**INTRODUCTION**

The role of biosciences in pre-nursing and nursing curricula is a well-described, international concern, as educational institutions respond to changes in the clinical environment (1). Key themes among studies include a shift from biosciences to humanistic sciences (sociology, psychology, etc.) in order to provide a more comprehensive, holistic care model (2); inadequate science content in nursing curricula (3–5); poor alignment between curricula and nursing practice (6–8); nurses' lack of confidence in educating patients and other healthcare professionals (9); and a need for curricula that are responsive to a changing clinical landscape (10). Less time devoted to curricula for bioscience, including microbiology, has also led to concerns about possible gaps in foundational knowledge related to patient care (11).

Several studies have attempted to identify learning deficits and assess their potential impacts on patient care (6, 12–15). These studies suggest that a particular concern among nurses and nurse educators is the nurses' lack of comfort in correlating patient symptoms with the underlying pathophysiology and making appropriate care interventions based on that information. Such discomfort can lead to inaction or incorrect actions, either of which may be detrimental to patient care. At least some of the nurses' discomfort may result from inadequate coverage of certain topics or knowledge applications in a foundational microbiology course (or from nurses not taking such a course in the first place). Without a solid foundation in microbiology, nurses may have knowledge shortfalls in related areas such as infection control, pathophysiology, antimicrobial resistance, critical values, and patient management.

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Nurses must have sufficient education and training in microbiology to perform many roles within clinical nursing practice (e.g., administering antibiotics, collecting specimens, preparing specimens for transport and delivery, educating patients and families, communicating results to the healthcare team, and developing care plans based on results of microbiology studies and patient immunological status). It is unclear whether the current microbiology courses required of nursing students in the United States focus on the topics that are most relevant to nursing practice. To gauge the relevance of current microbiology education to nursing practice, we created a confidential, web-based survey that asked nurses about their past microbiology education, the types of microbiology specimens they collect, their duties that require knowledge of microbiology, and how frequently they encounter infectious diseases in practice. We used the survey responses to develop data-driven recommendations for educators who teach microbiology to pre-nursing and nursing students.

Two hundred ninety-six Registered Nurses (RNs) completed the survey. The topics they deemed most relevant to current practice were infection control, hospital-acquired infections, disease transmission, and collection and handling of patient specimens. Topics deemed least relevant were the Gram stain procedure and microscope use. In addition, RNs expressed little interest in molecular testing methods. This may reflect a gap in their understanding of the uses of these tests, which could be bridged in a microbiology course.

We now have data in support of anecdotal evidence that nurses are most engaged when learning about microbiology topics that have the greatest impact on patient care. Information from this survey will be used to shift the focus of microbiology courses at our university to topics more relevant to nursing practice. Further, these findings may also support an effort to evolve national recommendations for microbiology education in pre-nursing and nursing curricula.
In 2012, an American Society for Microbiology (ASM) Task Force published curriculum guidelines specific to undergraduate education in microbiology (16), based on survey feedback from microbiology educators. These guidelines recommended six concept areas as focal points in undergraduate microbiology courses—evolution, cell structure and function, metabolic pathways, information flow and genetics, microbial systems, and the impact of microorganisms. The guidelines were intentionally not specific to any one professional program; rather, they sought to outline a well-rounded, foundational microbiology education for a range of undergraduate students.

Nursing programs presently devote limited time to microbiology, and many are considering further reducing or even eliminating microbiology instruction. Therefore, it is vital that any microbiology topics they cover be salient to nursing practice. Relevance is key to student success and engagement, and to the proper application of knowledge in the healthcare workplace (4, 10, 17). Although researchers have assessed the microbiology curricula at various institutions and gathered faculty views on the standards for undergraduate microbiology courses (16, 18), no survey, to our knowledge, has asked currently employed nurses for their input on the content and quality of pre-nursing or nursing microbiology courses.

Our objective was to assess nurses’ perceptions of the relevance of various topics in microbiology and infectious disease to nursing practice, in order to develop data-driven recommendations for educators who teach microbiology to pre-nursing and nursing students.

METHODS

To identify the relevance of current microbiology education to nursing practice, we developed an Internet-based survey in which we asked nurses about their educational background in microbiology and related topics, about their use of microbiology knowledge in their current work, and about the relevance of specific microbiology course topics in the workplace. The nurses also answered questions about their demographic and place of employment. The microbiology topics included in the survey were from our university’s pre-nursing microbiology course syllabus. This syllabus is loosely based on the American Society for Clinical Laboratory Science Entry Level Curriculum (19) recommendations for Medical Laboratory Science students; it has been modified based on input from nursing and physician educators. The study was submitted to the Institutional Review Board and designated as exempt.

The link to the survey was distributed through the University of Utah College of Nursing alumni network in May 2015. Responses from this convenience sample were collected through November 2015. Targeted participants were Registered Nurses (RNs) practicing in the United States or Canada who had completed their undergraduate nursing education in the United States or Canada. RNs practicing in any healthcare setting were eligible to participate. Nurses licensed as Advanced Practice Registered Nurses (i.e., nurse practitioners or clinical nurse specialists) were directed to another, similar survey.

Data were collected and managed using REDCap (Research Electronic Data Capture) tools hosted at the University of Utah (20) with the support of the CTSC grant (1 UL1 RR024989 from NCRR/NIH). REDCap is a secure, web-based application designed to support data capture for research studies, providing 1) an intuitive interface for validated data entry; 2) audit trails for tracking data manipulation and export procedures; 3) automated export procedures for seamless data downloads to common statistical packages; and 4) procedures for importing data from external sources. Data were analyzed using IBM SPSS Statistics for Macintosh, Version 22.0. The primary analysis focused on descriptive statistics (frequencies, means, and measures of variance). Independent t-tests were used to examine differences between hospital and community-based nurses, and other demographic groups.

RESULTS

Two hundred ninety-six RNs completed the survey. As expected due to dissemination of the survey through a university alumni network, most respondents had baccalaureate or graduate degrees (Table 1). Representation was very good across all years of work experience. The majority of respondents work in hospital settings (81.9%); the rest are in community settings (18.1%). Most respondents had a formal microbiology course either prior to or during their program (77.3%), and over half (55.1%) had a microbiology lab.

| TABLE 1. Survey respondent demographics (N = 296). |
|-----------------------------------------------|
| Demographic Characteristics | n (%)            |
|-------------------------------|------------------|
| Highest degree in nursing     |                  |
| Associate                     | 19 (6.4)         |
| Baccalaureate                 | 210 (70.7)       |
| Master                        | 54 (18.2)        |
| Other                         | 13 (4.4)         |
| Years of experience as a RN   |                  |
| <1                            | 15 (5.1)         |
| 1–5                           | 87 (29.3)        |
| 6–10                          | 71 (23.9)        |
| 11–15                         | 24 (8.1)         |
| 16–20                         | 14 (4.7)         |
| 21–25                         | 16 (5.4)         |
| 26–30                         | 20 (6.7)         |
| 31–40                         | 35 (11.8)        |
| >40                           | 14 (4.7)         |

RN = registered nurse.
Nurses were surveyed about duties they routinely performed that related to microbiological topics, about the specimens they most frequently collected for microbiological testing, and about the types of infections they most frequently encountered. Among the more frequently performed duties were administration of intravenous/oral antibiotics, patient education regarding specimen collection, and patient education regarding the nature of their infections (Table 2). Specimens most frequently collected by nurses included urine, stool, blood, and sputum (Table 3). Wound and urinary tract infections were the most frequent infection types encountered by respondents (Table 4). Almost half of survey respondents (43.6%) indicated that they routinely encountered fungal infections, which was almost the same percentage as for upper respiratory tract infections (43.9%).

To assign relevance to different microbiological topics, respondents were asked to rate each topic from 1 (no relevance) to 5 (extremely relevant). The highest-rated topics were infection control, hospital-acquired infections, and disease transmission; the lowest-rated were microscope use and the Gram stain procedure (Fig. 1). While there was slight variation in the mean relevance that different age groups assigned to topics, these differences were not statistically significant.

Nurses working in hospital settings identified several microbiology course topics as having greater relevance to their practice than nurses working in community settings did. These topics included the collection and handling of specimens \( t = 2.9, p = 0.005 \), knowledge of medically important microorganisms \( t = 2.4, p = 0.016 \), and infection in the immunocompromised host \( t = 2.0, p = 0.045 \). As expected, hospital-based nurses gave the topic of hospital-acquired infections a significantly higher relevance rating than did the community-based nurses \( t = 4.4, p < 0.001 \). Among hospital-based nurses, those working in the emergency department rated the topic of bioterrorism as having higher relevance than did those on acute care units \( t = 2.1, p = 0.043 \).

We used a similar five-point rating scale (1 = no interest, 5 = extremely interested) to evaluate the nurses’ interest in continuing education (CE) in the same microbiology course topics that were listed under relevance. These data generally follow the same pattern as the relevance data, with the highest- and lowest-rated topics remaining the same (Fig. 2).

| TABLE 2. Duties routinely performed (N = 296). |
|-----------------------------------------------|
| Duties                                       | %  |
| Administer intravenous (IV) antibiotics       | 64.5 |
| Educate patients about collection of sputum, urine, or stool specimens | 59.8 |
| Administer oral (PO) antibiotics              | 60.8 |
| Educate patients about the nature of their infections | 61.1 |
| Routinely interpret results from bacteriology laboratory tests and communicate significant results to healthcare team members | 38.5 |
| Deliver specimens from hospital unit or clinic to laboratory | 33.8 |
| Read throat cultures inoculated to agar plates and identify Group A Streptococcus | 3.4 |
| Perform Gram stains                           | 1.7 |
| Inoculate specimens to culture media and streak the agar plates for isolation of bacteria | 0.7 |

| TABLE 3. Specimens routinely collected for microbiology tests (N = 296). |
|-----------------------------------------------|
| Specimen Type                               | %  |
| Urine culture                               | 67.2 |
| Stool culture                               | 53.0 |
| Blood culture from central venous catheter  | 42.2 |
| Sputum culture                              | 40.2 |
| Blood culture from peripheral vein           | 39.9 |
| Wound culture                               | 35.1 |
| Anaerobic culture                           | 24.3 |
| Ova and parasites                           | 19.6 |
| Cervical/vaginal culture for sexually transmitted infections | 10.8 |
| Skin scraping                               | 7.8 |
| None                                        | 22.0 |

| TABLE 4. Infection types routinely encountered (N = 296). |
|-----------------------------------------------------------|
| Infection Type                                            | %  |
| Wound                                                     | 68.9 |
| Urinary tract                                             | 68.6 |
| Lower respiratory tract                                   | 57.4 |
| Gastrointestinal                                          | 55.1 |
| Sepsis                                                    | 54.7 |
| Skin                                                      | 53.0 |
| Viral                                                     | 52.0 |
| Upper respiratory tract                                   | 43.9 |
| Fungal                                                    | 43.6 |
| Central venous catheter/central line                      | 41.9 |
| Bone                                                      | 26.7 |
| Joint                                                     | 26.4 |
| Eye                                                       | 25.0 |
| Central nervous system                                    | 23.0 |
| Sexually transmitted                                      | 20.3 |
| Ear                                                       | 19.9 |
| Parasitic                                                 | 17.2 |
| Obstetric/perinatal                                        | 12.2 |
FIGURE 1. Relevance of microbiology course topics (mean; 1 lowest to 5 highest). Error bars represent the standard error of the mean.

FIGURE 2. Interest in continuing education (means; 1 lowest to 5 highest). Error bars represent the standard error of the mean.
The high relevance assigned to infection control, hospital-acquired infections, and disease transmission reflects the importance of these topics in patient care. These topics should be strongly emphasized throughout the nursing pre-requisite microbiology course. We find it concerning that approximately one in four surveyed nurses did not have a microbiology course as part of their nursing education, given that these topics are unlikely to be covered with a microbiology focus in other nursing curriculum courses. The literature has established that nurses need to understand microbiology topics in order to effectively prevent and recognize healthcare-acquired infections. Attempts at infection control will be interspersed throughout the curriculum, to highlight potential sources of healthcare- and community-associated infections. Instruction on the use of a microscope will decrease, because of its lack of relevance to current nursing practice. Although nurses did not view microbial genetics as particularly relevant, the practical applications of this topic will be emphasized. For example, the course will discuss how organims can quickly acquire and share antimicrobial resistance via plasmids, and how detection of those mechanisms can result in decreased patient morbidity and mortality. Some limitations were noted in this study. Entry-level proficiency, which was not assessed, could impact the relevance assigned to particular topics in less experienced vs. more experienced nursing professionals.

As a result of this study, several changes will be made in the authors’ medical microbiology curriculum. Most of the major topics in the present curriculum were viewed as relevant by respondents, so few changes are planned in the topics themselves. However, the emphasis given to different subjects within each major topic will shift (Table 5). For example, discussions of diagnostic methods and their applications, and of basic specimen types and collection methods, will be woven through most lectures. The comparison of various infection types (e.g., bacterial vs. viral vs. fungal) will be strengthened. Discussions of infection control will be interspersed throughout the curriculum, to highlight potential sources of healthcare- and community-associated infections. Instruction on the use of a microscope will decrease, because of its lack of relevance to current nursing practice. Although nurses did not view microbial genetics as particularly relevant, the practical applications of this topic will be emphasized. For example, the course will discuss how organisms can quickly acquire and share antimicrobial resistance via plasmids, and how detection of those mechanisms can result in decreased patient morbidity and mortality. Similarly, the nurses did not view microbial cell biology as relevant. This topic will be retained, but with a greater emphasis on how virulence factors impact infection progression and treatment.

In addition to changes based on the survey results, due to increased recognition of its importance, the human microbiome will be discussed along with microorganism
characteristics. This will highlight the complexity of human-microbe interactions and how various infections are prevented by the microbiome or result from a disruption of it.

The results from our study raise the question of whether nursing should have microbiology education guidelines that are distinct from the American Society for Microbiology (ASM) undergraduate curriculum guidelines (16). While many topics that are relevant to nursing either overlap with or are encompassed by the ASM guidelines, certain areas may need different amounts of attention and detail (Table 6). This study highlights areas where current curricula may diverge from practice-relevant concepts. Additional work is needed to ensure that educators are able to meet the educational needs of future nursing personnel. To further this work, an interdisciplinary group could be assembled and tasked with creating new guidelines for microbiology education in pre-nursing/nursing curricula. Such guidelines could be grounded in the existing ASM curriculum guidelines.

There is no microbiology course requirement in the current Essentials of Baccalaureate Education for Professional Nursing Practice (23). The only references to

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### TABLE 5.
Summary of proposed changes for microbiology topics and concepts.

| Reduce | Increase |
|--------|----------|
| • Microscopy principles and use of the microscope | • Cell biology as it pertains to virulence, transmission, and treatment |
| • Details of Gram stain beyond basic theory, interpretation, and application to patient care | • Microbiome |
| • Culture identification testing method details (e.g., biochemical) | • Clinical correlation between organism and disease |
| | • Diagnostic testing methods, including basic comparison of methods and introduction to molecular testing methods |
| | • Appropriate specimen selection, collection, and basic transport conditions |
| | • General treatment approaches (e.g., antibiotics, surgery, supportive therapy, etc.) |
| | • Basic antimicrobial resistance development and transmission (tie in basic microbial genetics) |
| | • Vaccines |
| | • Infection control and epidemiology |

**Consider**

- Discussion on patient education regarding infections and correction of misinformation (e.g., vaccines, antibiotics for viral infections, etc.)

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### TABLE 6.
Comparison of survey topics with American Society for Microbiology (ASM) Curriculum Guidelines.

| Survey Topics with Relevance ≥ 2.0 with Appropriate Curriculum Concepts and Competencies* | Key to ASM Curriculum Guidelines Concepts and Competencies* |
|------------------------------------------------------------------------------------------|----------------------------------------------------------|
| Infection control | A, E, F |
| Hospital-acquired infections | A, E, F, G |
| Common medically important microbe groups | A, E, G |
| Disease transmission | A, C, G |
| Epidemiology of infectious disease | A, E, F, G |
| Principles of antimicrobial therapy | A, B, C, G |
| Infection in the immunocompromised host | A, B, E, G |
| Host defense mechanisms and immune reactions | B, E, G |
| Vaccines | A, B, E, F, G |
| Interpretation of culture results | F, G, H |
| Epidemics and pandemics | E, G |
| Differentiation of normal flora vs. pathogens | C, D, E, F |
| Interpretation of susceptibility reports | A, C, F |
| Collection and handling of specimens | G, H |
| Bioterrorism | E, F, G |
| Microbiology cell biology | A, B, G |
| Microbial genetics | A, B, G |
| Molecular testing methods | G, H |

*Adapted from Merkel (16).
infection or infectious disease in this document pertain to infection control and related issues such as antibiotic resistance. In a climate where nursing program administrators are facing pressure to reduce the number of required credits in order to reduce costs and accelerate the preparation of nurses, bioscience could be targeted for removal. However, the high relevance of many microbiology topics to the nurses in this study, the continued emergence of infectious disease regionally, nationally, and globally, and the rising challenges associated with fighting infectious disease all indicate that a knowledge of microbiology is essential to nursing. We strongly recommend that national curriculum guidelines be more prescriptive regarding bioscience prerequisites, particularly microbiology. The fact that most nurse practitioner programs do not require additional coursework in microbiology makes the microbiology component of the pre-nursing curriculum even more critical, since nurse practitioners are independently diagnosing and treating infectious disease.

CONCLUSION

The results from this study offer clear evidence that nursing professionals view a broad range of medical microbiology topics as strongly relevant to nursing practice. Thus, it may be inappropriate to reduce or eliminate microbiology from the core bioscience curricula required of nurses, as some programs have done. Covering essential topics such as infection control, healthcare-associated infections, and disease transmission will help prepare nursing professionals to recognize infectious diseases and initiate appropriate patient care interventions.

SUPPLEMENTAL MATERIALS

Appendix 1: Microbiology education in nursing practice survey

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