or higher for antibiotic use and antimicrobial resistance and stewardship. To compare my findings with those reported in the two previous studies that used the survey (Inácio et al., 2017; Rábano-Blanco et al., 2019), I extracted information from the published Tables about the numbers of respondents with correct responses for each item and converted these values to percentages by dividing by the total number of respondents in the 3rd and 4th year of the program. The mean percentage for the survey was then computed for knowledge of antibiotic use and knowledge of antimicrobial resistance and stewardship by summing the percentage for each item and then dividing by the total number of items in each section[1]. Similar to the findings from my study, scores for knowledge of antibiotic use tended to be

[1] Rábano-Blanco et al. (2019) included only 14 items, instead of 15, for the knowledge of antimicrobial resistance and stewardship section.

higher than scores for the knowledge of antimicrobial resistance and stewardship (88% and 76% in Inácio et al., 2017; 87% and 74% in Rábano-Blanco et al., 2019).

An examination of the percentage of correct responses to individual items revealed some potential content areas warranting consideration. For example, a high percentage of respondents in all three studies correctly agreed that inappropriate antibiotic use can contribute to antimicrobial resistance (100% in my study; 96% in Inácio et al., 2017; 95% in Rábano-Blanco et al., 2019). However, only 40% in my study were aware that AMR can occur even with the appropriate use of antibiotics which was actually higher than the percentages computed for the other two studies (28% in Inácio et al., 2017; 29% in Rábano-Blanco et al., 2019). An item that was poorly answered by respondents in all three studies dealt with the definition of antibiotic stewardship. Only 8% of respondents in my study correctly answered this question which was considerably lower than the percentages reported in the other studies (36% in Inácio et al. 2017; 40% in Rábano-Blanco et al. 2019). One possible explanation for the lower percentage of correct responses in my study was the time taken to complete the survey. The majority of respondents (92%) completed the 41-item survey in less than 8 minutes which suggests respondents spent approximately 10 seconds on each item. This may not have allowed sufficient time for respondents to appreciate that the provided definition was for antimicrobial resistance rather than antibiotic stewardship. Neither Inácio et al. (2017) nor Rábano-Blanco et al. (2019) reported on the time taken by respondents to complete the survey. Another possible explanation is that the term is not included in the undergraduate curriculum at UNB as all respondents indicated they had never heard

about antibiotic stewardship. However, familiarity with the term is not sufficient if we are to tackle the problem of antimicrobial resistance. In an Australian study of 321 pre-registration nursing students, while 45% of respondents indicated familiarity with the term "antimicrobial stewardship", 71% reported very little or no knowledge of what it actually entails (Bouchoucha et al., 2021).

To be an antimicrobial steward, students need to be able to differentiate conditions that require antibiotics from ones that do not. While 96% of respondents in my study correctly agreed that antibiotics are useful for bacterial infections, only 88% correctly disagreed that antibiotics are useful for viral infection. Similar percentages were observed in the other two studies (100% and 93% in Inácio et al., 2017; 100% and 90% in Rábano-Blanco et al., 2019). In addition, only 84% of respondents correctly disagreed with the statement that antibiotics are indicated to reduce any kind of pain and inflammation. A similar percentage (87%) was observed in the study by Rábano et al. (2019); however, a higher percentage (97%) was observed in the one by Inácio et al. (2017). It is noteworthy that all students from my study disagreed with the statement that colds and coughs should always be treated with antibiotics for clients/patients to recover more quickly. The percentage of correct responses was also high in the two other studies (97% in Inácio et al., 2017; 99% in Rábano-Blanco et al., 2019). Respondents' disagreement with this item may have been due to the use of the phrase "should always". In their coursework, students may have learned that there are only a few absolutes in healthcare practice. A re-examination of the wording of items may be warranted prior to using the survey in future studies.

Associations between Students' Perception of Education and their Knowledge

At the beginning of this study, I hypothesized that students who perceive they had received adequate education on antibiotic use and antimicrobial resistance would have higher knowledge scores. However, this hypothesis was not supported by the findings. Students who perceived their education as more adequate (i.e., summative score) tended to have poorer knowledge of antibiotic use and AMR. A possible explanation for the negative association could be students' interest in learning more about AMR. Students who scored higher on the knowledge test may perceive that they require more information to fully grasp important concepts pertaining to AMR in order to be an antimicrobial steward. This explanation is supported by the finding that the majority of respondents rated knowledge of antibiotics and infection control as very important to their future practice (rated as a 9 or 10 out of 10). However, it is important to note the observed association was not statistically significant which was attributed to the small sample. Neither Inácio et al. (2017) nor Rábano-Blanco et al. (2019) investigated the association between students' perception of the adequacy of their education and their knowledge of antibiotic use and AMR in their studies.

Study Strengths and Limitations

The generalizability of the study findings is limited due to the involvement of students from only one health occupation program (i.e., nursing) and insufficient power to yield statistically significant results. Despite this, the study extends previous research on this topic area by attempting to examine the associations among students' knowledge

of antibiotic use and AMR and their perceptions of the adequacy of their education on this topic as well as its importance for their future practice.

Implications for Practice, Policy, and Research

Currently there are no standards as to what constitutes core knowledge on antimicrobial resistance and stewardship for students enrolled in a health occupation program in Canada. Efforts have been initiated by nurse educators in the USA and UK to establish standards for curriculum content to help ensure students acquire essential knowledge of antibiotic use and antimicrobial resistance (Cadavid et al., 2017; McEwen & Burnett, 2018; Mohamed, 2016). Such efforts are facilitated by the WHO development of a curricula guide for the education and training of prescribers and non-prescribers on antimicrobial resistance. In this curricula guide, the recommended outline for non-prescribers, such as nurses, includes: (a) foundations that build awareness of antimicrobial resistance; (b) appropriate use of antimicrobial agents; (c) infection prevention and control; (d) diagnostics stewardship and surveillance; and (e) ethics, leadership, communication, and governance (WHO, 2019). It is important for nursing students to acquire knowledge of antimicrobial resistance and stewardship in their program so they will be able to discuss the appropriateness of antimicrobial therapy with patients/clients and other health care providers (prescribers and non-prescribers) in their future practice (Cadavid et al., 2017).

Knowledge Translation

Efforts will be taken to share the findings with nursing students as well as those involved in the education of future nurses. Study findings will be circulated as a plain

language summary using platforms such as UNB Newsroom blog post and the Nurses Association of New Brunswick newsletter (Info Nursing). Findings from this study will be presented at the 27th Nursing Research Day to be held virtually in September 2022.

Conclusion

Because all health care providers have a responsibility to be antimicrobial stewards, it is essential that students enrolled in a health occupation program acquire basic knowledge of antibiotic use and antimicrobial resistance, factors contributing to antimicrobial resistance, and actions they can take to help reduce its development. To achieve this, work is needed to establish interdisciplinary standards as to what is core knowledge of antibiotic use and antimicrobial resistance for students enrolled in health occupation programs in Canada. In addition, replication of this study with students from more than one health occupation program is needed to identify factors specific to the individual (i.e., students) as well as the program that explain differences in students' knowledge of AMR and perceptions of their role as antimicrobial stewards.

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Appendix A

Search Strategy and Citations

Search #	Key terms	PubMed Query (All fields)	# Citations
Search 1	antimicrobial resistance	anti infective agents antimicrobial* resist* resistance* resistant* resisted resistence* resistent resistibility resisting resistive* resistivities resistivity	**286,879**
Search 2	antibiotic use	anti bacterial agents antibiotic* antibiotical	**907,766**
Search 3	Search 1 OR Search 2		**1,015,783**
Search 4	MeSH exploded: students, health occupations students, dental students, medical students, nursing students, pharmacy students, premedical students, public health		**69,074**
Search 5	Search 3 AND Search 4		**218**

Legend: *Truncations; Search date, 13th August 2020

Appendix B

A Survey of the Knowledge of Antimicrobial Resistance and Antibiotic Use among Students in a Health Occupation Program

Demographic Information

This information will be used to describe the characteristics of those who completed the survey

1. Do you identify as:
    a. Female
    b. Male
    c. Other
    d. I prefer not to say
2. In which of the following age group do you belong?
    a. Less than 20 years
    b. 20 to 25 years
    c. Greater than 25 years
3. Which practice area are you interested in working in after you graduate?
    a. Community nursing
    b. Pediatric nursing
    c. Obstetric-gynecologic nursing
    d. Mental health nursing
    e. Occupational nursing
    f. Geriatric nursing

g. Surgical-medical nursing

h. Emergency nursing

i. Teaching

j. Other

k. I have not decided yet

4. Do you have a family member or close friend who works in a health-related field?

   a. Yes b. No

5. What year of your program are you currently in?

   a. 3rd year basic Bachelor of Nursing program

   b. 4th year basic Bachelor of Nursing program

   c. 2nd year Advanced Standing Bachelor of Nursing program

6. Have you successfully completed a course in clinical microbiology?

   a. Yes

   b. No

7. Have you successfully completed a course in pharmacotherapeutics?

   a. Yes

   b. No

Knowledge of Antibiotic Use

Please complete the following to the best of your knowledge without the use of external resources

For each of the following statements, indicate if you agree, disagree, or are not sure (correct answer)

8. Amoxicillin is an antibiotic. **(agree)**
9. Aspirin is an antibiotic. **(disagree)**
10. Cefuroxime is a cephalosporin. **(agree)**
11. Antibiotics are useful for bacterial infections. **(agree)**
12. Antibiotics are useful for viral infections. **(disagree)**
13. Antibiotics are indicated to reduce any kind of pain and inflammation. **(disagree)**
14. Antibiotics can cause secondary infections after destroying good bacteria present in our body. **(agree)**
15. Antibiotics can cause allergic reactions. **(agree)**
16. Antibiotics may be stopped as soon as patients/clients starts feeling better. **(disagree)**
17. Colds and coughs should always be treated with antibiotics as patients/clients will recover more quickly. **(disagree)**
18. Antibiotics should always be prescribed as preventive measure to fight against future infections. **(disagree)**
19. Antibiotics cannot treat influenza. **(agree)**

Awareness of Antibiotic Resistance and Antibiotic Stewardship

Indicate Yes or No

20. Have you ever heard about antibiotic resistance?
21. Have you discussed the problem of antibiotic resistance during your nursing program?
22. Have you ever heard about antibiotic stewardship?

23. Have you discussed antibiotic stewardship during your nursing program?

Knowledge of Antibiotic Resistance and Antibiotic Stewardship

Please complete the following to the best of your knowledge without the use of external resources

For each of the following statements, indicate if you agree, disagree, or are not sure (correct answer)

24. Antibiotic resistance happens when a bacterium loses its sensitivity to an antibiotic. **(agree)**
25. Inappropriate use of antibiotics causes antibiotic resistance. **(agree)**
26. Prescribing broad-spectrum antibiotics increases antibiotic resistance. **(agree)**
27. Poor infection control practices by healthcare professionals can cause spread of antibiotic resistance. **(agree)**
28. Antibiotics are overused nationally and internationally in healthcare. **(agree)**
29. Appropriate use of antibiotics can cause antibiotic resistance. **(agree)**
30. Antibiotic stewardship is a phenomenon for which a bacterium gains resistance to an antibiotic. **(disagree)**
31. Exposure to antibiotics appears to be the principal risk factor for the development of antibiotic resistant bacteria. **(agree)**
32. Antibiotic resistance can be minimized by using narrow-spectrum therapy after identification and susceptibility testing to determine bacteria causing infection. **(agree)**

33. Use of antibiotics in livestock production and agriculture contributes to antibiotic resistance. **(agree)**
34. Improving techniques for bacterial diagnostics will improve efforts to combat antibiotic resistance. **(agree)**
35. Improved hand hygiene helps to control antibiotic resistance. **(agree)**
36. Today's research in developing new antibiotics will be sufficient to meet future needs. **(disagree)**
37. Antibiotic resistance could be a greater clinical problem in my future career. **(agree)**
38. Teaching healthcare students about the proper usage of antibiotics may help reduce the occurrence of antibiotic resistance. **(agree)**

Perceptions about antibiotic education in Bachelor of Nursing program

For each of the following statements, indicate if you agree, disagree, or are not sure

39. I have had sufficient education to identify the best antibiotic for a specific infection.
40. I have had sufficient education to identify an appropriate regimen (dose, route, and frequency) of antibiotic therapy.
41. I have had sufficient education to understand the mechanisms of antibiotic resistance.
42. I have had sufficient education to handle a patient/client who demands antibiotics therapy when it is not indicated.
43. I have had sufficient education regarding appropriate use of antibiotics.

44. I would like more education on antibiotic use, resistance, and stewardship.
45. I would like more education on microbiology and infection control.

Importance of knowledge of antibiotics and infection control

Indicate the importance of each of the following statements on a numerical rating scale

46. How important will knowledge of antibiotics be in your future nursing career *with 1 being "not important" to 10 being "very important"*?
47. How important will knowledge of microbial and infection control be in your future nursing career *with 1 being "not important" to 10 being "very important"*?
48. Use this space to provide any additional information, suggestions, or opinions about the topics addressed in this survey

By clicking the 'Submit' button, you will be indicating consent to use your responses for research purposes.

Thanks for your interest in this study, however, completion of courses in clinical microbiology and pharmacotherapeutics is required to take part.

Thanks for your responses.

Appendix C

Invitation to Participate in a Research Study

Project Title

Knowledge of Antimicrobial Resistance and Antibiotic Use among Students in a Health Occupation Program

Principal Researchers

Surajudeen Shittu, B.Pharm.	Interdisciplinary Studies	✉ s.shittu@unb.ca
Marilyn Hodgins, RN, PhD	Faculty of Nursing	✉ mhodgins@unb.ca
Donna Bulman, RN, PhD	Faculty of Nursing	✉ dbulman@unb.ca

Dear Prospective RNs,

My name is Surajudeen Shittu and I am sending this email to invite you to take part in an online survey examining knowledge of antimicrobial resistance and antibiotic use among students in a health occupation program. I am doing this research as part of my Masters' program in Applied Health Services Research. Students who are currently enrolled in the Bachelor of Nursing program and have successfully completed courses in clinical microbiology and pharmacotherapeutics are eligible to take part in this study.

Important Things that You Should Know about this Study:

- To take part in this study, you will complete a survey that consists of 8 sections (up to 48 questions). It should take no more than 15 minutes to complete the survey, although, there is no time limit.
- You will have access to the survey until Jan. 26th at 2359. An email reminder will be sent to you in 3 days and after 10 days.
- You can answer the questions using your personal computer or mobile device.
- Participation in the study is voluntary, you may choose not to take part.

- You may choose to withdraw from the study at any time or refuse to answer a specific question.
- Whether you participate in the study will not affect your academic standing. It will not affect your grades.
- No personal information such as your name or email will be collected.
- Your responses to the survey will be stored on the UNB password protected and multi-factor authentication server.
- I do not foresee any risk associated with taking part in this study.
- Although you may not benefit directly from participating in this study, findings may assist in curriculum development that may benefit future students.
- I would ask that you complete the survey independently without using external resources such as textbooks, notes, the internet, or classmates.
- To provide you with access to the study findings, a report will be shared with UNB Nursing Undergraduate Society.
- Your responses may be used in another research study. This will only occur if approval is obtained from the UNB Research Ethics Board.
- If you have any concerns or questions about this research study, you may contact:

  One of the researchers listed above or

  Dr. B. Keyes, UNBSJ Research Ethics Board Chair by phone (506)-648-5994 or by email reb@unb.ca.
- By clicking the "Submit" button at the end of the survey, you will be indicating your consent to have your responses used for research purposes.

This study was reviewed by the UNB Research Ethics Board and is on file as UNB REB File #043-2021

To complete the survey, click on this link:

https://forms.office.com/r/s1f9dDBVEi

Thank you for participating in this study,

Surajudeen Shittu

Appendix D

e-Reminder to Participate in Research Study

Project Title

Knowledge of Antimicrobial Resistance and Antibiotic Use among Students in a Health Occupation Program

Principal Researchers

Surajudeen Shittu, B.Pharm.	Interdisciplinary Studies	✉ s.shittu@unb.ca
Marilyn Hodgins, RN, PhD	Faculty of Nursing	✉ mhodgins@unb.ca
Donna Bulman, RN, PhD	Faculty of Nursing	✉ dbulman@unb.ca

Dear Prospective RNs,

This is a reminder that access to the online survey examining knowledge of antimicrobial resistance and antibiotic use among students in a health occupation program is still open.

If you have already completed the survey, Thank You!

If you have not yet completed the survey, there is still time. The survey will remain open until 25th January 2022.

Important Things that You Should Know about this Study:

- If you are currently enrolled in the BN program and have successfully completed courses in clinical microbiology and pharmacotherapeutics, you are eligible to take part in this study.
- To take part in this study, you will complete a survey that consists of 8 sections (up to 48 questions). It should take no more than 15 minutes to complete the survey, although, there is no time limit.

- You will have access to the survey until 26th January 2022 at 2359.
- You can answer the questions using your personal computer or mobile device.
- Participation in the study is voluntary, you may choose not to take part.
- You may choose to withdraw from the study at any time or refuse to answer a specific question.
- Whether you participate in the study will not affect your academic standing. It will not affect your grades.
- No personal information such as your name or email will be collected.
- Your responses to the survey will be stored on the UNB password protected and multi-factor authentication server.
- I do not foresee any risk associated with taking part in this study.
- Although you may not benefit directly from participating in this study, findings may assist in curriculum development that may benefit future students.
- I would ask that you complete the survey independently without using external resources such as textbooks, notes, the internet, or classmates.
- To provide you with access to the study findings, a report will be shared with UNB Nursing Undergraduate Society.
- Your responses may be used in another research study. This will only occur if approval is obtained from the UNB Research Ethics Board.
- If you have any concerns or questions about this research study, you may contact:

  One of the researchers listed above or

  Dr. B. Keyes, UNBSJ Research Ethics Board Chair by phone (506)-648-5994 or by email reb@unb.ca
- By clicking the "Submit" button at the end of the survey, you will be indicating your consent to have your responses used for research purposes.

This study was reviewed by the UNB Research Ethics Board and is on file as UNB REB File #043-2021

I would ask that you only submit the survey once.

To complete the survey, click on this link:

https://forms.office.com/r/s1f9dDBVEi

Thank you for participating in this study,

Surajudeen Shittu

Appendix E

Introductory Email to Program Directors

Subject: Follow-up to Dr. Hodgins email on AHSR thesis project

Good morning Dr. Read (emily.read@unb.ca; Moncton) or Mr. Thomas (scott.thomas@unb.ca; St. John) or Ms. Amirault (debra.amirault@unb.ca; Fredericton),

My name is Surajudeen Shittu and I am a graduate student in the Applied Health Services Research program at UNBF. I am working on my master's research project with Drs. Hodgins and Bulman. I believe Dr. Hodgins discussed my project with you during the fall term. The purpose of my study is to investigate knowledge of antimicrobial resistance and antibiotic use among students enrolled in a health occupation program. I plan to survey students currently enrolled in the 3rd and 4th year of the Bachelor of Nursing program at UNBF and UNBSJ as well as students in the 2nd year of the Advanced Standing program at the Moncton campus. My proposal has been reviewed by the UNB REB and is on file (#043-2021).

I am writing to ask for your assistance in distributing an e-invitation to students in the 3rd and 4th year of your program (2nd year of your program – Dr. Read). I would appreciate if this e-invitation is distributed on Wednesday, January 12th. To increase participation, I plan to send two reminder emails. I will email you the e-reminders on Monday, January 17th and Friday, January 21st for distribution.

If you have any questions or suggestions about my study or distribution plan, feel free to contact me or Drs Hodgins or Bulman. I appreciate your help with my thesis research. For your information, I have attached the abstract of my research study and a copy of the e-invitation.

I will send you the initial e-invitation for distribution on Wednesday, January 12th.

Best Regards,

Surajudeen Shittu

Curriculum Vitae

Candidate's full name: Surajudeen Shittu

Universities attended (with dates and degrees obtained):

- Eastern Mediterranean University, Bachelor of Pharmacy 2018

- University of New Brunswick, Master of Applied Health Services Research 2022

Publications:

NA

Conference Presentations:

- Nursing Students' Knowledge of Antibiotic Use better than their Knowledge of Antimicrobial Resistance and Stewardship. 27th Annual Nursing Research Day.

- Endothelin-1 as it relates to nitric oxide synthase. 4th Annual Congress "The Mosaic 2018" of Eastern Mediterranean University Pharmacy Society.