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Perspectives

Microbiology Education and Infection Control Competency: Offering a New Perspective

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Healthcare-associated infections (HAIs) have become a significant and costly problem for healthcare institutions worldwide. Despite the crucial role of infection prevention and control (IC) procedures, there is a substantial body of evidence to indicate that IC knowledge and practices of health professional graduates is, however, sub-optimal. This paper presents a discussion of the critical role microbiology plays in infection control education and practice, arguing that without an ability to apply microbiology knowledge to IC decision-making, there is an inherent risk of incorrect application of IC practices and thus a risk to patient (and nurse) safety. The authors propose a re-conceptualization of infection control competency, using nursing as an exemplar profession, to reflect practice that is not based on simple memorization of protocols but rather on a sound understanding of microbiology and informed decision-making. The proposal for re-conceptualizing the definition and assessment of IC competence, if adopted, would potentially enhance students' understanding and synthesis of microbiology knowledge and help build students' capacity to apply that knowledge to practice.

INTRODUCTION

Health care–associated infections (HAIs) have become a significant and costly problem for health care institutions worldwide (1). Indeed, some HAIs place patients at a threefold increased, risk of death in hospital (2). These infections are therefore a major risk to patient safety (3) in addition to adding billions of dollars to healthcare budgets each year (4). This complex problem is compounded by increasing antibiotic resistance and an unprecedented resurgence of infectious diseases such as Zika virus, chikungunya virus, dengue, and Ebola (5). For example, the Zika virus, discovered in 1947, was relatively unknown until 2007 (6) but has since reached epidemic proportions in Brazil and been identified in at least 13 other countries including Italy, Mexico, and Australia (7, 8). The virus's rapid rate of spread and the health risk it poses to unborn babies prompted international health alerts by the World Health Organization. In this epidemiological "minefield," it is more important than ever for healthcare workers (HCWs) to be capable of safely working with patients who have transmissible or potentially transmissible diseases. Seriously ill patients may prompt the use of infection control behaviors; however, other patients who seek help may not initially demonstrate a recognizable condition. Thus, the importance of relevant, effective infection prevention and control (IC) in healthcare environments cannot be overstated. Despite this professional and ethical imperative, a substantial body of literature identifies suboptimal infection control knowledge and practices among nursing students and graduates as a significant and ongoing global issue (9–12). In this discussion paper, we propose curriculum and pedagogical modifications to address this issue.

BACKGROUND

Since the transfer of nursing education into the higher education sector there has been debate around graduates' preparedness for practice. New graduates report feeling unprepared for the demands of the workplace (13) while employers have reported new graduates to be lacking both practice expertise and the confidence to deal with resurgence and emergence of illnesses (14). Concerns about new graduates' competency in other patient-care areas such as medication and IC have also been raised (15, 16). While graduate nurses begin their career armed with a beginner's knowledge and understanding of what constitutes a "competent clinical nurse" (17), they are not always able to apply their knowledge to authentic practice. In the area of IC, this may be due, in part, to variation in the duration and delivery of IC education within the undergraduate nursing curriculum.

Effective IC policies are underpinned by microbiological principles, and prevention and control of infection relies on sound knowledge and understanding of the relevant

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causative microorganisms. Transmission-based precautions are cited as "the foundation of IC for serious organisms and infections" (18). Appropriate application of these precautions requires an understanding of the severity and impact of an infection and the mode of transmission of different microorganisms. Inadequate knowledge of particular microorganisms has been shown to manifest in incorrect application of transmission-based procedures (19), and this can have fatal consequences if an early-stage infection of a serious disease is not identified correctly.

The nursing-practice literature, however, indicates that HCWs often make decisions about how to adhere to IC policies based on their (often partial or incorrect) assessment of risk (20, 21) rather than an understanding of microbiology principles. Wynaden et al. (22) interviewed Australian HCWs (doctors and nurses) about their perceptions of IC. For some HCWs, a self-perceived ability to accurately assess risk of infection based on patient factors (familiarity with the patient and the nature of known infectious disease diagnoses) and fear of "catching something" were used as an informal decision-making process for balancing the need for IC with heavy workloads. Therefore, it is feasible that any misperceptions about microorganisms (e.g., mode of transmission and/or potential pathogenicity) could result in incorrect assessment of risk and subsequent inappropriate or inadequate application of IC precautions, thereby posing a safety risk to both HCWs and patients.

MICROBIOLOGY EDUCATION

Healthcare professionals require sufficient foundational knowledge to marshal and appropriately apply infection control knowledge in different clinical scenarios. Microbiology is commonly taught as part of larger bioscience subjects in the nursing curriculum. Bioscience subjects—which commonly incorporate elements of anatomy, physiology, microbiology, chemistry, and pharmacology knowledge—are a central component of pre-registration nursing curricula. There is, however, considerable disparity in the proportion of the curriculum and teaching hours devoted to biosciences across different higher-education institutions (23, 24) and the microbiology content is limited (25). Nursing students and graduates alike have raised concerns about the limited time devoted to science content (including microbiology and pharmacology) in the curriculum (26) and the associated implications for their preparation for practice (27). Ward (28) interviewed English clinical nurse educators (n = 32) and students (n = 31) about their perceptions of the IC education needs of nursing students. The mentor participants in that study acknowledged that while students had a basic knowledge of IC procedures such as standard precautions, there was a perceived lack of theoretical microbiology knowledge. They expressed a desire for students to have a better understanding of types of microorganisms, and modes of transmission in particular, prior to clinical placements. Conversely, the students in that study felt that universities should provide more comprehensive clinical skill knowledge—specifying the "correct" procedure for individual nursing interventions—to help lessen any confusion about appropriate application of IC practices.

In light of the important role of microbiology education as foundational knowledge for IC practice, particularly in the current epidemiological climate, re-evaluation of the nursing curriculum guidelines regarding the bioscience and microbiology has been advocated (25, 29).

RE-THINKING IC COMPETENCE AND PROFESSIONAL PRACTICE

Based on the plethora of evidence in the literature, one could argue that failure to comply with IC policies not only compromises patient safety but could also be considered as practicing below the required standard of competency. That is not to say that failure of a healthcare worker to comply with IC policies automatically implies incompetence; it may simply reflect adherence to peer-group practices, and does reflect the need for re-evaluation of the professional competency statements regarding infection control. Two previous studies have proposed essential IC competencies for new graduate nurses (15) and hospital-based HCWs (30). Both studies listed "basic microbiology" knowledge as a component of these core competencies. Carrico et al. (30) identified two broad microbiology competency statements, "Describe the role of microorganisms in disease" and "Describe how microorganisms are transmitted in health care settings," with nine associated terminal objectives (measurable activities). Liu et al. (16) used a Delphi method to identify a total of 81 competency items. Seven of these competency statements were listed under the "Basic microbiology" domain:

- Identify the components required for infection transmission
- Identify different routes of transmission of infectious organisms
- Recognize a person who is suspected to be infected with pathogens
- Recognize the concept of multi-resistant organisms
- Realize that there are different types of microorganisms and that they infect in different ways
- Read and interpret microbiology results/reports from the laboratory at the basic level
- Describe the normal microbial flora of the body

Panelists in this study (n = 93) were also asked to rate the importance ("very important," "somewhat important," "not very important," or "irrelevant") of the broad areas of competency identified. While hand hygiene and personal protective equipment (PPE) competency were rated "very important" by over 97% of the panelists, only 58% of the panelists rated basic microbiology as "very important." The remainder of panelists rated it "somewhat important."

Both studies (15, 30) also identified "Critical thinking"/ "Critical assessment" as an essential competency domain. Carrico *et al.* (30) listed one competency statement in this domain: "Demonstrate ability to problem-solve and apply knowledge to recognise, contain, and prevent infection transmission." The terminal objectives associated with that competency statement, however, are arguably insufficient to achieve that competency:

a. Explain how to access infection control resources including policies and procedures.
b. Discuss own role in infection prevention and control (e.g., recognizing unsafe activities)
c. Describe practice changes (e.g., altered standard of care) in the event of limited resources.

The skills performed by nurses "are not professionally meaningful as isolated acts and should not be viewed as separate from knowledge and judgement" (31); nursing practice requires knowledge, intention, and implementation. There is little doubt that without relevant real-life practice experience to guide them, new graduates do benefit from rules, guidelines, and protocols in their early-career clinical practice. However, Benner (32) argued that rules do not always prescribe the most appropriate action in particular situations, and thus a requirement for new graduates to simply follow rules may, in fact, hinder successful performance. Gustavsson (33) espoused that "knowing how" means "both being able to do certain operations, a skill, and being able to present a reasoned argument about what has been done." Thus, while the IC competencies identified by Liu et al. (16) and Carrico et al. (30) provide a good foundation, it is proposed here that given the well-documented suboptimal IC knowledge and practices of HCWs, further reconceptualization of IC competency objectives and assessment is urgently warranted.

For example, the Australian registration standards for registered nurses (RNs) contain only one competency statement specifically related to infection control: "maintains standards for infection control" (34). Similarly, the professional code for RNs and midwives in the UK (35) states that RNs must "keep to and promote recommended practice in relation to controling and preventing infection, and take all reasonable personal precautions necessary to avoid any potential health risks to colleagues, people receiving care and the public." Although the Australian RN competency standards state that the standards "remain broad and principle-based so that they are sufficiently dynamic for practising nurses and the nurse regulators to use as a benchmark to assess competence in practise," it could be argued that these competency statements are too broad as they do not make reference to understanding the underpinning scientific knowledge (in this case, microbiology). We propose that timely reconceptualization of IC competency for RNs is warranted. While the proposed changes outlined in the following section are primarily informed by consideration of non-US curricula, there is undeniable overlap in the pre-registration nursing curricula on different continents and the issue of suboptimal microbiology and IC knowledge is of global concern.

We suggest that parallels can be drawn between IC competence and medication competence. While IC practice is underpinned by microbiology knowledge, medication competence is underpinned by pharmacology knowledge. Limited pharmacology content in the nursing curriculum (36) and insufficient understanding of pharmacological principles (37) have been cited as factors which negatively impact nursing graduates' medication competence and safety. Sulosaari et al. (15) proposed the following definition for medication competence in pharmacology: "Registered nurses' medication competence consists of theoretical, practical and decision-making competence." We suggest that limited microbiology content in the nursing curriculum may likewise impact IC competence, and given the parallels between medication competence and IC practice described in the previous section, we suggest that IC competence be conceptualized in the same way: infection prevention and control competence consists of theoretical, practical, and decision-making competence. According to this proposed definition, students would need to understand, analyze, synthesize, and apply their microbiology knowledge. Since the proposed definition of IC competence incorporates "practical and decision-making competence," it could be argued that in order to assess competence, one must do more than simply observe IC practice (e.g., hand-hygiene audits). Infection control practice based on reflexive use of protocols can masquerade as informed clinical decision-making. A new graduate who demonstrates adherence by applying the correct protocol or PPE to a particular case scenario or patient is not demonstrating their decision-making competence, or their ability to synthesize and apply knowledge. In short, correct practice alone does not equate to competence, and this may have grave consequences when a new disease emerges or an older one changes virulence or mode of transmission (for example, SARS or MERS). In a profession that requires nurses to be autonomous and accountable for their actions, it is imperative that new graduates have the ability to "make decisions based on appropriate scientific evidence rather than potentially erroneous 'ritualised associations'" (38). The ultimate goal of reconceptualizing competency in this way would be to teach IC practice that is not based on simple memorization of protocols but is based on sound understanding and informed decision making. An understanding of microbiology would be central to this process in the case of IC. For example, students would need to demonstrate an understanding of the transmission mode of microorganisms and application of that knowledge to personal protective practices in a variety of contexts. This is particularly relevant with new and emerging infectious diseases for which an IC protocol may not currently exist. This would also build IC self-efficacy, ensuring that students can apply that knowledge to practice. Given the multitude of factors which can impact IC behavior, it would be unrealistic

to assume that changing the competency standards alone will guarantee better IC practice. The revised competency standards could, however, drive curriculum development and improved IC practice. The following section outlines recommendations for curricular change and actionable steps to facilitate implementation of those recommendations. Recommendations are summarized in Table 1.

RECOMMENDATIONS FOR CURRICULUM AND EDUCATORS

An important step in reconceptualizing IC competency would be determining curriculum content that encourages students to develop the necessary skills and knowledge to demonstrate competency. A review of the placement, nature, and timing of microbiology teaching in pre-registration nursing curricula is urgently needed to identify the pedagogies being used and ensure that the "time-gap between the introduction of the theoretical knowledge and its first use in professional practice is not too large" (39). Identification of threshold concepts for microbiology—conceptual "gateways" that lead to "a new way of understanding, interpreting, or viewing something" (40)—could form the basis of a revision of the conceptual framework being used to teach microbiology concepts. Modification of the Microbiology Concept Inventory (41) and/or the Host-Pathogen Interactions Concept Inventory (HPI-CI) (42) to focus on the microbiological concepts identified by practicing nurses in the Durrant, et al. study (25) as most relevant for future clinical practice would be a useful first step in this process. Educators could employ the modified concept inventories to explicitly identify student knowledge and understanding of microbiological principles prior to their initial microbiology training and/or at the commencement of the final year of the pre-registration program. This would provide educators with an opportunity to intervene and address preconceptions and/or misconceptions.

TABLE 1.
Summary of proposed recommendations.

	Recommendations for Curriculum
1	A review of the placement, nature, and timing of microbiology teaching in pre-registration nursing curricula.
2	Identification of threshold concepts for microbiology.
3	Modification of a concept inventory tool to focus on microbiology concepts identified as relevant and necessary for future clinical practice.
4	Administration of the modified inventory at the commencement of the first and final years of the pre-registration program to explicitly identify pre-existing knowledge and misconceptions of microbiological principles.
5	Implement an appropriate intervention to address any misconceptions and/or deficits of microbiology/IC knowledge.
6	Enhance students' understanding of their own health beliefs (as per the Health Belief Model).
7	Integration of leadership training, including distributed leadership, role modeling, and coaching, sequentially across all years of the pre-registration curriculum.
	Recommendations for Educators
1	Professional development activities for bioscience teachers that focus on microbiological concepts considered "important" by IC professionals.
2	The use of active-learning models for teaching of microbiology and IC within the curriculum.
3	Academics provide material to clinical supervisors to enhance familiarization with the microbiology concepts being taught to students as part of the pre-registration curriculum.
4	Modeling of IC best practices by clinical supervisors of students on work placements
5	Post-clinical-placement debriefing sessions (with university academics) including provision of opportunities for students to enact/practice coaching skills in both formal and informal settings and receive feedback.

It seems reasonable for educators of health professionals to focus on communicating theoretical and very necessary professional craft knowledge (43); however, Higgs et al. (44) assert that health professional practice is also informed by "knowledge of one's self, values and beliefs" (p. 31). This notion is echoed by Sulosaari et al. (15), who note that "medication competence is always interrelated and linked to a nurse's values and attitudes." The literature suggests the same is true of IC competence. Thus, there is a need to enhance students' understanding of their own health beliefs, as per the Health Belief Model (45) and the concept of positive deviance, which implies helpful non-normative behavior (46). New graduates require the skills (and must be prepared) to communicate concern and advocate for good practice from an evidence-based standpoint. Leadership training traditionally occurs in the final year of study. To strengthen these leadership skills, it has been suggested that leadership and management courses should be integrated, sequentially, across the pre-registration curriculum (47). In addition to the inclusion of materials addressing distributed leadership and role modeling, we propose that re-visioning of the leadership training of pre-registration students, with a specific focus on creating a "coaching culture" (48)—similar to that being implemented in staff training processes in many business and institutional settings—may further enhance graduates' leadership skills. The syllabus would include: identification of the role of a coach; opportunities for people at various levels within any business/institution to enact coaching; training for potential coaches. The benefit of coaching training for students, in this context, would be development of skills in leading change through influence and persuasion rather than by simple demand or request.

In the clinical environment, clinical supervisors and nurse mentors need to both model good IC practices and support students in applying their microbiology knowledge to inform decision making about IC practices. Assisting

clinical supervisors and mentors to become more familiar with the microbiology component of the pre-registration curriculum may enhance this process. The use of active-learning models, such as problem-based learning, in teaching microbiology and IC may also enhance application of that knowledge to practice by enhancing self-efficacy (49). Post-clinical-placement debriefing sessions should provide opportunities for students to enact/practice coaching skills in both formal and informal settings and receive feedback.

CONCLUSION

Alongside highly desirable attributes such as compassion and empathy, infection prevention and control is a mainstay of daily nursing practice. Poor IC knowledge and practice pose a risk to patient (and health practitioner) safety; thus, it is essential that new graduates are competent in IC practice. Given the ongoing prevalence and impact of HAIs and the continuing emergence of new pathogens, the role of microbiology education and training as an integral component of infection control competence must not be overlooked or undervalued. Any improvements in IC practice that may be achieved through redefining IC competence and enhancing nursing students' IC self-efficacy skills will not only ensure patient safety but potentially save hundreds, perhaps thousands, of lives, including those of the nurses themselves.

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