MPhil in Health Professions Education
Stellenbosch University

Research Assignment

Best practices for the teaching healthcare workers about infection prevention and control: A systematic review

Student: Magdalena C Aucamp
Student number: 12409006
Date: March 2016

Supervisors:
Prof Susan van Schalkwyk
Deputy Director: Teaching (SURMEPI)
Centre for Helath Professions Education
Faculty of Medicine and Health Sciences
Stellenbosch University

Prof Shaheen Mehtar
Extraordinary Professor
Unit for Infection Prevention and Control (UIPC)
Faculty of Medicine and Health Sciences
Stellenbosch University

Declaration

I, the undersigned, hereby declare that the work contained in this assignment is my original work and that I have not previously submitted it, in its entirety or in part, at any university for a degree.

Date: March 2016

Best practices for teaching healthcare workers about infection prevention and control: A systematic review

Table of contents

List of figures

List of tables

Reference lists

Addenda

ABSTRACT

Background: Education and training of healthcare workers (HCWs) in the theory and practice of infection prevention and control (IPC) is widely regarded as a pivotal measure to reduce the risk of healthcare-associated infection (HAI). Although IPC programmes in healthcare facilities devote much time and effort to teach HCWs about IPC, the education methods may not always be effective to establish immediate and long-term changes in IPC practices.

Aim of the study: The aim of the study is to determine which teaching strategies have been used with success to teach HCWs about IPC and to recommend a set of best practices for effective IPC education and training.

Method: The researcher conducted a systematic review of primary studies on IPC education interventions published from 1990 to 2013. A total of 76 studies were eventually selected from sources identified by means of an extensive electronic literature search in several databases. Data was extracted and then analysed using a combination of qualitative and quantitative methods. Finally the data was synthesized and the limitations in the methodology acknowledged.

Results: The interventions mostly employed a combination of two or more teaching methods and made a conscious attempt to actively engage students in the learning process. There was a strong focus on behaviour change and reinforcement of learning to ensure long-term compliance with IPC standards. Assessment of learning and e-learning was left mostly underutilized and unexplored. No new or useful insights could be obtained from interventions done in resource-poor healthcare facilities.

Limitations: Only interventions published in English were reviewed. Most of the interventions were done in resource-rich settings and in urban tertiary education facilities.

Conclusion: IPC education strategies require careful consideration, perhaps in equal measure to the subject matter that is being taught, to facilitate effective learning that will result in a change in behaviour and practice in the long term. The systematic review revealed that the approach to IPC education and training needs to be holistic: Apart from the teaching content, consideration must be given to the context within which the teaching will provided, as well as teaching methods that will actively engage HCWs in the learning process and stimulate behaviour change. There should be continuous reinforcement of

learning by various means. These considerations and more are included in a set of recommended best practices for in-service education and training in IPC. Recommendations are made for future research projects.

ABSTRAK

Agtergrond: Onderrig en opleiding van gesondheidsorgwerkers in die teorie en praktyk van infeksievoorkoming en -beheer (IVB) word allerweë as 'n deurslaggewende maatstaf beskou om die risko van gesondheidsorgverwante infeksies te verminder. Hoewel infeksiebeheerprogramme in gesondheidsorgfasiliteite baie tyd en moeite bestee om gesondheidsorgwerkers van IVB te leer, is die onderrigmetodes moontlik nie altyd effektief om onmiddellike en langtermynveranderinge in IVB-praktyke te bewerkstellig nie.

Doel van die studie: Die doel van die studie is om te bepaal welke onderrigstrategieë met sukses aangewend is om gesondheidsorgwerkers van IVB te leer en om ‘n stel beste praktyke vir doeltreffende IVB-onderwys en -opleiding aan te beveel.

Metode: Die navorser het ‘n sistematiese oorsig van primêre studies oor IVB-onderrig-intervensies wat van 1990 tot 2013 gepubliseer is, gedoen. ‘n Totaal van 76 studies is uiteindelik geselekteer uit bronne geïdentifiseer deur middel van ‘n uitgebreide elektroniese soektog in verskeie databasisse. Data is onttrek en daarna geanaliseer deur van ‘n kombinasie van kwalitatiewe en kwantitatiewe metodes gebruik te maak. Laastens is die data gekombineer met ‘n erkenning van die beperkinge in die metodologie.

Resultate: Die intervensies het meestal ‘n kombinasie van twee of meer onderrigmetodes gebruik en het ‘n doelbewuste poging aangewend om studente aktief by die leerproses te betrek. Daar was ‘n sterk klem op gedragsverandering en die versterking van leer ten einde volgehoue navolging van IVB-standaarde te verseker. Assessering van leer en e-leer is meestal onderbenut en onverkend gelaat. Geen nuwe of bruikbare insigte kon verkry word van intervensies wat in hulpbron-arm gesondheidsorgfasiliteite gedoen is nie.

Beperkings: Slegs intervensies wat in Engels gepubliseer is, is geëvalueer. Die meeste intervensies het in hulpbronryke lande en in stedelike tersiêre onderriginstellings plaasgevind.

Gevolgtrekking: IVB-onderrigstrategieë en –opleidingsmetodes moet sorvuldig oorweeg word, moontlik met net soveel aandag as wat aan die onderwerp gegee word, ten einde

effektiewe leer te bewerkstellig wat tot ‘n verandering in gedrag en praktyk op die lang termyn sal lei. Die sistematiese oorsig toon dat die benadering tot IVB-onderrig en –opleiding holisties moet wees: Behalwe vir die onderrig-inhoud, moet die konteks waarbinne die onderrig sal plaasvind, ook oorweeg word tesame met onderrigmetodes wat gesondheidsorgwerkers aktief in die leerproses sal betrek en gedragsverandering sal stimuleer. Daar moet voortdurende versterking van leer op verskillende maniere wees. Hierdie oorwegings en ander is in ‘n aanbevole stel beste praktyke vir indiensopleiding in IVB ingesluit. Aanbevelings vir toekomstige navorsing word gemaak.

1. INTRODUCTION

It is a fundamental right of each individual to receive safe medical care without any adverse outcome caused by medical interventions that should have resulted in health benefit rather than harm. The ultimate aim of infection prevention and control (IPC) programmes in healthcare facilities is to promote patient safety by reducing the risk of healthcare-associated infection (HAI). Amidst increasing antimicrobial resistance of pathogens, growing immune-deficient patient populations and dwindling healthcare resources, the burden of HAI is a concern worldwide and the focus of major on-going research projects and efforts in both resource-rich and resource-poor healthcare settings to address contributory factors (Pittet, 2005:258-259).

The HAI burden is particularly heavy in resource-poor healthcare settings and can mainly be ascribed to limited resources, overcrowding, understaffing, a lack of infrastructure, IPC knowledge, training and competency, resulting in the inability to implement policies and guidelines to deal with IPC under the given circumstances (Allegranzi, Bagheri Nejad, Combescure, Graafmans, Attar, Donaldson, & Pittet, 2011:228-241; Pittet, Allegranzi, Storr, Bagheri Nejad, Dziekan, Leotsakos & Donaldson, 2008:285-292; Bagheri Nejad, Allegranzi, Syed, Ellis & Pittet, 2011:757-765; Zaidi, Charles-Huskins, Thaver, Bhutto, Abbas, & Goldman, 2005:1175-1188; Raka, 2009:292-298, and Raza, Kazi, Mustafa & Gould, 2004:294-299).

Education and training of healthcare workers (HCWs) in the theory and practice of IPC is widely regarded as a pivotal measure to reduce the risk of HAI. **IPC education** provides HCWs with a knowledge base and insight that act as a driving force behind future activities, whereas **IPC training** is task-orientated within a specific working milieu and helps HCWs to acquire skills to complete clinical procedures to set standards of care. In their publications and guidelines, leading organisations in the field of IPC such as the World Health Organization (WHO), the Association for Professionals in Infection Control (APIC), the Centres for Disease Control and Prevention (CDC), the Society of Healthcare Epidemiology of America (SHEA), and the Institute for Healthcare Improvement (IHI) are consistently emphasizing the need for continuous IPC training of all categories of HCWs.

In a bid to improve compliance with IPC standards, healthcare facilities have turned towards providing in-service education and training on IPC to their new and existing staff in varying degrees. This form of education typically has limited or no link to formal tertiary education

programmes. Healthcare students, however, may be exposed to in-service education and training presented at healthcare facilities as part of their service-learning experience.

Most of the teaching is provided by IPC practitioners or healthcare staff appointed to fulfil infection control functions within the healthcare facilities. Apart from giving consideration to the teaching content, the educators must decide on the teaching methods that are best suited to a particular target group in a particular setting. In the planning of education sessions, the principles of teaching and learning may not always get due consideration and although the educators may be knowledgeable in the field of IPC, they may have little knowledge of, and experience with, effective teaching methods as is the case for many experts in the medical field who teach at tertiary level (Van der Vleuten, Dolmans & Scherpbier, 2000:246-250). Practical considerations such as available time, teaching space, technology, and teaching material may often determine the type of teaching method.

In this study the focus will be on teaching methods employed to teach HCWs about IPC and an attempt will be made to determine which teaching strategies will deliver the best results to improve IPC knowledge and practice.

2. LITERATURE REVIEW

In order to explore the nature and scope of IPC education and training at healthcare facilities, the literature review looks at the IPC curriculum and how the curriculum is guided by evidence-based practice guidelines. It further explores the context within which IPC teaching and learning takes place, considering the demand for IPC education and training, the IPC teachers, and the diversity among the HCWs who are the recipients of IPC education. The literature review then considers design and quality requirements of IPC education programmes followed by a brief overview of effective teaching strategies and e-learning. Assessment of learning, performance feedback, and behaviour change has some unique features in the field of IPC teaching and learning. These features are discussed in conjunction with strategies to improve compliance with IPC standards. The literature review then also briefly focuses on the evaluation of IPC education programmes. Finally, it looks at the key findings of existing systematic reviews on IPC education.

2.1 Aim of IPC education and training

The aim of IPC education and training is to provide HCWs with a solid foundation in evidence-based theory and practice of IPC principles, thereby enabling them to apply and transfer their knowledge and skills into the workplace and in doing so help to reduce the risk of HAI (Allegranzi, Bagheri Nejad, Combescure, Graafmans, Attar, Donaldson, & Pittet, 2011:228-241; Pittet, 2005:258-267; Hambraeus, 2006:217-223).

2.2 Teaching content

According to the WHO (2011b:210-240), the IPC curriculum for HCWs should consist of both knowledge and performance outcomes. Knowledge outcomes include an understanding of the causes, scope and repercussions of HAI, the types of HAI, modes of infection transmission in healthcare facilities, and the main principles and methods to prevent and control HAI (i.e. standard and transmission-based precautions). Performance outcomes include the ability of students to apply standard and transmission-based precautions appropriately. The WHO further encourages educators to ensure that the IPC education is contextually and culturally appropriate and to make the necessary adaptations to meet local requirements, settings, available resources, and student learning needs (WHO, 2011b:18). Carrico, Rebmann, English, Mackey & Cronin (2008:691-701) did an extensive review of IPC competencies for hospital-based healthcare workers. They listed several learning outcomes that are the same as those proposed by the WHO. They however listed three additional dimensions, namely occupational health, emergency preparedness, and critical thinking

skills (risk identification and management). The learning outcomes of IPC education therefore represent a strong mixture of both theory and practical skills.

IPC subject matter should be centred on evidence-based guidelines that have been translated into standardized practice requirements (policies or standard operating procedures). Voss (2009:932) believes that IPC guidelines must be specific and give clear directions rather than making suggestions. Guidelines also need to unambiguous and focus on specific tasks, methods to complete the tasks, responsibilities, expectations and exceptions (Gurses, Seidl, Vaidya, Brochicchio, Harris, Hebden, Xiao, 2008:351-359). Standardization of tasks or work processes improves the reliability of the outcome. It further stands to reason that guidelines must be practical, applicable to the healthcare context, feasible (based on available resources), and well communicated, with specific consideration to social and cultural context (Cinel & Dellinger, 2006:483-488; Edwards, Sevdalis, Vincent & Holmes, 2012:25-29).

The need for a strong connection between theory and practice cannot be more relevant than in resource-poor settings. Guidelines for infection control best practice are mainly generated in resource-rich settings and large portions of these guidelines are impractical or even impossible to implement in developing, resource-low settings (Zimmerman, 2007:494-500). Resource-limited settings should generate their own best practice standards based on sound principles that are cost-effective and realistic. These standards should be included in infection control education and training programmes with a strong emphasis on practical implementation (Mehtar, 2008:325). They should also be reflected in the learning outcomes.

2.3 Providers of IPC education and training

A significant portion of the work output of IPC practitioners is devoted to education and training. Both the US-based APIC and the European Centre for Disease Prevention and Control (ECDC) have developed conceptual models outlining required competencies of IPC practitioners (Murphy, Hanchett, Olmsted, Farber, Lee, Haas & Streed, 2012: 296-303; ECDC, 2013:9). These models can be applied in all healthcare practice settings to varying degrees. Both models have identified education as a core competency and require that IPC practitioners must be able to:

- Perform IPC education needs assessments
- Design and deliver IPC education and training programmes
- Select appropriate training methods to achieve the learning outcomes
- Evaluate the effectiveness and impact of the education and training

In South Africa there is a growing demand for IPC education and training. The national core standards for healthcare establishments of the South African Department of Health (DoH, 2011:23) require that 50% of healthcare professionals within each healthcare facility receive training in basic IPC principles annually. The implicit expectation is that the training be provided mainly by the healthcare facilities, i.e. the infection control staff in the healthcare facilities.

Tygerberg Hospital, a 1400-bed teaching and tertiary referral hospital in Cape Town linked to Stellenbosch University, South Africa, has a well-established IPC programme. In terms of the provincial health authority's staff performance management system, 20% of the weight of output of the IPC practitioners is allocated to the key performance area of educating staff in the principles and management of IPC (Western Cape Government, 2002). The IPC practitioners are required to plan and create learning opportunities, provide IPC education at the request of provincial agencies, and inform newly-appointed staff as well as undergraduate and postgraduate healthcare students about the hospital's IPC programme and IPC practice requirements.

2.4 Recipients of IPC education and training

IPC in-service education and training in all healthcare settings generally has to be provided to a diverse group of healthcare professionals (among which doctors, nurses, physiotherapists, occupational therapists, and radiographers) and other staff (among which decontamination and sterilization operators, porters, environmental cleaners, and maintenance staff).

Numerous surveys done among mainly doctors and nurses in both resource-rich and resource-poor healthcare settings revealed that they had inadequate knowledge of, and insight into, core elements of IPC. Many of them had preconceived notions, traditional beliefs or acquired misconceptions about IPC. But most importantly, they had received very little to no IPC instruction as part of their professional training and very little in-service training in IPC, and the healthcare facilities in which they worked, lacked standardization of IPC practices (Higgins & Evans, 2008:48-53; Taneja, 2009:104-107; Labeau, Vandijck, Rello, Adam, Rosa, Wenisch, Bȁckman, Agbaht, Csomos, Seha, Dimopoulos, Vandewoude & Blot, 2009:320-323; Stein, Makarawo & Ahmad, 2003:68-73; McHugh, Hill & Humphreys, 2010:96-100; O'Brien, Richards, Walton, Phillips & Humphreys, 2009:171-175; Marjadi & McLaws, 2010:399-403). These knowledge deficits emphasize the need for effective and continuous education and training for all categories of staff (Cohn, 2009:80-86). Moreover,

health professions educators should reconsider how IPC education at undergraduate level can be designed to establish a stronger foundation for future IPC practice, which could have a profound impact on HAI outcomes (Cox, Simpson, Letts & Cavanagh, 2015:55-67).

Apart from diverse professions and occupations there is also diversity within each group in relation to age, cultural background, qualifications, rank, experience, interests, literacy (including computer literacy) and language proficiency. Existing knowledge of IPC therefore varies widely. Several teaching strategies have been suggested to achieve effective learning in a diverse group:

- Get to know the students and recognize their diversity (Williams & Calvillo, 2002: 223).
- Create a positive and supportive learning environment where diversity is embraced. Students should feel at ease to ask questions and to contribute to discussions. They should be made to feel that their opinions are respected (Williams & Calvillo, 2002:225). The teacher should be sensitive about matters such as use of language (avoiding colloquialisms/idiomatic expressions) if English is not the first language of some of the students (Johnston & Mohide, 2009:343-346).
- Include discussion and subject material on diversity issues. The teacher should select material and examples from the wide range of backgrounds represented by the students (*Teaching Matters*, 2000:1). Deliberately including diversity issues into class discussions and perhaps even in the teaching plan will have the additional benefit that it will promote complex thinking skills and cultural and social awareness among students, adding to their ability and skills to deal with diversity issues as professionals (Sciame-Giesecke, Roden & Parkison, 2009: 156-157)
- Rather than being reactive to diversity the teacher should proactively plan to meet the diverse student needs and interests by modifying the teaching content, teaching methods and learning activities accordingly. This will help to ensure that the teaching-learning interaction remains meaningful (Tomlinson, Brighton, Hertberg, Callahan, Moon, Brimijoin, Conover & Reynolds, 2003:121-122,131).
- Accommodate differences in knowledge levels by selecting additional reading material and plan additional learning activities that students may need (*Teaching Matters*, 2000:1): Advanced students who already have a sound knowledge base can be given additional material to challenge them and to take their knowledge to deeper level; for those students who struggle with the content, the teacher may select material that explains it in a different way (e.g. case scenarios with different solutions for how a problem can be addressed) and provides more examples to promote

understanding. Teaching schedules should be flexible to allow the students to devote more time to study activities that they struggle with and give them the opportunity to repeat learning tasks until they have shown that they mastered the task (Tomlinson *et al.*, 2003:132; *Teaching Matters*, 2000:1).

2.5 Inter-professional education

Another dimension of teaching that links to diversity is the matter of inter-professional education. Different professions of healthcare workers would often receive IPC education in the same classroom or clinical area but just as often it would be regarded as preferable and more feasible to train the different professions separately so that the focus can be on the particular IPC challenges that each profession encounters in practice. For example, doctors usually insert central venous lines while nursing staff are mainly responsible for the proper maintenance of and access to the line. The focus of their training on central lines is therefore different, but there are communal factors that they need to be educated on, such as the management and removal of the line (Berenholtz, Pronovost, Lipset, Hobson, Earsing, Farley, Milanovich, Garrett-Mayer, Winters, Rubin, Dorman & Perl, 2004:2014-2020). The idea of inter-professional education has therefore been practiced to some extent in the field of IPC but rather mostly for convenience than by design.

Manasse (2009) strongly believes that healthcare professionals can no longer work in isolation. Interdisciplinary decision-making and problem-solving based on expertise is required to provide optimal and holistic patient care. In order to achieve interdisciplinary teamwork and cohesion it is necessary to provide opportunities where the different health professions can learn together. According to the WHO, inter-professional education "…occurs when students from two or more professions learn about, from and with each other to enable effective collaboration and improve health outcomes" (WHO, 2010:7). The concept of inter-professional education in IPC merits further exploration since the very nature of IPC programmes lends itself to inter-professional collaboration and it can be argued that inter-professional IPC education will help to make IPC practice contextually more relevant. According to Hammick, Freeth, Koppel, Reeves & Barr (2007:735–751) inter-professional education is often used as a tool to enhance the development of practice and to improve services.

2.6 Designing an IPC education programme

The researcher would argue that the design of an IPC education programme in a healthcare facility merits the same time, effort and methodology as a curriculum development process at a tertiary education institute. At the core of the design lies a dynamic interaction between

a needs assessment, learning aims and objectives, learning content, teaching strategies, learning experiences, assessment, and curriculum evaluation (Geyser, 2004:148-151; McKimm, 2003; Harden, 2005:10-11; Grant, 2006:3; Cannon & Newble, 2000:142-164). In this systematic review, the researcher will evaluate how these core elements were employed in IPC education and training.

2.7 Effective teaching strategies

According to Van der Vleuten, Dolmans & Scherpbier (2000:246-250) medical education is often directed by intuition and tradition rather than evidence. Educators do not make a habit of reading literature on education and tend to make some false assumptions about teaching and learning. One of these assumptions is that teaching equals learning. Lecture-based teaching is most often used and the assumption is that students will learn by listening to the lecturer delivering a lecture. Students however need to structure and restructure information in order to fully understand and use the information. (This falls in the realm of the constructivist theory of learning.) The teaching process must enable learning to take place by adding meaningful contexts to the information, by building on prior knowledge, by expecting the student to participate actively in the learning process, by applying the knowledge in different contexts, and by stimulating motivation (Gravett, 2005:19-20). According to the Van der Vleuten, Dolmans and Scherpbier (2000), educators do not take into account the profound impact of assessment on learning, i.e. that assessment drives learning. For this reason there must be a good match between the learning objectives and the assessment design.

Teaching methods have a substantial impact on student learning (Ende, 1997:S41; Krueger, Neutens, Bienstock, Cox, Erickson, Goepfert, Hammoud, Hartmann, Puscheck, & Metheny, 2004:408). IPC educators therefore need to consider education theory as well as learning and teaching principles. Besides giving attention to the teaching content, the quality of IPC teaching methods should be evaluated in terms of their impact on effective learning and practice (Sax, Allegranzi, Uçkay, Larson, Boyce & Pittet, 2007. 67:9-21). The teacher has to create a learning environment that is positive, responds to the needs of each student, encourages active learning by offering a variety of teaching formats, and promotes a deeper understanding so that knowledge can be translated into practice (Ramsden, 2003:62-83). There are several strategies that have proven to facilitate effective learning:

- **Focus on learning styles:** Students, including HCWs who have to learn about IPC, have diverse learning styles. Teaching methods should incorporate the different learning styles of HCWs in order to maximize learning. For example, the teacher should include a combination of lectures and discussions for auditory learners, visual

presentations and materials for visual learners, and physical involvement in learning tasks for tactile learners (Felder & Brent, 2005: 57, 62; Williams & Calvillo, 2002: 224-225; Tomlinson *et al.*, 2003:131). By exposing HCWs to different teaching modes, they have the opportunity to benefit from their preferred learning style for part of the teaching session and then develop the skills/capacity to deal with other learning styles as well (Felder & Brent, 2005:62; Buckridge & Guest, 2007:134-135,137; *Teaching Matters*, 2000:1).

- **Student-centred, active learning:** A stimulating learning environment is based on students' active participation with the emphasis on dialogue, cooperative learning and enquiry-type of activities (Cannon & Newble, 2000:17-18; Michael, 2006:159-167; Prince, 2004:223-231). The diversity that is usually found in classes where IPC teaching is provided can be used by asking HCWs to contribute examples from their own healthcare environments and experiences. This can be done in group work, class discussions, or case studies (Williams & Calvillo, 2002: 225; *Teaching Matters*, 2000:1). HCWs should be able to build on their existing IPC knowledge, focus on making sense of the new subject (insight), and see the relevance of what they are learning (Tomlinson *et al.*, 2003:131).
- **Small-group learning.** The benefits of small-group learning (cooperative learning) for cognitive growth and deep learning have been well documented (Springer, Stanne & Donovan, 1999:21-25; Oakley, Felder, Brent & Elhajj, 2004:9; Bitzer, 2004:43-44; Cabrera, Amaury, Crissman, Terenzini, Bernal & Pascarella, 2002:20-22, 31; Tomlinson *et al.*, 2003:132; Cannon & Newble, 2000:38-58). Small groups should consist of 3 to 4 HCWs. (If the group is too small there might not be a sufficient variety of ideas and skills to solve problems; if the group is too big some members will not participate actively and leave the other students to do the work.) Small groups will help the HCWs to achieve deep learning, retain the information longer. The teacher should form the teams based on the HWC diversity (stronger/weaker students, different educational backgrounds, different intellectual abilities, different experience levels, and different backgrounds) instead of the HCWs forming the groups themselves since the stronger learners will tend to group themselves together and leave the weaker learners out. The weaker learners will find role models in the stronger learners and be tutored by the stronger learners; the strong learners who do the tutoring may in turn benefit from the teaching experience (teaching being a good way to learn). It is important to set clear guidelines and expectations for the HCWs so that there is no confusion about their assignments (Oakley, Felder, Brent & Elhajj, 2004:9-13).

- **Class discussions:** HCWs can be asked to contribute their existing knowledge about IPC to class discussions and then to incorporate new material into the discussion, thereby building on their existing knowledge. Insight and application of the new knowledge can be tested by giving the HCWs problems to solve. The HCWs can for example be given case studies dealing with contentious IPC issues, or they can be asked to write a plan of action to state what changes they are going to bring about in their clinical areas based on what they have learned during the teaching session. Linking existing knowledge to the new material makes the learning more meaningful (Williams & Calvillo, 2002: 225) and constructing knowledge in this way is the foundation of the constructivist theory of learning (Gravett, 2005:19-20).

2.8 E-learning

E-learning has several advantages: It increases accessibility to information; it is easy to make adjustments to educational content; it is easy to distribute the course material and there is no limit to the number of students who can enrol for the course at the same time; students have control over the pace and time of learning; content and accountability is standardized; it can provide automated tracking of student activities; it can also assess learning; and active learning can be arranged by means of interactive tasks. E-learning was found to be at least as good as traditional instructor-led lectures and although the initial acquisition of e-learning technology and the creation of e-learning content may be expensive in terms of cost of equipment/software and staff time, cost savings will eventually occur due to reduced instructor training times, travel costs and a reduced demand on infrastructure (Ruiz, Mintzer & Leipzig, 2006:207-212).

Within the field of IPC, there are several examples of e-learning in the published literature, the need for e-learning being dictated by the need for continuous education combined with demanding workloads and shift work in healthcare facilities (Bryce, Yassi, Maultsaid, Gamage, Landstrom, LoChang & Hon, 2008:228 – 237; Humphreys, McHugh, Dimitrov, Cowman, Tierney and Hill, 2012:644).

2.9 Role of assessment and feedback on performance

Assessment is much more than a way to determine if a student has acquired sufficient knowledge or competency measured against the objectives of the teaching programme to receive a pass mark or to be declared competent. Intermittent assessment and feedback to the student can measure learning progress and help the student to address shortcomings. It can thus become an important teaching mechanism (Cannon & Newble, 2000:166). According to Nicol & Macfarlane-Dick (2006:199-218) feedback to students has many

purposes, among which some relate to behaviour change: Feedback helps to develop self-assessment (reflection) in learning and promotes positive motivational beliefs, thereby facilitating behaviour patterns that close the gap between current and desired performance.

Assessment is also a primary motivational factor for learning because students tend to be focused on what they need to know to achieve a pass mark. It is generally recognized that assessment in fact drives learning (Geyser, 2004:90-91). Assessment must however be planned carefully to achieve optimal learning. It must have a clear purpose and meet the required standards of validity, i.e. assessing what it intends to assess rather than what is easy to assess, and reliability, i.e. different assessors marking diverse groups of students consistently the same in different situations (Wass, Bowden & Jackson, 2007:11-26; Geyser, 2004:90-110).

2.10 Strategies to change behaviour and improve compliance with IPC standards

The gap between “knowing” and “doing” has become a focal point in IPC education and training. HCWs often know what the correct practice is (e.g. the need to perform hand hygiene) but do not always adhere to the practice standards (Borg, 2014:161-168). According to Edwards, Sevdalis, Vincent & Holmes (2012:25-29) who did a systematic review on the use of behaviour change in IPC in acute healthcare facilities, educators need to consider social and cultural influences on behaviour and practice as well as factors such as time pressures and a lack of interest and insight in the relevance of IPC. Often HCWs may have acquired understanding of IPC measures but cannot translate them into daily clinical practice. The authors recommend that clear and measurable behaviour change objectives be added to IPC learning outcomes. In order to achieve behaviour change, the authors suggest that much can be learned from commercial marketing strategies and how audiences are reached and sold on ideas.

In addition to behaviour change, strategies to reinforce learning and support practice have become topical in IPC research literature. Ample evidence is available to confirm that in addition to education, motivation for behaviour change, performance feedback, reminders at the workplace about expected standards of care, administrative support, and provision for adequate facilities and supplies (thereby enabling the HCWs to carry out the actions that are required of them) should be included in education interventions to improve IPC practice (Flodgren, Conterno, Mayhew, Omar, Pereira & Shepperd, 2013; Mathai, Allegranzi, Seto, Chraïti, Sax, Larson, & Pittet.(2010:349-356); Pittet, 2004:1-13; Pittet, 2000:381-386; Naikoba & Hayward, 2001:173-180); Allegranzi, Sax, Pittet, 2013:S3-S10).

In 2009, the WHO “Clean Care is Safer Care” programme developed a multi-modal hand hygiene improvement strategy based on scientific evidence. The strategy included five components, namely system change, HCW education, monitoring of hand hygiene compliance with performance feedback, reminders in the workplace, and improvement of the institutional patient safety climate (WHO, 2009).

2.11 Evaluation of education programmes

A traditional approach to the evaluation of education programmes is that of student ratings. Berk (2013), however, warns against the use of student ratings as the only measure to judge the effectiveness of teaching, stating that such ratings will only give partial information. He suggests that the educator should instead use self, peer, and mentor rating scales in addition to student rating scales to obtain a range of perspectives. Berk further advises that the educator should look at the content and quality of the rating scales and how useful these scales will be to make informed decisions related to teaching.

In the healthcare environment where IPC is applied in practice, the educator has additional sources of information at hand to measure teaching effectiveness (albeit indirectly), namely outcome measurements (e.g. HAI rates) and process measurements (compliance to IPC standards as measured by means of IPC audits).

2.12 Existing systematic reviews of literature on IPC education

There is an existing body of literature on IPC education, including five systematic reviews that were retrieved during the search process. Conclusions drawn from the five reviews (Safdar & Abad, 2008:933-940; Ward, 2011:9-17; Naikoba & Hayward, 2001:173-180; Cherry, Brown, Neal & Shaw, 2010:198–218; Gould, Drey, Moralejo, Grimshaw & Chudleigh, 2008:193-202) are that:

- Education of HCWs may improve compliance with IPC standards and reduce HAI rates in the short term only, unless a concerted effort is made to sustain the compliance by means of repeated education sessions and continuous reinforcement of learning.
- There are many factors that affect compliance with IPC standards, e.g. work load, the attitude of HCWs, lack of supplies, and suboptimal facilities. It was therefore not possible to consider the effect of education alone.
- Since most studies used a combination of interventions and had different approaches to education and training, it was not possible to single out one particular educational intervention that was the most effective.

- Increased knowledge does not necessarily improve practice.
- Education interventions should be combined with continued monitoring of and feedback on performance, placement of reminders at prominent places in clinical areas, and making appropriate supplies available.
- The description of education methods and intervention design lacked sufficient details.
- Further studies are needed to determine the independent effects of education on HAI and cost savings.

These conclusions reinforce the evidence that a multifaceted approach is essential to support education in order to achieve compliance with IPC practice requirements. Table 1 below provides a summary of findings of each of the individual systematic reviews.

Systematic reviews on IPC education
• Safdar & Abad, (2008:933-940) did a systematic review of literature to determine the effect of HCW education on HAI rates. The review included 26 studies (randomized controlled trials, controlled before-and-after studies, and interrupted time-series analyses) that described an educational intervention for the prevention of HAI. They authors concluded that the implementation of educational interventions may reduce HAI rates significantly and recommended cluster randomized trials using validated educational interventions and costing methods to determine the independent effect of education on reducing HAI and cost savings. They could not determine which particular educational intervention is the most effective because the studies used different approaches combined with other interventions to reduce HAI. Education interventions in resource-poor settings and non-teaching hospitals also had a beneficial effect. They noted the lack of detailed description of the content of the educational interventions. • Ward's (2011:9-17) systematic review highlighted the experience of student nurses and midwives with relation to learning IPC in clinical practice and to determine the role of education in IPC. The review included 39 studies that were mostly quantitative studies utilizing pre- and post-interventional, quasi-experimental and comparative trial designs. The author's findings were that there is no conclusive evidence that education improves compliance with IPC precautions or reduces the HAI rates, especially in the long term. Many factors can have an impact on practice and HAI, e.g. workload, skill levels, staff perceptions of risk, time pressures and the facilities that the staff use. It is not possible to isolate and consider education alone. Increased knowledge does not necessarily

improve practice. The author recommends that further research is necessary to determine the reason for this.

- Naikoba & Hayward (2001:173-180) did a systematic review to establish the effectiveness of education interventions aimed at increasing HCW compliance with hand hygiene. The review included 21 studies (17 uncontrolled trials, two randomized controlled trials and one observational study).The authors found that once-off interventions had a short-term effect on hand washing behaviour. A combination of interventions that included education, continued feedback of performance, placement of hand washing reminders in clinical area, and placement of alcohol hand rub close to the patient bed can have an effect on hand washing compliance and reduce the HAI rate.

- Cherry, Brown, Neal & Shaw (2010:198–218) reviewed education interventions focusing on the aseptic insertion and maintenance of central venous catheters (CVCs) to establish which characteristics had the most profound and prolonged impact to change HCW infection control behaviour and thereby improve patient outcomes. The review included 47 studies (the type of studies were not mentioned). Their conclusion is, among others, that educational interventions should be applied together with audits, feedback and the availability of appropriate clinical supplies; education sessions should be repeated regularly, be part of daily practice and have practical participation from students; HCW must be actively involved and be motivated; and the dissemination of information through peers or higher management may have a limited impact to change practice.

- Gould, Drey, Moralejo, Grimshaw & Chudleigh (2008:193-202) did a systematic review of studies that evaluated the effectiveness of education interventions to increase hand hygiene compliance. The review included four studies - one randomized clinical trial, one controlled before and after study, and two interrupted time series studies. The authors deplored the lack of sufficient description of the education framework and recommended that future studies include a rationale for the education method, details about the educators together with their preparation, the programme content, the number of HCWs educated, evaluation, required changes to the educational programme, and the impact of the educational intervention. They further recommend that a clear distinction between the terms ‘education’ and ‘training’ be made. Their findings conclude that both clinical and behavioural scientists should be consulted to design future studies and that interrupted time-series studies may offer the best information to determine the impact of

hand hygiene interventions.

Table 1: Summary of systematic reviews on IPC education

Assessment of the **methodological quality of the five systematic reviews** by means of the AMSTAR (A Measurement Tool to Assess Systematic Reviews) checklist (Addendum C) shows low scores for all but two of the systematic reviews. The results of this assessment confirm that further systematic reviews on IPC education based on established methodology for systematic reviews are needed.

From this literature review it is evident that the design of IPC teaching programmes in healthcare facilities requires thoughtful planning so that learning needs, learning content, education methods, and assessment form a cohesive unit, IPC education requires a strong focus on behaviour change. It is also important to make sure that teaching programmes are contextually appropriate and that the teaching strategies include continuous reinforcement of learning.

3. AIM AND OBJECTIVES OF THIS STUDY

Although most IPC programmes in healthcare facilities spend much time and effort to teach HCWs about IPC with the aim of achieving better compliance with IPC practice standards, the effectiveness of the teaching methods needs to be determined. It would be worthwhile to determine which teaching strategies have been used with success to teach HCWs about IPC and to recommend a set of best practices for effective IPC education and training keeping in mind the range of factors that influence such education and training. Rather than providing broad recommendations on teaching strategies, the intention is to make give specific directions that have practical applicability to improve teaching and learning in IPC. McMillan (2010:3-7) strongly endorses the view that educational research should go further than description and should in addition produce explanations that are educationally significant and that can be applied in practice. In addition, very few systematic reviews have been conducted on IPC education. A comprehensive review of IPC education interventions should therefore add to the body of existing knowledge and help to find evidence for best practices with regards to IPC education. This set of best practices may form the basis for further research in this field

The **aim of this study** is therefore to collect and review studies on primary IPC education interventions done in healthcare facilities worldwide and in all types of healthcare settings. Based on the review of these studies, the **objectives** are to:

- Analyse the studies in terms of teaching methods and other strategies employed and how they were applied.
- Identify unique contextual challenges that face IPC education.
- Determine what teaching methods are the most effective to improve IPC knowledge, attitudes, and practice.
- Determine what teaching methods will be the most effective in resource-limited settings and how do they differ from teaching methods in resource-rich settings.
- Determine what can be done to ensure that knowledge retention is long-term rather than short-term.
- Develop recommendations that constitute best practice in IPC education.
- Add to the body of evidence in IPC education.

.

4. METHODOLOGY

4.1 Criteria for considering studies for the review

In order to achieve the aim of the study, namely to determine best practices for teaching HCWs about IPC in healthcare facilities, the researcher considered all studies that included IPC in-service education and training of HCWs with the aim of improving patient outcomes. All types of before-and-after interventions (including cohort studies, controlled studies, observation studies, experimental studies, and interrupted-time-series studies) were considered. The researcher conducted a systematic review of primary intervention studies (i.e. not reviews) on IPC education interventions using methods described in established guidelines for systematic reviews (JBIEBNM, 2001:1-6; Higgins & Green, 2008:83-293; Wright, Brand, Dunn & Spindler, 2007:23-29; Cook & West, 2012:943-952) but in particular the preferred reporting items for systematic reviews and meta-analyses (PRISMA) statement checklist (Addendum D) and PRISMA flow diagram (Figure 1), adapted from Moher, Liberati, Tetzlaff, Altman & PRISMA Group (2009: 264-269). The researcher found the PRISMA methodology easy to comprehend and considered that the methodology would provide her with the best chance to achieve transparent and complete reporting of the systematic review.

The **inclusion criteria** for the IPC education intervention studies were:

- Studies published from 1990 to 2013.
- Studies that included one or more IPC education interventions, provided a description of the teaching method(s), and were deemed successful based on one or more measured outcomes of the intervention. (The assumption was made that most of the education intervention studies that fail would not be published and making an analysis of the few published studies with failed outcomes would be biased.)
- The IPC education intervention entailed in-service education and/or training in any type of healthcare facility and for any HCW category (doctors, nurses, nursing assistants, physiotherapists, respiratory therapists, occupational therapists, radiographers, and pharmacists, i.e. who render clinical care to patients).
- Studies with outcome measures that included knowledge tests, HAI rates, compliance rates, and/or consumption of supplies used for IPC purposes.

The **exclusion criteria** for the intervention studies were:

- Review and systematic review studies. (The search process for primary studies yielded several review and systematic review studies. Some of these were useful items and they were added to the literature review.)

- Studies on the management of outbreaks. Education interventions during outbreaks are usually conducted in a hurry and are focused solely on the cause of the outbreak. HCWs are also usually under great pressure from the healthcare facility management to step up their performance. The outcome of such education interventions may therefore not be a true reflection of the education provided but rather that of outside factors.
- Trials with new devices or products aimed at preventing/reducing infection (e.g. antimicrobial catheters). Such trials are often accompanied by incentives (e.g. gifts or sponsorship) to use the product and the outcome of education interventions accompanying such trials may therefore be biased.
- Interventions with no clear description of the education methods employed.
- Interventions that did not have successful outcomes.
- Interventions that focused on patient education.
- Studies that focused on tertiary education courses or modules presented at tertiary education institutions.

4.2 Identification of primary intervention studies (non-review studies)

In order to ensure that the literature search was thorough and correct, the researcher enlisted the help of a research librarian to conduct searches in the PubMed/Medline database. The librarian applied filters to retrieve abstracts in English from 1990 to 2013. The following initial searches were conducted:

- A search using the search terms (teach* OR learn* OR instruct* OR educat* OR train* OR in-service training) AND (infection OR infection control OR infection prevention OR healthcare-associated infection OR HAI) AND (best practice* OR teaching strateg*)
- A search using the search terms (teach* OR learn* OR instruct* OR educat* OR train* OR in-service training) AND (health care worker* OR community health worker*) AND (infection OR infection control OR infection prevention OR healthcare-associated infection OR HAI) AND (best practice* OR most effective*)
- A search using the search terms (teach* OR learn* OR instruct* OR educat* OR train* OR in-service training) AND (health care worker* OR community health worker*) AND (infection OR infection control OR infection prevention OR healthcare-associated infection OR HAI) AND (Africa* OR developing countr* OR developing world* OR third world* OR low income countr* OR resource-poor countr*)
- A search using the search terms (teach* OR learn* OR instruct* OR educat* OR train* OR in-service training) AND (infection OR infection control OR infection

prevention OR healthcare-associated infection OR HAI) AND (CAUTI OR CLABSI OR SSI OR VAP)

- A search using the search terms (teach* OR learn* OR instruct* OR educat* OR train* OR in-service training) AND (health care worker* OR community health worker*) AND (infection OR infection control OR infection prevention OR healthcare-associated infection OR HAI) AND (review OR systematic review)

During 2013 the researcher then conducted additional searches (using the same search terminology as described above) in the databases of the following publications since they are known to publish frequently on IPC education interventions and are renowned for the quality of their studies:

- *American Journal of Infection Control*
- *Critical Care Medicine*
- *Hospital Infection Control*
- *Infection Control and Hospital Epidemiology*
- *Pediatrics*
- *The Canadian Journal of Infection Control*

The total number of records identified through database searching was 693. In a bid to retrieve more education intervention studies, the researcher scanned the **references** used in systematic reviews on IPC-related subjects from the **Cochrane Database of Systematic Reviews** as well as references used in published guidelines of the WHO, CDC, APIC and IHI focusing on IPC, device-related as well as procedure-related infections. This process yielded 53 records.

Finally, the researcher added 17 intervention studies from her own collection – these were collected over a period of more than ten years during which time the researcher had engaged in periodic IPC research. A grand total of 763 records were identified.

4.3 Study selection

When all the duplicates were removed, 431 records remained. These records consisted of abstracts as well as full-text articles. (Potentially useful references from the systematic reviews and guidelines mentioned above were directly retrieved as full-text articles.)

The researcher did not make use of a second reviewer during the screening process since the clearly defined inclusion and exclusion criteria made it a simple and clear-cut process to

determine which records had potential to be included in the study. This could, however, be regarded as a limitation of the study. The screening process (scanning of abstracts and retrieved full-text articles) eliminated a further 278 records, leaving behind a total of 153 potentially useful records. The full texts of the abstracts were then retrieved.

The researcher used a nine-question instrument (Table 2) to appraise the quality of the remaining 153 intervention studies. The instrument served as a guideline since it covered the elements that the researcher required to be present in the methodology and description of the intervention studies in order to make data extraction from these studies possible. All or most of the questions had to get a positive answer before the researcher would accept an intervention study. The researcher also had to be convinced that the outcome indicators could be linked to the education interventions.

Education intervention appraisal instrument
1. Is there a clear question which the study seeks to answer?
2. Is there a clear learning need which the intervention seeks to address?
3. Is there a clear description of the educational context for the intervention?
4. Is the precise nature of the intervention clear?
5. Is the study design able to answer the question posed by the study?
6. Are the methods within the design capable of appropriately measuring the phenomena which the intervention ought to produce?
7. Are the outcomes chosen to evaluate the intervention appropriate?
8. Are there any other explanations of the results explored in the study?
9. Are any unanticipated outcomes explained?
(Morrison, Sullivan, Murray & Jolly, 1999:890-893)

Table 2: Instrument used to critically appraise reports of educational interventions

The eligibility review together with the quality appraisal narrowed the records down to 85 intervention studies. During the data extraction process the researcher excluded a further nine studies, which resulted in a final number of 76 studies that comprise the body of evidence for this systematic review. The researcher reviewed the rejected studies twice with a time interval of three months apart to ensure that no useful studies were rejected by mistake. With the second check (again with the use of the appraisal instrument) the researcher was convinced that she did not omit any studies by mistake and therefore did not deem it necessary to request a second person to evaluate to rejected studies. For a larger-scale project it would be regarded as imperative to have a second person cross-check the selection process in order to reduce the possibility of bias.

The literature search process also retrieved five systematic reviews on IPC education that were excluded in terms of the exclusion criteria but were used in the literature review and for comparative purposes.

4.4 Data extraction and risk of bias assessment

The researcher used a Microsoft Excel spread sheet to extract data (Addendum B) using a predetermined set of categories required to analyse the data. The categories are linked to the aim and objectives of the study and comprised the following:

- Setting, i.e. type of healthcare facility/ward/unit and country
- Study design and duration of the study
- Target group for IPC education and/or training
- Aim of intervention
- Description of the intervention and teaching methods employed
- Outcome of the education intervention

Risk of bias in the studies was assessed to a limited extent by means of the appraisal instrument described in Table 2. The instrument helped the researcher to reject studies with gross and apparent bias. It is acknowledged that this instrument is insufficient for a comprehensive risk of bias assessment and that an established tool such as The Cochrane Risk of Bias Tool could have been employed instead.

4.5 Data management and synthesis

In order to analyse the setting, study design, duration of the study, target group, and aim of the intervention, the researcher used simple quantitative data analysis methods by dividing each data category into subcategories and counting the number of occurrences. In order to determine whether the setting of the educational intervention was located in a resource-rich or resource-poor healthcare setting, the International Monetary Fund (IMF) listing for the economic development status of countries was used (IMF, 2012).

The data category “description of the intervention and teaching methods employed” as well as the data category “outcome” required quantitative data analysis. Using data analysis methods described by Cousin (2009:31-50) and Maree (2011:99-120), the researcher made use of content analysis to identify and summarize concepts, continuously keeping the aim of the study in mind. The process was inductive since the researcher did not work with a predetermined set of categories and had to explore and form relations between emerging

subcategories of concepts. The process was also iterative since the researcher looked for repeating concepts as they emerged. The researcher then used coding to give the subcategories of concepts meaningful names. Eventually the codes were structured and combined based on their relationship to each other. The codes were combined into themes such as education and training methods, features of interactive learning, reinforcement of learning, assessment methods, and outcome measurement. At first the researcher created a preliminary coding system and reviewed five full text articles to determine how applicable the coding was. The coding system was eventually refined and adjusted four times before it was deemed correct, feasible and appropriate for the systematic review. The extracted data and applied codes were cross-checked twice by the researcher at different time intervals. The researcher acknowledges the risk of bias by not including a second person to review the data extraction process. This omission was in the context of the project being on a small scale. Any further evolvement of this project (e.g. preparation for possible publication) would require the input of a second researcher.

The focus of the data interpretation phase was to find answers to the main research question, namely what are the best practices for teaching HCWs about IPC. The researcher connected some of the findings and described themes, explaining their significance in relation to IPC education and training. She pointed out the inherent biases in the systematic review and questions that the review was not able to answer.

The researcher further evaluated the study designs of the education intervention studies pointing out where there was possible room for improvement and where more detailed description would be required to enable reviewers to analyse the effectiveness of teaching methods used. She also evaluated the teaching methods in relation to learning theory.

She compared the review findings with the findings of other review studies and pointed out similarities in the findings but also where this systematic review retrieved additional findings, thereby contributing to the body of evidence. Finally, based on the literature review and systematic review of IPC education intervention studies, she was able to propose a set of best practices for IPC education and training in healthcare facilities.

In the process, constant cross-checks were made to the PRISMA checklist.

4.6 Assumptions and limitations

Inevitably the study is based on some key assumptions and includes some limitations:

- When data was extracted from the databases of well-known journals the assumption was made that the best primary studies on IPC education interventions would be obtained from these sources.
- Only literature studies done in English were included.
- The Campbell Collaboration's database was not searched for systematic reviews relevant to IPC education and training.
- No searches were done in the Best Evidence Medical Education (BEME) Collaboration database although one of their systematic reviews relating to IPC education (Cherry, Brown, Neal & Shaw, 2010:198-218) was retrieved in the initial general search process and used in the literature review.
- The researcher could have validated the screening process by using a second person to evaluate texts that were both included and excluded from the systematic review. At the same time it can be argued that the screening and eligibility review had been accurate as suggested by the fact that the findings of the systematic review confirmed much of what is already in the literature.
- The researcher could have reduced the risk of data extraction bias by using a second person to evaluate the data extraction process.
- The researcher could have used an established tool to do a thorough risk of bias assessment of the studies included in the review.

5. RESULTS

5.1 Search results and description of studies

The findings below are based on an analysis of the 76 education intervention studies that met the inclusion criteria (Figure 1).

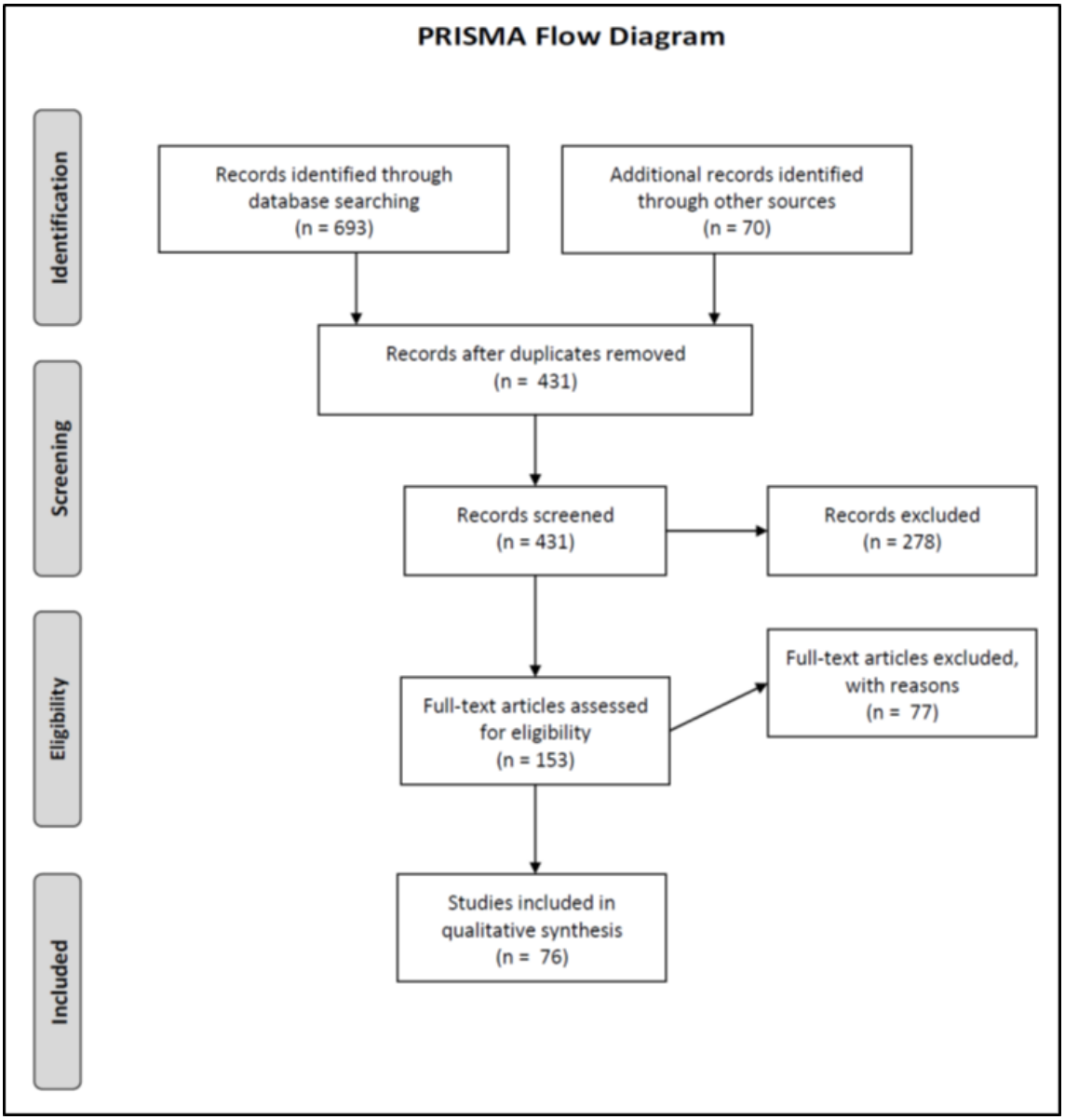

Figure 1: PRISMA flow diagram

The analysis is based on the main data categories used for the extraction of data together with themes and ideas that emerged from them. The data categories are the setting (type of healthcare facility and country), study design and duration of study, target group for IPC education and training, aim of the intervention, description of the intervention, teaching methods employed, and outcome of the education intervention.

5.1.1 Setting

Most of the studies (44%; n=33) originated from North America, followed by Europe (25%; n=19), Asia (13%; n=10), Central and South America (12%; n=9), the Middle East and North Africa (5%; n=4), and Australia (1%; n=1). Most of the interventions (74%; n=56) were done in resource-rich locations and the remaining (26%; n=20) in resource-poor locations (IMF, 2012:179-183). See Table 3.

Region	Country	Studies per country (n)	Total per region	% per region
North America	USA *	28	33	44
	Canada *	4		
	Mexico **	1		
Europe	Switzerland *	5	19	25
	Spain *	5		
	UK and Northern Ireland *	3		
	France *	2		
	Ireland*	1		
	Italy *	1		
	Netherlands *	1		
	Russia **	1		
Asia	China *	4	10	13
	Thailand **	2		
	India **	2		
	Vietnam **	1		
	Indonesia **	1		
Central and South America	Argentina **	5	9	12
	Brazil **	3		
	Guatemala **	1		
Middle East and North Africa	Egypt **	1	4	5
	Israel *	1		
	Pakistan **	1		
	Saudi Arabia **	1		
Australia	Australia *	1	1	1
	TOTAL	**76**	**76**	**100**
	*Advanced economy, resource-rich		56	74
	** Emerging market or developing economy, resource-poor		20	26
	TOTAL		**76**	**100**

Table 3: World region and location where the intervention studies were done

Most of the interventions (84%; n=64) were done in single HCFs; nine of the interventions (12%) were collaborations between two to four HCFs, and three interventions (4%) were collaborations between five or more HCFs. As can be expected with the research focus of the interventions, 89% (n=68) of the studies were initiated by tertiary teaching HCFs in urban areas (Table 4).

5.1.2 Study design

The majority of the studies were pre- and post-intervention cohort studies (n=68; 89%) whilst seven studies (9%) were pre- and post-intervention controlled studies. One study was an observational comparison of two interventions. Most of the studies were non-random in design with the settings and target group purposefully selected. One study was a cluster randomised control trial where the target group was large (staff working at 48 nursing homes) and 100% inclusion of all staff could not be achieved, and two studies focused on a cross-section of HCWs in particular settings. Four of the cohort studies had an interrupted time series built into the post-intervention phase to determine the long-term effect of the educational intervention. Nine of the studies were quasi-experimental and six were trials. The design of 21 (28%) of the studies was observational, focusing on HCW behaviour change to measure the outcome of educational interventions. (The outcome measures of the remainder of the studies were knowledge assessment and HAI rates). Most of the study designs were described in sufficient detail to be replicated.

5.1.3 Focus of education intervention

The main focus of the interventions was on the prevention of device-related infections, namely central line-associated bloodstream infection (CLABSI), ventilator-associated pneumonia (VAP), catheter-associated urinary tract infection (CAUTI), and peripherally-inserted intravenous (PIV) devices (combined 54% of the interventions ; n=41) as well as the improvement of hand hygiene compliance (28%; n=21).

Study features*		Studies (n)
Type of healthcare facility where the interventions were done	Tertiary and/or teaching hospitals	68
	Community hospitals	13
	Long-term healthcare facilities	5
	Paediatric hospital	1
	Paediatric rehabilitation hospital	1
	Step-down healthcare facility	1
Focal area(s) of the interventions	Adult intensive care units (ICUs)	33
	Entire healthcare facility	22
	Neonatal intensive care units (NICUs)	11
	Paediatric intensive care units (PICUs)	5
	General wards	4
	Operating rooms	4
	Paediatric ward	1
	Bone marrow transplant unit	1
	Neonatal nursery	1
Study subject (aim of intervention)	Reduction of central line-associated bloodstream infection (CLABSI)	26
	Improvement of hand hygiene	21
	Reduction of ventilator-associated	10

	pneumonia (VAP)	
	Improvement of general IPC practices	9
	Reduction of CAUTI	4
	Management of multi-drug-resistant (MDR) organisms	4
	Prevention of percutaneous injuries	2
	Prevention of peripheral intravenous line (PIV)-related infections	1
	Reduction of surgical site infection (SSI)	1
	Reduction of HAI in low birth weight infants	1

Table 4: Features of the intervention studies

** Some of the studies were collaborations between different types of HCFs and different types of wards; other studies looked at more than one outcome indicator, e.g. CLABSI and VAP rates.*

5.1.4 Resource-poor education environments

The studies did not reveal significant information on how education interventions in resource-poor healthcare settings may differ from interventions in resource-rich healthcare settings with relation to study design, approach, and teaching methods. The authors of a study done in Thailand that focused on the reduction of VAP (Apisarnthanarak, Pinitchai, Thongphubeth, Yuekyen, Warren, Zack, Warachan & Fraser, 2007:704-711) specifically mentioned that they used an intervention model that had been used with success in the USA.

Several education interventions done in resource-poor healthcare settings realized that the training they provided would not result in the expected changes in clinical practice unless they made provision for the supplies needed to perform certain procedures. For this reason their intervention strategies included the acquisition of basic supplies and equipment such as alcohol hand rub, hand washbasins, hand towels, washstands, and/or sharps containers (Brown, Lubimova, Khrustalyeva, Shulaeva, Tekhova, Zueva, Goldmann & O'Rourke, 2003:172-179;; Huang & Wu, 2008:164-170; Nguyen, Nguyen & Jones, 2008:1297-1302; Picheansathian, Pearson & Suchaxaya, 2008:315-321; Richard, Kenneth, Ramaprabha, Kirupakaran & Chandy, 2001:163-165). According to one study (Duerink, Farida, Nagelkerke, Wahyono, Keuter, Lestari, Hadi & Van den Broek (2006:42) education interventions can only be successful when basic improvement in facilities are done.

An intervention done in Indonesia had to adjust the standard teaching content on sharps management by teaching HCWs how to recap needles using the one-handed method due to the fact that no sharps containers were available (Duerink, Farida, Nagelkerke, Wahyono, Keuter, Lestari, Hadi & Van den Broek, 2006:36-43). One study (Huang & Wu, 2008:164-170) mentioned that they had to make provision for teaching to take place in two local languages.

5.1.5 Unique contextual challenges that face IPC education

The review yielded insufficient data on the contextual challenges within the field of IPC education. This research question remains significant since context has the potential to have a profound impact on the provision of IPC education. The subject is best explored by means of a separate and different research design.

5.2 Education and training programme analysis

Education and training programme analysis	
Features of the training interventions	**Studies* [ ] = total**
Planning	
Education and training based on evidence-based guidelines / protocols / policies outlining expected standards of care and practice requirements	1, 2, 4, 6, 8, 9, 11, 12, 14, 18, 19, 20, 22, 23, 24, 26, 27, 29, 30, 31, 33, 34, 35, 37, 40, 42, 43, 44, 47, 49, 51, 53, 54, 55, 56, 57, 58, 59, 60, 61, 64, 65, 66, 68, 69, 70, 71, 72, 74, 75 **[50]**
Determined learning needs by surveys, practice observation and/or from other data sources (e.g. knowledge tests, HAI rates) and developed the education and training programme based on these findings	2, 3, 10, 11, 15, 17, 18, 19, 30, 31, 34, 35, 38, 42, 43, 51, 60, 69, 76 **[19]**
Teaching methods	
Lectures only	46 **[1]**
Lectures combined with other teaching methods	2, 3, 4, 6, 7, 8, 9, 10, 11, 12, 13, 17, 18, 21, 22, 24, 26, 27, 28, 29, 32, 33, 34, 35, 37, 38, 40, 41, 42, 43, 44, 45, 47, 49, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 64, 65, 66, 67, 68, 69, 70, 71, 72, 74, 75, 76 **[57]**
Self-study in addition to other teaching methods	3, 6, 14, 18, 24, 30, 70, 71, 72, 75 **[10]**
Practical demonstrations	5, 7, 10, 11, 15, 17, 19, 22, 24, 29,

	32, 34, 51, 52, 65, 76 **[16]**
Demonstrations with return demonstrations	8, 13, 27, 28, 33 **[5]**
Practical exercises	2, 14, 15, 16, 20, 22, 24, 37, 44, 66, 76 **[11]**
Programmes with prominent focus on case scenarios / problem-based learning	4, 5, 28, 33, 34, 37, 42 **[7]**
Train-the-trainer programme	13 **[1]**
Interactive learning	
Group discussions	4, 10, 12, 13, 19, 21, 28, 32, 36, 37, 39, 41, 42, 48, 49, 54, 57, 59, 60, 63, 76 **[21]**
Quizzes (online or between groups), use of interactive audience response system, role play, contests, games	5, 10, 67, 69, 73 **[5]**
Learner involvement in performance improvement plan	1, 22, 26, 41, 49 **[5]**
E-learning	
E-learning only	1, 5 **[2]**
E-learning combined with other education methods	9, 14, 24, 42, 43 **[5]**
Use of visual material	
Posters at prominent places in clinical areas that served as eye-catching, visual reminders of expected practice	3, 6, 12, 15, 18, 20, 22, 26, 30, 31, 33, 34, 38, 39, 42, 45, 48, 49, 50, 58, 59, 62, 63, 68, 69, 70, 71, 72, 74, 75 **[30]**
Videos / DVD's	1, 5, 7, 8, 22, 25, 30, 35, 37, 40, 42, 51, 61, 67, 76 **[15]**
PowerPoint Presentations / slides / photographs / storyboards	5, 7, 12, 19, 24, 32, 34, 47, 58, 63, 68, 70 **[12]**
Visual display of charts/graphs (denoting HAI and compliance rates) in clinical areas to give feedback to HCWs about progress with the intervention and at the same time to serve as constant visual reminders of required standards of care	5, 9, 11, 12, 13, 22, 29, 30, 36, 38, 40, 53, 54, 55, 56 **[15]**

Visual display of procedure checklists, photos/illustrations of procedures (e.g. insertion of a central line) or other reminders at patient bedside	17, 38, 39, 59, 61 **[5]**
Fingerprints or environmental swabs showing microbial growth on agar plates; fluorescent marking of hands or the environment	13, 18, 20, 28, 48, 63, 64, 65 **[8]**
Reinforcement of learning	
Reminders (email, computer screen savers, documents attached to pay slips, newsletters)	1, 2, 12, 15, 61 **[5]**
Repetition of learning material in different formats	4, 30, 33, 38, 57, 59, 69, 72 **[8]**
Repetition of learning material over time	1, 3, 7, 10, 25, 33, 38, 50, 53, 54, 64, 69 **[12]**
Appointed staff to check practice and remind staff about required practice (frequent visits by IPC staff, reminders by e.g. ward link nurse, hand hygiene role model, CLABSI champion)	7, 11, 12, 13, 19, 27, 28, 40, 45, 47, 50 **[11]**
Made reference and learning material available (printouts or electronic)	6, 11, 12, 17, 18, 22, 32, 40, 47, 54, 57, 58, 65, 69, 70, 71, 72, 74, 75 **[19]**
Created checklists to guide staff through all the required steps in a clinical procedure	9, 14, 18, 29, 43, 61, 65, 70, 74 **[9]**
Reduce learning material to few essential points to remember in the form of pamphlets	3, 6, 12, 18, 20, 26, 32, 38, 42, 51, 61, 62, 65 **[13]**
Created easy-to-remember slogans or acronyms (e.g. WHAP VAP) to remember key performance points	3, 6, 63 **[3]**
Deliberate (stated) focus on behaviour change	1, 12, 17, 24, 28, 36, 41, 48, 58 **[9]**
Assessment of learning	
Pre- and post-tests	1, 3, 5, 6, 8, 14, 18, 26, 32, 33, 39, 41, 46, 60, 67, 68, 70, 71, 72, 75 **[20]**
Post-tests only	30, 43, 54, 62 **[4]**

Repeated post-test until minimum score is achieved	3, 6, 9, 24, 75 **[5]**
Competency tests, including repeated competency tests until a minimum score is achieved or a technique is mastered	8, 10, 11, 14, 27, 30, 58, 66, 74 **[9]**
Other forms of formative assessment	5, 8 **[2]**
Self-assessment of performance	1, 36, 48 **[3]**
Indirect assessment of learning via overall outcome measurements (HAI rates related to the focus of the educational intervention)	1, 7, 9, 10, 13, 15, 16, 17, 20, 21, 22, 24, 28, 29, 30, 31, 32 33, 34, 36, 37, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 52, 53, 54, 55, 57, 60, 61, 62, 63, 64, 67, 68, 69, 70, 74, 76 **[49]**
Indirect assessment of learning via overall staff performance measurement (compliance rate, audit results)	2, 4, 6, 8, 9, 10, 17, 18, 19, 24, 25, 26, 27, 28, 29, 33, 35, 36, 37, 39, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 53, 54, 55, 56, 59, 61, 62, 65, 66, 67, 68, 70, 71, 72, 74, 75, 76 **[48]**
Performance feedback	
Test/exam results	14 **[1]**
Competency results	8, 10, 11, 14, 58 **[5]**
Compliance results (audits)	7,10, 11, 13, 21, 22, 28, 29, 30, 31, 34, 36, 37, 38, 39, 40, 42, 43, 44, 47, 48, 49, 50, 52, 54, 55, 57, 62, 63, 64, 67, 69, 74, 76 **[34]**
Outcome measures (HAI rates)	4, 9, 10, 11, 14, 18, 19, 20, 25, 29, 36, 37, 38, 39, 40, 42, 43, 44, 47, 48, 49, 50, 53, 54, 55, 56, 58, 59, 62, 65, 67, 74, 75, 76 **[34]**
Support for clinical practice (enabling staff to meet performance requirements)	
Changes in/procurement of supplies and equipment;	2, 9, 13, 14, 15, 16, 18, 20, 22, 24,

standardized supplies; removal of supplies that can lead to wrong practices; creation of supply packs for certain procedures	32, 33, 34, 36, 40, 43, 45, 49, 51, 57, 63, 65, 69, 70, 73 **[25]**

Table 5: Education and training programme analysis

* See corresponding numbers in intervention study reference list

5.2.1 Planning

Sixty-six percent (n=50) of the interventions based their training content on the published and evidence-based guidelines of renowned institutions such as the Centres for Disease Control and Prevention (CDC), Infectious Diseases Society of America (IDSA), IHI, SHEA and WHO. In most interventions the guidelines were incorporated into facility-based policies, protocols, or standard operating procedures (SOPs). The SOPs clearly and specifically outlined expected standards of care and practice requirements within the given healthcare setting. Procedures were standardised to ensure all HCWs do procedures in the same way using the same type of supplies, e.g. antiseptic solutions. For the most part, the practice requirements were measurable.

5.2.2 Assessment of learning needs

Prior to launching an education intervention, 25% (n=19) of the studies specifically mentioned that they did learning needs assessments using one or a combination of the following data sources to determine both knowledge and practice deficits:

- Surveys among healthcare workers to find out more about their knowledge and attitudes about IPC matters (to a limited extent)
- Practice observation, e.g. how central venous lines are inserted, how frequently and how hands are washed
- HAI surveillance results, e.g. CLABSI and VAP rates

They then incorporated their findings into the education and training programmes, aiming to correct the deficits. Although not all the studies specifically mentioned who was responsible for the design and content of the education intervention, several did mention that they formed a multidisciplinary team consisting of key stakeholders (many of whom work in the targeted clinical areas) to analyse the practice problems, to draft policies and SOPs for expected standards of care, and to decide on the content of the education and training content. The learning content was only described in broad terms in the studies. Not one study specifically mentioned the drafting of learning outcomes and matching those up with the aims and objectives of the education intervention.

5.2.3 Teaching methods

Most of the interventions used a multifaceted teaching strategy. Only one of the interventions used lectures as the only education method. 75% (n=57) of the studies used lectures combined with other teaching methods, among which interactive learning, to deliver the education and training programme. Self-study in addition to other teaching methods was used in 13% (n=10) of the interventions. None of the interventions were based on self-study alone. The teaching methods and content was however not described in sufficient detail to be replicated in other studies.

5.2.3.1 Competencies

Practical competence was a strong feature in 42% (n=32) of the studies and competence was taught by means of practical demonstrations with return demonstrations as well as practical exercises, thereby ensuring that the HCWs not only understand the expected standards of care but can actually practice it as well.

5.2.3.2 Interactive learning

Interactive learning was used to complement lectures. 28% (n=21) of the interventions made use of group discussions to engage the students. Some of the studies (7%, n=5) made successful use of quizzes (online or between groups), interactive audience response systems, role play, contests, or games. Five studies (7%) involved their target groups in the intended performance improvement processes, letting them help to analyse deficits in knowledge and practice, and give input on how best to address the deficits, including the learning content and methodology.

5.2.3.3 E-learning

Only 7 studies (7%) made use of e-learning, five of which combined e-learning with other teaching methods. Alemagno, Guten, Warthman, Young & Mackay (2010:463-471) made use of email to send tips, information, and motivational messages about hand hygiene to HCWs in order to reinforce learning and to encourage compliance with hand hygiene practices. The online course presented by Atack & Luke (2008:175-180) allowed participants to work through the study material in their own time. The course also had strong features of interactive learning as well as formative and summative assessment.

5.2.3.4 Use of visual material

Provision of visual material was considered a significant contributor to effective education. 40% (n=30) of the interventions made use of posters. The posters would either contain slogans or illustrations that served as reminders of expected performance. The creators took

trouble to make sure that these posters would attract the attention of HCWs by placing them at prominent places. 20% (n=15) of the interventions made visual displays of charts/graphs denoting HAI and compliance rates. The intention with these displays was to give feedback to HCWs about progress with the intervention and at the same time to serve as constant visual reminders of required standards of care. Five interventions (7%) placed procedure checklists, photos/illustrations of procedures (e.g. the steps to insert a central line) or other reminders right next to the patient bedside, i.e. at the point where care is given and specific performance standards are to be met.

The use of video's/DVDs was a prominent feature in 20% (n=15) of the interventions. The visual material was mostly demonstrations of procedures. The use of PowerPoint presentations, slides, photographs and storyboards to deliver lectures were specifically mentioned in 16% (n=12) of the intervention studies. These teaching tools could have been used in some of the other teaching interventions as well but were not specifically mentioned.

Eleven percent (n=8) of the interventions made use of fingerprints or environmental swabs showing microbial growth on agar plates, or used fluorescent marking of hands or the environment. These actions served as powerful visual evidence to present microscopic evidence that would otherwise not be visible by the naked eye. The evidence was also taken from the HCWs themselves or their immediate environment, giving the evidence personal relevance.

5.2.3.5 Reinforcement of learning

Several methods were used to reinforce learning. The most prominent of these were to:

- Make reference and learning material available (printouts or electronic)
- Reduce the core of the learning material to a few points and to print these points on pamphlets or posters
- Repeat learning material over time
- Appoint staff to check practice and remind staff about required practice (frequent visits by IPC staff, reminders by e.g. ward link nurse, hand hygiene role model, CLABSI champion)
- Create checklists to guide staff through all the required steps in a clinical procedure.

5.2.4 Behaviour change

Twelve percent (n=9) of the interventions stated a deliberate intention to change behaviour. Alemagno, Guten, Warthman, Young & Mackay (2010:463-471) used personal relevance

and motivation as key elements to change behaviour and expected the students to do self-assessment of behaviour. Bouadma, Mourvillier, Deiler, Le Corre, Lolom, Régnier, Wolff, & Lucet (2010:789-796) as well as Coopersmith (2004:131-136) used multi-modal strategies that included clearly outlined expected standards of care (i.e. behaviour), repeated education sessions, a variety of education methods, reinforcement of learning, assessment of learning by means of frequent direct observation, and continuous performance feedback. Eggimann, Harbarth, Constantin, Touveneau, Chevrolet, & Pittet (2000:1864-1868) also had a multifaceted approach but in particular focused on individual training with a strong emphasis on the risk factors for HAI. Helder, Brug, Looman, Van Goudoever & Kornelisse (2010:1245-1252) had a problem-based education programme focusing on theory and practice with performance feedback and a strategy to enhance responsibility awareness about hand hygiene. In their attempt to improve hand hygiene by means of behaviour change Larson, Bryan, Adler, & Blane (1997:3-10) held focus group sessions with the staff to review the results of the survey and to discuss practices, beliefs and opinions about handwashing, findings from previous hand washing behavioural studies, staff's reported practices, practices documented by observers, and HAI rates. The group process was also used to develop a unit-based plan for improving handwashing, thereby involving the education target group to seek their own solutions. Marigliano, Barbadoro, Pennacchietti, D'Errico, & Prospero (2012:692-695) also involved their target group in finding practice solutions and thereby the training content. They furthermore made sure that their target group understood the reason why certain practice elements were necessary.

Based on the theory of planned behaviour Pessoa-Silva, Hugonnet, Pfister, Touveneau, Dharan, Posfay-Barbe & Pittet (2007:e382-e390) distributed an anonymous self-report questionnaire to HCWs to determine their attitude towards and their intention to comply with hand hygiene requirements. After measuring hand hygiene compliance they implemented a multifaceted education programme. They also had focus group discussions based on the results of the self-assessments, the hand hygiene compliance results and the possible impact of non-compliance on HAI. Emphasis was placed on identifying solutions to overcome difficulties to comply with hand hygiene (practical considerations).

During their educational intervention to reduce VAP, Ross & Crumpler (2007:132-136) focused on establishing understanding and insight among their students about the importance of oral care in order to change their behaviour. They established a change from task to outcome orientation. Their methodology was to implement a multifaceted education programme that included visual displays, self-learning components, competency checks, and feedback.

5.2.5 Assessment of learning

Knowledge assessments in the form of tests were done in 34% (n=26) of the educational interventions. Twenty-six percent (n=20) of the interventions did a pre- and post-test; 4 interventions did post-tests only; and 5 interventions repeated the post-test until a minimum score was achieved. Competency tests were included in 9 of the interventions, including repeated competency tests until a minimum score was achieved or a technique was mastered.

The intervention studies did not elaborate on the format of the test papers, i.e. the type of questions (multiple choice, open-ended, or long answer) or what levels of competence were tested (knowledge, insight, and/or application). There is also no indication that attention was paid to the reliability, validity and feasibility of the questions or that the questions matched the learning objectives (McAleer & Hesketh, 2003:588; Hays, 2008:24-26). The quality of the tests could therefore not be evaluated.

The assessment methods most often used in the interventions were indirect assessment of learning by measuring outcome measures, i.e. HAI rates related to the focus of the educational intervention (65%; n=49) and/or indirect assessment of learning by measuring staff performance, i.e. practice compliance rates or audit results (63%; n=48).

Three interventions made use of self-assessment of performance.

5.2.6 Performance feedback

Most of the intervention studies (63%; n=48) gave performance feedback to the HCWs as a deliberate strategy to reinforce learning and improve learning outcomes. The feedback was mainly based on compliance results (audits) and outcome measures (HAI rates). The feedback was often given on a continuous basis. Five studies made mention that they gave feedback on competency results and only one study on test results.

5.2.7 Support for clinical practice

When HCWs are taught to meet certain practice requirements, the studies have shown that the necessary resources must be available. Thirty-three percent (n=25) of the intervention studies recognized the value of having appropriate equipment and supplies at hand and made sure that these were available at the time of the intervention. These included studies done in resource-poor healthcare settings (paragraph 5.4). In some cases it was necessary to remove certain supplies from the clinical environment to prevent HCW from using them,

e.g. disinfectants that were no longer considered to be appropriate for use. In other instances supplies were put together in prepared packs to facilitate certain procedures, e.g. the insertion of a central line.

5.2.8 Measurement of the outcomes of the intervention over time

Post-intervention measurement ranged from 0 months (only measuring the immediate effect of the intervention) to 84 months. The mean post-intervention measurement period was 12 months.

Post-intervention measurement period	n	%
0 months	12	16
< 12 months	29	38
12 – 24 months	25	33
> 24 months	10	13

Table 6: Short-, medium- and long-term measurement of the effect of the intervention

The measurement was mainly focused on performance measures (compliance with expected behaviour) and outcome measures (HAI rates) rather than assessment of knowledge retention. Successful long-term outcomes were achieved by repeated education sessions, regular and continuous monitoring, and ongoing performance feedback. Helder, Brug, Looman, Van Goudoever & Kornelisse (2010:1245–1252.) did an education intervention on hand hygiene and reported a decline in hand hygiene compliance over time in the absence of constant reinforcement of learning.

5.2.9 The teachers

Only 35 studies (46%) mentioned who provided the IPC teaching. For the most part (among the studies that did make mention of the teachers), IPC staff and/or infectious diseases specialists/epidemiologists were involved. For the remainder of the studies the teaching was provided by the physicians and/or nurses working in the area where the intervention was planned. In four of the studies, nurse educators were asked to help with the training. Not one of the studies specifically mentioned the knowledge, experience or capabilities of the trainers to provide effective education although the presumption is that the nurse educators at least would have some educational background.

5.2.10 Evaluation of the IPC education and training provided

Only one study mentioned that the HCWs were asked to evaluate the education programme (Atack & Luke, 2008:175-180).

6. DISCUSSION AND RECOMMENDATIONS

It has been established that the main aim of teaching HCWs about IPC is to improve their compliance with IPC standards in order to reduce HAI rates and thereby improve patient outcomes. Although this aim is very much focused on the practice outputs of HCWs, it is understood that teaching IPC theory is equally important so that deeper knowledge can create understanding and insight that will in turn translate into behaviour change and application.

The original research question - what constitutes effective IPC education strategies in healthcare facilities has shown that two major themes have evolved from this review: The first theme is that IPC education and training methods require careful consideration and effort, perhaps in equal measure to the subject matter that is being taught, to facilitate effective learning that will result in a change in behaviour and practice in the long term. The second theme is that education and training alone is not sufficient to ensure long-term compliance with IPC standards. Learning needs to be reinforced by means of:

- Constant (visual) reminders at the point where clinical care is provided
- Continuous observation of practice with feedback to the HCW's
- Supportive measures in the healthcare environment such as adequate and available facilities, equipment and supplies.

It is also necessary to focus on strategies to change HCW behaviour since HCWs may theoretically know what desired IPC practices are, but their knowledge does not always translate into practice.

The group of 76 education intervention studies that form the basis of this systematic review present the following inherent biases:

- They do not give a fair representation of healthcare facilities worldwide since most of the studies were done in healthcare facilities in resource-rich settings.
- Most of the studies were done in tertiary teaching hospitals in urban settings. These hospitals (both in resource-poor and resource-rich healthcare settings) tend to be better equipped than their rural counterparts.
- Most of the interventions were done in ICUs, which limited the skills level of the staff that formed part of the interventions to that particular speciality.

Several of the studies replicated the research designs of already published studies and produced similar methodology. Although the duplication helped to make comparison of study results easier, it would have been useful if more studies had been experimental in design so that the subject of effective education methods could have been explored further. The descriptions of the research designs were good and the designs were appropriate for the purpose of the studies. The focus of the education intervention studies were mostly on device-related infections and hand hygiene. These priorities were well-chosen since indwelling devices such as central intravenous lines together with non-compliance with hand hygiene are the major contributors to HAI.

No new or useful insights could be obtained from interventions done in resource-poor healthcare settings apart from a confirmation that, since resource-poor healthcare facilities generally have inadequate infrastructure as well as equipment and supply shortages, the intervention designers had to adjust IPC practice standard requirements to match the local conditions. They also had to make special provision for supplies (e.g. alcohol hand rub) to be available for the intervention. This begs the question as to how long these HCFs would be able to sustain the provision of supplies and to what extent the practices in the facilities will revert back to the pre-intervention status if the supplies are no longer available.

Despite the limitations and inherent biases in the collected study material, the researcher is of the opinion that some valuable information could be derived from this systematic review. One aspect is evidence for best practice to establish or revise the learning material (content) for IPC in-service education. The study designers consulted national and international guidelines on particular subject matter in order to get the latest published evidence of best practice. These guidelines usually have a strong research base with ample motivation for each recommendation, and often a scale indicating the strength of each recommendation is attached. The designers would then rewrite the guidelines into facility-based policies and standard operating procedures. The policies and SOPs serve as a major reinforcement of the learning material and help HCWs to translate theory into practice. There are other merits to the policies and SOPs as well:

- They concisely describe processes, procedures and methods rather than broad ideas or vague recommendations.
- They are adapted to the local working environment, making them feasible.
- They are practical and written in unambiguous terms, clearly stating required standards of care and assign task responsibilities to specific staff (i.e. they answer

the questions who?, what?, when?, where?, why?, and how?). The advantage is that the HCWs know precisely what is required of them.

- Standardization of tasks mean that the tasks will be done in the same way by all healthcare workers, thereby reducing risk and ensuring positive patient outcomes.
- The standards written into the policies are measurable. These standards are usually incorporated into IPC audits tools that are used to measure compliance with practices.
- Healthcare facility policies are approved and mandated by the facility management. They therefore carry authority. Where the guidelines give recommendations, the policies make the prescribed care mandatory in a particular facility. Staff can therefore be held accountable for non-compliance to the policies.
- Before policies are submitted to hospital management for approval, they are usually scrutinized by a multidisciplinary team of stakeholders, e.g. a policy and practice committee. Their input also ensures that all angles of patient care have been considered and that the execution of the policy is feasible.

Many of the interventions were organized by a multidisciplinary team, some of whom would be working actively in the clinical area where the intervention was done. They would contribute to the policy writing process. There is merit in the idea of having staff who are responsible to implement the policy be involved in the writing of the policy since they would be able to point out shortcomings and feasibility issues.

Whilst the studies to a large extent concentrated on the establishing practice guidelines and basing their teaching on these guidelines, some did recognize the importance of including additional learning material to deepen the knowledge base of the HCWs and to create understanding and insight by specifically focusing on why certain practice standards were required and what the outcome would be if they were not followed.

None of the studies mentioned that they documented the full learning plan (aims and objectives, learning outcomes, teaching content, assessment, and evaluation). Such a plan is not only necessary to ensure that that all aspects of teaching and learning are incorporated but is also a quality control measure that can ensure that more than one teacher can use the plan thereby contributing to consistency and ensuring that the aims and objectives of the teaching programme are met.

More of the intervention studies could have made use of **learning needs assessment** to guide decisions on the learning content. None of the studies mentioned that they specifically analysed the education target group with relation to HCW category, experience, cultural differences or other diversifying factors so that they could adjust the learning content accordingly. It appears as if the purpose of the pre-tests used in some of the studies in conjunction with post-tests was mostly to help determine the effectiveness of the learning intervention rather than to determine learning needs. The intervention studies could also have consulted the HCWs themselves about their learning needs. Since behaviour change was the ultimate aim of most of the studies, staff surveys to determine staff knowledge and attitude were also lacking. Such surveys could also have provided useful guidance to determine what motivate staff and to plan behaviour change strategies.

In the field of infection control, process indicators (IPC audit results) and outcome indicators (e.g. HAI rates) can provide useful information to determine learning needs since these indicators point towards practice deficits which in turn point towards knowledge deficits. It is a good strategy to include audit results and HAI rates in the teaching material since they provide clear-cut evidence to the HCWs about their performance and in doing so provide a sense of personal involvement and responsibility, which can be an instigator for behaviour change.

The structure and layout of the teaching programmes lacked sufficient description, making it difficult to analyse the adequacy of especially learning objectives, the learning outcomes and assessment. From the study descriptions there is little evidence that the designers paid deliberate attention to the different learning domains (knowledge, behaviour, and skills) in the planning of their interventions although some of the interventions did include all the domains. Had the designers been more deliberate in their planning, they might have adjusted their methodology and learning content to include all three domains, thereby improving the learning experience for the HCWs. This could have ensured that their education interventions had better success.

With regards to teaching methods, it is impossible to state which teaching method provided the best results since most of the studies used more than one teaching method. The studies also did not motivate why they chose specific teaching methods above others. Evaluating the full complement of teaching methods employed, most of the studies adhered to sound teaching and learning principles by promoting active learning (engaging the students in the learning process, allowing them to build up knowledge on top of existing knowledge, and enabling them to establish links to other sets of knowledge), reinforcing learning in a variety

of ways including repetition and providing reminders, making use of visual material and tactile material, and translating theory into practice by focusing on competencies. Using a variety of teaching methods helped to keep the attention of the students, accommodated different learning styles, and contributed to full and effective learning experiences.

Bearing in mind the diversity among HCWs who have to attend IPC education and training, a single, ready-made IPC education package cannot be applied in all settings and for all target groups. The IPC educator has to take cognisance of the diversity, different learning needs and styles, and would need to adapt teaching methods to accommodate these differences. If diversity is not accommodated pro-actively during the learning experience, there is a risk that participants can feel alienated. As a result they will not engage fully in the learning activities and effective learning will not occur. Instead of regarding diversity as a challenge or hindrance, it can rather be embraced and accommodated in such a way that the students can learn from one another so that the learning experience is enhanced even further.

Behaviour change implicitly and explicitly featured strongly in most of the intervention studies. It appears that behaviour strategies are closely linked to motivational factors and that HCWs need to be convinced that the consequences of non-compliance with certain practice requirements can indeed result in severe harm to the patient. It also appears that there is no uniform “recipe” for behaviour change in IPC; rather that it should be tailor-made to suit a particular situation. IPC educators need to think “outside the box” and learn from commercial marketing in order to bring messages across in new and inventive ways that will influence HCWs in the right direction.

The concept of e-learning in IPC remained mostly unexplored. At the time that most of the interventions were done, the concept of e-learning had not been well established yet. Access to computers and the internet would have been a challenge for low-income healthcare facilities. Nevertheless, e-learning has the potential to reach many HCWs. It also lends itself to customized education programmes with ample visual material and interactive teaching methods. Overfull healthcare facilities and staff shortages often prevent HCWs from attending scheduled IPC teaching sessions. E-learning provides a workable alternative since it allows HCWs to learn about IPC in their own time and at their own pace.

Of all the elements required in a well-balanced education programme, assessment of learning most probably received the least attention in the intervention studies. Almost the only area where formative and summative assessment was used successfully was in the competency assessments. Applied correctly, both formative and summative assessment

with feedback on the assessment can become a powerful teaching tool. If students are aware that they will be assessed and how they will be assessed, the assessment will become a strong motivator for learning. It might be a good idea to make it mandatory that each HCW complete an annual IPC refresher course that includes knowledge and competency tests with a minimum score to be achieved for successful completion and a mandatory repetition of the course until the minimum score is achieved.

This systematic review confirms the widely accepted viewpoint in IPC that an education programme as a stand-alone intervention is insufficient to influence sustained compliance with practice requirements on the long term. A customized multi-faceted intervention package is required in which education and training has a prominent place but where additional strategies such as HCW performance feedback, behaviour modification, reminders in the workplace of required practice standards, administrative support, and provision of adequate facility infrastructure and supplies contribute to reinforce and sustain efforts to ensure compliance with IPC standards. All these measures that are in addition to education and training serve to support and strengthen learning.

Table 7 below presents a summary of best practices for in-service education and training in IPC that were identified from the literature review as well as the systematic review of IPC education interventions. These practices can be used as a checklist when IPC education interventions are designed.

Recommended best practices for in-service education and training in IPC
CONTEXT • Identify the target population: HCW category, level of knowledge, experience, cultural diversity, language, age categories • Assess their learning needs • Outline the aims and objectives of the education/training programme. Make sure they correspond with the findings of the needs assessment and the learning content. • Identify the stakeholders that will benefit from the education (patients, healthcare facility, HCWs). • Get managerial and administrative support. • Ensure that the education programme meets and does not contradict the regulatory requirements of the healthcare facility and health authorities at provincial and national level.

- Determine how the planned education and/or training fits into the broad IPC education programme of the healthcare facility.

CONTENT

- Determine the learning outcomes and make sure they match the aims and objectives of the education programme.
- Include the three learning domains of knowledge, behaviour/attitude, and skills.
- Consult the latest national and international guidelines and scientific publications for evidence-based standards and practice requirements.
- Set clear standards of practice. The standards must be contextually appropriate, measurable, and feasible. Write the standards into policies and SOPs. Include HCWs (those who have to execute the policies and SOPs) in the policy-writing process. Reduce policies to easy-to-read checklists.
- Make sure the sequence of topics is logical and the topics are coherent and inclusive.
- Address knowledge and practice deficits identified in the learning needs assessment.
- Make allowance for diversity in the target group.

TEACHING METHODS

- Choose the most appropriate teaching methods to fit the learning content.
- Make the learning content readily available (lecture notes, summaries, reference material).
- Use a variety of teaching methods to accommodate different learning styles. Include visual, tactile, and practical components.
- Actively engage the students in the learning process and promote deep learning by presenting case scenarios and problem-solving exercises that will stimulate thought and help HCWs to apply IPC principles in diverse and complex situations.
- Reinforce learning by repeating the learning content at different times and in different formats.
- Assign staff in clinical areas to constantly monitor and reinforce practice requirements and to act as role models.
- Consider E-learning to allow HCWs to learn in their own time and at their convenience.
- Place visible reminders (posters, photos, checklists) at prominent places in the clinical areas and make study/reference material available on the subject matter.
- Include strategies to address behaviour modification.
- Assess learning by means of both formative and summative assessment. Include both knowledge assessments and competency tests where applicable. Ensure that

assessment corresponds with the learning outcomes.

- Give feedback on assessment results. Pay particular attention to problem areas. Also give regular feedback about process and outcome measures such as HAI surveillance, audit reports, and compliance reports. Link the data to specific actions in the ward.
- Request administrative support.
- Facilitate provision of adequate facility infrastructure and supplies.

IMPLEMENTATION PLAN

- Do a pilot test of the education programme and use feedback from peers and students to make adjustments/improvements.
- Set a timetable: Determine the duration and frequency of classes. Consider the best time to present the teaching.
- Consider the teaching venue, technology required (e.g. computer with projector, sound system), equipment and supplies for demonstration/practice, student access to the internet if required.
- Consider if the available budget makes the teaching feasible.
- Consider best options to advertise the education programme and how communication with regards to the programme will be done.
- Document the education plan so that more than one educator can deliver the education if needed.

EVALUATION OF EDUCATION PROGRAMME

- Evaluate the teaching provided by means of different rating scales: self, student, peer, and supervisor ratings. Make adjustments as required.

Table 7: Recommended best practices for in-service education and training in IPC

6.1 Conceptual model of an IPC education intervention

Drawing on literature that has been reviewed, the following conceptual model of an IPC education intervention can be considered (Figure 2). At its core the model matches the plan, do, study, act (PDSA) contintuous quality improvement cycle (Deming Institute).

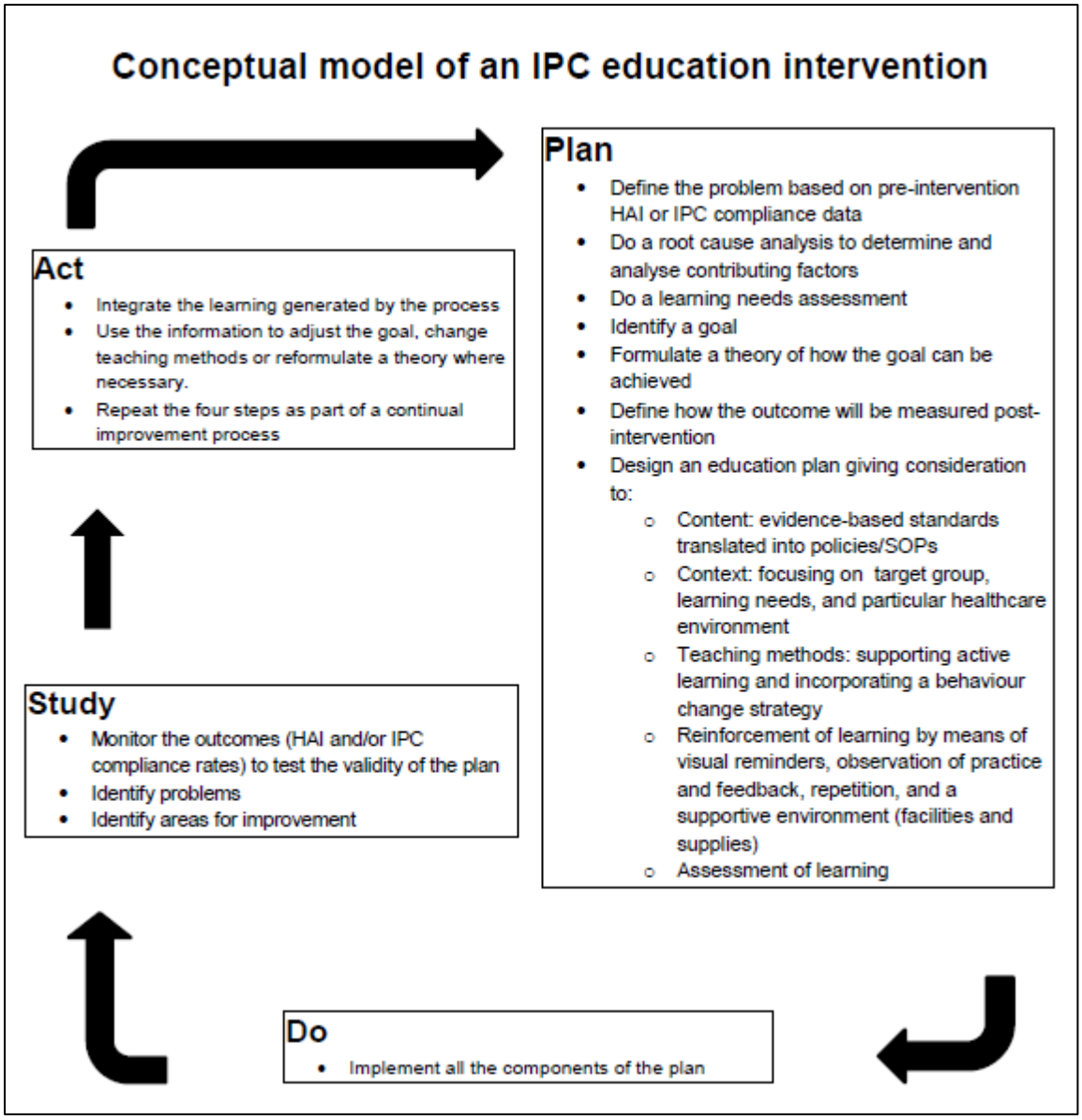

Figure 2: Conceptual model of an IPC education intervention

6.2 Further research recommendations

Further studies are needed to continue exploring best practices for IPC education, in particular on the following subjects:

- Best practices for effective E-learning programmes to use as part of IPC in-service education and training of HCWs
- Strategies to change HCW behaviour in relation to IPC
- The nature and frequency of IPC in-service education and training to achieve sustained practice compliance
- Inter-professional teaching and learning
- Appropriate IPC education and training for each HCW category

- How IPC programmes and IPC educators can be empowered helped to improve their teaching strategies.

A final recommendation is that future education intervention studies be more transparent about the learning outcomes, teaching methods and assessment, especially formative assessment.

7. CONCLUSION

The need for continuous education of HCWs in IPC theory and practice is widely recognized. IPC education strategies require careful review, perhaps in equal measure to the subject matter that is being taught, to facilitate effective learning that will result in a change in behaviour and practice in the long term. This systematic review has revealed that the approach to IPC education and training needs to be holistic: Consideration must be given to the context within which the teaching will provided, diversity in and among HCW categories, the content of the teaching programme to ensure sufficient emphasis on application of IPC principles, teaching methods that will actively engage HCWs in the learning process and stimulate behaviour change, continuous reinforcement of learning by means of repetition, reminders, and performance feedback, assessment of learning, the implementation plan so that best use is made of budget and technology, and evaluation of the teaching provided so that the teaching programme can be adjusted and improved continuously. These considerations are included in a set of recommended best practices for in-service education and training in IPC.

No new or useful insights could be obtained from interventions done in resource-limited HCFs. Assessment of learning and E-learning was left mostly underutilized and unexplored and should receive much more emphasis in future education intervention studies. Further research is also needed to consider strategies to change HCW behaviour in relation to IPC, the nature and frequency of IPC in-service education and training to achieve sustained practice compliance, inter-professional teaching and learning, appropriate IPC education and training for each HCW category, and how IPC programmes and IPC educators can be empowered helped to improve their teaching strategies.

Reference list of sources used in the text

Allegranzi, B., Bagheri Nejad, S., Combescure, C., Graafmans, W., Attar, H. Donaldson, L. & Pittet, D. 2011. Burden of endemic health-care-associated infection in developing countries: Systematic review and meta-analysis. *The Lancet*: 377:228-241.

Allegranzi, B., Sax, H. & Pittet, D. 2013. Hand hygiene and healthcare system change within multi-modal promotion: a narrative review. *Journal of Hospital Infection*, 83(S1):S3-S10.

AMSTAR. A measurement tool to assess systematic reviews (AMSTAR) checklist. [Online]. Available: http://amstar.ca/Amstar_Checklist.php [2016, January 22].

Bagheri Nejad, S., Allegranzi, B., Syed, S.B., Ellis, B. & Pittet, D. 2011. Health-care-associated infection in Africa: A systematic review. *Bulletin of the World Health Organisation*, 89:757-765, doi:10.2471/BLT.11.088179.

Berenholtz, S.M., Pronovost, P.J., Lipset, P.A., Hobson, D., Earsing, K., Farley, J.E., Milanovich, S., Garrett-Mayer, E., Winters, B.D., Rubin, H.R., Dorman, T. & Perl, T.M. 2004. Eliminating catheter-related bloodstream infections in the intensive care unit. *Critical Care Medicine*, 32(10):2014-2020.

Berk, R.A. 2013. Top five flashpoints in the assessment of teaching effectiveness. *Medical Teacher*, 35:15-26.

Bitzer, E. 2004. Cooperative learning, in S. Gravett & H. Geyser (eds.). 2004. *Teaching and learning in higher education.* Pretoria: Van Schaik. 41-65.

Borg, M.A. 2014. Lowbury Lecture 2013. Cultural determinants of infection control behaviour: Understanding drivers and implementing effective change. *Journal of Hospital Infection,* 86(3):161-168.

Bryce, E., Yassi, A., Maultsaid, D., Gamage, B., Landstrom, M. LoChang, J. & Hon, C-Y. 2008. E-learning of infection control: It's contagious. *The Canadian Journal of Infection Control*, 23(4): 228 – 237.

Buckridge, M. & Guest, R. 2007. A conversation about pedagogical responses to increased diversity in university classrooms. *Higher Education Research & Development,* 26(2):133-146.

Cabrera, A.F., Amaury, N., Crissman, J.L., Terenzini, P.T., Bernal, E.M. & Pascarella, E.T. 2002. Collaborative learning: Its impact on college students' development and diversity. *Journal of College Student Development,* 43(1):20-34).

Cannon, R. & Newble, D. 2000. *A handbook for teachers in universities & colleges: A guide to improving teaching methods.* 4th edition. London: Routledge Falmer.

Carrico, R.M., Rebmann, T., English, J.F., Mackey, J. & Cronin, S.J. 2008. Infection prevention and control competencies for hospital-based health care personnel. *American Journal of Infection Control*, 36(10):691-701.

Cherry, M.G., Brown, J.M., Neal, T. & Shaw, N.B. 2010. What features of educational interventions lead to competence in aseptic insertion and maintenance of CV catheters in acute care? BEME Guide No.15. *Medical Teacher*, 32:198-218.

Cinel, I. & Dellinger, R.P. 2006. Guidelines for severe infections: are they useful? *Current Opinion in Critical Care*, 12:483-488.

Cohn, K.H. 2009. Changing physician behaviour through involvement and collaboration. *Journal of Healthcare Management,* 54(2):80-86.

Cook, D.A. & West, C.P. 2012. Conducting systematic reviews in medical education: A stepwise approach. *Medical Education*, 46:943-952.

Cousin, G. 2009. *Researching learning in higher education: an introduction of contemporary methods and approaches.* New York: Routledge.

Cox, J.L., Simpson, M.D., Letts, W. & Cavanagh, H. 2015. Re-thinking microbiology/infection control education to enhance the practice-readiness of health professional students: More than just a curriculum issue. *Journal of Learning Design*, 8(1):55-67.

Deming Institute. The plan, do, study, act (PDSA) cycle. [Online]. Available: https://www.deming.org/theman/theories/pdsacycle [2016, January 22].

Department of Health (DoH). 2011. *National Core Standards for Health Establishments in South Africa.* Tshwane: DoH.

Edwards, R., Charani, E., Sevdalis, N., Alexandrou, B., Sibley, E., Mullett, D. Loveday, H.P., Drumright, L.N. & Holmes, A. 2012. Optimisation of infection prevention and control in acute health care by use of behaviour change: A systematic review. *The Lancet*, 12:318-329.

Edwards, R., Sevdalis, N., Vincent, C. & Holmes, A. 2012. Communication strategies in acute health care: evaluation within the context of infection prevention and control*. Journal of Hospital Infection*, 82:25-29.

Ende, J. 1997. What if Osler were one of us? Inpatient teaching today. *Journal of General Internal Medicine,* 12: S41-S48.

European Centre for Disease Prevention and Control (ECDC). 2013*. Core competencies for infection control and hospital hygiene professionals in the European Union*. Stockholm: ECDC.

Flodgren, G., Conterno, L.O., Mayhew, A., Omar, O. Pereira, C.R. & Shepperd, S. 2013. Interventions to improve professional adherence to guidelines for prevention of device-related infections (Review). *Cochrane Database of Systematic Reviews*, Issue 3. [Online].

Available: http://onlinelibrary.wiley.com/doi/10.1002/14651858.CD006559.pub2/pdf [2010, February 10].

Felder, R.M. & Brent, R. 2005. Understanding student differences. *Journal of Engineering Education,* 94(1):57-72.

Geyser, H. 2004. Programme development and a curriculum design perspective, in Gravett, S. & Geyser, H. (eds). *Teaching and learning in higher education*. Pretoria: Van Schaik. 139-155.

Gould, D.J., Drey, N.S., Moralejo, D., Grimshaw, J. & Chudleigh, J. 2008. Interventions to improve hand hygiene compliance in patient care. *Journal of Hospital Infection*, 68:193-202.

Grant, J.2006. *Principles of curriculum design.* Edinburgh: Association for the Study of Medical Education.

Gravett, S. 2005. *Adult learning: Designing and implementing learning events: A dialogic approach.* 2nd edition. Pretoria: Van Schaik Publishers.

Gurses, A.P., Seidi, K.L., Vaidya, V., Bochicchio, G., Harris, A.D., Hebden, J. & Xiao, Y. 2008. Systems ambiguity and guideline compliance: a qualitative study of how intensive care units follow evidence-based guidelines to reduce healthcare-associated infections. *Quality and Safety in Health Care*, 17:351-359.

Hambraeus, A. 2006. Lowbury Lecture 2005: Infection control from a global perspective. *Journal of Hospital Infection,* 64:217-223.

Harden, R.M. 2005. Curriculum planning and development, in Dent, J.A. & Harden, R.M. *A practical guide for medical teachers*. Edinburgh: Elsevier.

Hammick, M., Freeth, D., Koppel, I., Reeves, S. & Barr, H. 2007. A best evidence systematic review of interprofessional education: BEME Guide no. 9. *Medical Teacher*, 29:735–751.

Hays, R. 2008. Assessment in medical education: roles for clinical teachers. *The Clinical Teacher*, 5:23-27.

Higgins, M. & Evans, D.S. 2008. Nurses' knowledge and practice of vascular access infection control in haemodialysis patients in the republic of Ireland. *Journal of Renal Care*, 34(2):48-53.

Higgins, J.P.T. & Green, S. (ed.). 2008. *Cochrane handbook for systematic reviews of interventions.* Chichester: Wiley-Blackwell.

Humphreys, H., McHugh, S., Dimitrov, B.D., Cowman, S., Tierney, S. & Hill, A.D.K. 2012. Web-based training to improve knowledge and change practice in preventing healthcare infection. *Infection Control and Hospital Epidemiology*, 22(6):644.

International Monetary Fund (IMF). 2012. *World Economic Outlook: Coping with debt and sluggish growth* [Online]. Available: http://www.imf.org/external/pubs/ft/weo/2012/01/ [2013, June 25].

Joanna Briggs Institute for Evidence Based Nursing and Midwifery (JBIEBNW). 2001. An introduction to systematic reviews. *Changing Practice,* supplement 1. [Online]. Available: http://www.joannabriggs.ed.au/CP2.pdf [2010, February 10].

Johnston, C. & Mohide, E.A. 2009. Addressing diversity in clinical nursing education: Support for preceptors. *Nurse Education in Practice,* 9:340-347.

Krueger, P.M., Neutens, J., Bienstock, J. Cox, S. Erickson, S. Goepfert, A., Hammoud, M., Hartmann, D. Puscheck, E. & Metheny, W. 2004. To the point: Reviews in medical education teaching techniques. *American Journal of Obstetrics and Gyneacology,* 191:408-11.

Labeau, S.O., Vandijck, D.M., Rello, J., Adam, S., Rosa, A. Wenisch, C. Bȁckman, C., Agbaht, K., Csomos, A., Seha, M., Dimopoulos, G., Vandewoude, K.H. & Blot, S.I. 2009. Centers for Disease Control and Prevention guidelines for preventing central venous catheter-related infection: Results of a knowledge test among 3 405 European intensive care nurses. *Critical Care Medicine*, 37(1):320-323.

Manasse, H.R. 2009. 2009 Rho Chi lecture: Interdisciplinary health professions education: A systems approach to bridging the gaps. *American Journal of Pharmaceutical Education*, 73(5) Article 90. [Online]. Available: http://www.ajpe.org/doi/pdf/10.5688/aj730590. [2015, November 12].

Marjadi, B. & McLaws, M-L. 2010. Rural Indonesian health care workers' constructs of infection prevention and control knowledge. American Journal of Infection control, 38(5):399-403.

Mathai, E., Allegranzi, B, Seto, W.H., Chraïti, M.-N., Sax, H., Larson, E. & Pittet, D. 2010. Educating healthcare workers to optimal hand hygiene practices: addressing the need. *Infection*, 38:349-356.

McAleer, S. & Hesketh, E.A. 2003. Developing the teaching instinct: 10: Assessment. *Medical Teacher*, 25(6):585-588.

McHugh, S.M., Hill, A.D.K. & Humphreys, H. 2010. Preventing healthcare-associated infection through education: have surgeons been overlooked? *The Surgeon*, 8:96-100.

McKimm, J. 2003. *Curriculum design and development, e-learning for clinical teachers*, London Deanery. [Online] Available: http://www.faculty.londondeanery.ac.uk/e-learning/explore-further/e-learning/setting-learning-objectives/Curriculum_design_and_development.pdf [2010, March 10].

Maree, K. (ed.). 2011. *First steps in research.* Pretoria: Van Schaik.

McMillan, W. 2010. Moving beyond description: Research that helps improve teaching and learning. *African Journal of Health Professions Education*, 2(1):3-7.

Mehtar, S. 2008. Lowbury lecture 2007: infection prevention and control strategies for tuberculosis in developing countries – lessons learnt from Africa. *International Journal of Infection Control,* 69:321-327.

Michael, J. 2006. Where's the evidence that active learning works? *Advances in Physiology Education*, 30:159-167.

Moher, D., Liberati, A., Tetzlaff, J., Altman, D.G. & PRISMA Group. 2009. Preferred reporting items for systematic reviews and meta-analyses: The PRISMA Statement. *Annals of Internal Medicine*, 151:264-269.

Morrison, J.M., Sullivan, F., Murray, E. & Jolly, B. 1999. Evidence-based education: Development of an instrument to critically appraise reports of educational interventions. *Medical Education*, 33:890-893.

Murphy, D.M., Hanchett, M., Olmsted, R.N., Farber, M.R., Lee, T.B., Haas, J.P. & Streed, S.A. 2012. Competency in infection prevention: A conceptual approach to guide current and future practice. *American Journal of Infection Control*, 40:296-303.

Naikoba, S. & Hayward, A. 2001. The effectiveness of interventions aimed at increasing handwashing in healthcare workers – a systematic review. *Journal of Hospital Infection*, 47:173-180.

Nicol, D.J. & Macfarlane-Dick, D. 2006. Formative assessment and self-regulated learning: A model and seven principles of good feedback practice. *Studies in Higher Education,* 31(2):199-218.

Oakley, B., Felder, R.M., Brent, R. & Elhajj, I. 2004. Turning student groups into effective teams. *Journal of Student Centred Learning,* 2(1):9-34.

O'Brien, D., Richards, J., Walton, K.E., Phillips, M.G.A. & Humphreys, H. 2009. Survey of teaching/learning of healthcare-associated infections in UK and Irish medical schools. *Journal of Hospital Infection*, 73:171-175.

Pittet, D. 2005. Infection control and quality health care in the new millennium. *American Journal of Infection Control*, 33(5):258-267.

Pittet, D. 2004. The Lowbury lecture: Behaviour in infection control. *Journal of Hospital Infection*, 58:1-13.

Pittet, D. 2000. Improving compliance with hand hygiene in hospitals. *Infection Control and Hospital Epidemiology*, 21(6):381-386.

Pittet, D., Allegranzi, B., Storr, J., Bagheri Nejad, S., Dziekan, G., Leotsakos, A. & Donaldson, L. 2008. Infection control as a major World Health Organization priority for developing countries. *Journal of Hospital Infection*, 68:285-292.

Prince, M. 2004. Does active learning work? A review of the research. *Journal of Engineering Education,* 93:223-231.

Raka, L. 2009. Lowbury Lecture 2008: Infection control and limited resources – searching for the best solutions. *Journal of Hospital Infection*, 72:292-298.

Ramsden P. Learning from the student's perspective, in Learning to Teach in Higher Education. 2nd edition. London: Routledge Falmer. 62-83.

Raza, M.W., Kazi, B.M., Mustafa, M. & Gould, F.K. 2004. Developing countries have their own characteristic problems with infection control. *Journal of Hospital Infection*, 57:294-299.

Ruiz, J.G., Mintzer, M.J. & Leipzig, R.M. 2006. The impact of e-learning in medical education. *Academic Medicine*, 81(3):207-212.

Respecting diversity, developing talents. 2000. *Teaching Matters,* 4(2):1.

Safdar, N. & Abad, C. 2008. Educational interventions for prevention of healthcare-associated infection: a systematic review. *Critical Care Medicine*, 36(3):933-940.

Sax, H., Allegranzi, B., Uçkay, I., Larson, E., Boyce, J. & Pittet, D. 2007. 'My five moments for hand hygiene': A user-centred design approach to understand, train, monitor and report hand hygiene. *Journal of Hospital Infection*, 67:9-21.

Sciame-Giesecke, S., Roden, D. & Parkison, K. 2009. Infusing diversity into the curriculum: What are faculty members actually doing? *Journal of Diversity in Highe*r Education, 2(3):156-165.

Springer, L., Stanne, M.E. & Donovan, S.S. 1999. Effects of small-group learning on undergraduates in science, mathematics, engineering, and technology: A meta-analysis. *Review of Educational Research,* 69(1):21-51.

Stein, A.D., Makarawo, T.P. & Ahmad, M.F.R. 2003. A survey of doctors' and nurses' knowledge, attitudes and compliance with infection control guidelines in Birmingham teaching hospitals. *Journal of Hospital Infection*, 54:68-73.

Taneja, J. 2009. Evaluation of knowledge and practice amongst nursing staff toward infection control measures in a tertiary care hospital in India. *The Canadian Journal of Infection Control*, 24(2):104-107.

Tomlinson, C.A. Brighton, C., Hertberg, H., Callahan, C.M., Moon, T.R., Brimijoin, K, Conover, L.A. & Reynolds, T. 2003. Differentiating instruction in response to student readiness, interest, and learning profile in academically diverse classrooms: A review of literature. *Journal for the Education of the Gifted,* 27(2/3):119-145.

Van der Vleuten, C.P.M., Dolmans, D.H.J.M., & Scherpbier, A.J.J.A. 2000. The need for evidence in education. *Medical Teacher*, 22(3): 246-250.

Voss, A. 2009. Healthcare associated infections: National bodies and guidelines should be less suggestive and more directive. *British Medical Journal*, 339:932.

Ward, D.J. 2011. The role of education in the prevention and control of infection: a review of literature. *Nurse Education Today*, 31:9-17.

Wass, V., Bowden, R. & Jackson, N. 2007. The principles of assessment design. In: Jackson, N., Jamieson, A. & Khan, A. (eds). *Assessment in medical education and training: A practical guide.* Oxford: Radcliffe Publishing.

Western Cape Government. 2002. Staff Performance Management System.

Williams, R.P. & Calvillo, E.R. 2002. Maximizing learning among students from culturally diverse backgrounds. *Nurse Educator,* 27(5):222-226.

World Health Organisation (WHO). 2011b. *Patient safety curriculum guide: Multi-professional edition.* Geneva: World Health Organisation. [Online] Available: http://www.who.int/patientsafety/education/curriculum/en/ [2013, February 2].

World Health Organization. 2009. *Guidelines on hand hygiene in health care*. Geneva: WHO.

World Health Organisation (WHO). 2010. Framework for action on interprofessional education and collaborative practice. Geneva: World Health Organisation. [Online] Available: http://www.who.int/hrh/resources/framework_action/en/ [2013, February 2]

Wright, R.W., Brand, R.A., Dunn, W. & Spindler, K.P. 2007. How to write a systematic review. *Clinical Orthopaedics and Related Research*, 455:23-29.

Zaidi, A.K.M., Charles-Huskins, W., Thaver, D., Bhutto, Z.A., Abbas, Z. & Goldman, D.A. 2005. Hospital-acquired neonatal infections in developing countries. *The Lancet*, 365:1175-1188.

Zimmerman, P.A. 2007. Help or hindrance? Is current infection control advice applicable in low- and middle-income countries? A review of the literature. *American Journal of Infection Control*, 35(8):494-500.

Reference list of sources used in the database

1. Alemagno, S.A., Guten, S.M., Warthman, S., Young, E. & Mackay, D.S. 2010. Online learning to improve hand hygiene knowledge and compliance among health care workers. *The Journal of Continuing Education in Nursing*, 41(10):463-471.

2. Andersen, C., Hart, J., Vermgal, P. & Harrison, C. 2005. Prospective evaluation of a multi-factorial prevention strategy on the impact of nosocomial infection in very-low-birthweight infants. *Journal of Hospital Infection*, 61:162-167.

3. Apisarnthanarak, A., Pinitchai, U., Thongphubeth, K., Yuekyen, C., Warren, D.K., Zack, J.E., Warachan, B. & Fraser, V.J. 2007. Effectiveness of an educational program to reduce ventilator-associated pneumonia in a tertiary care center in Thailand: A 4-year study. *Clinical Infectious Diseases*, 45:704-711.

4. Arabi, Y., Haddad, S., Hawes, R., Moore, T., Pillay, M., Naidu, B., Issa, A., Yeni, B., Grant, G. & Alshimemeri, A. 2007. Changing sedation practices in the intensive care unit: Protocol implementation, multifaceted multidisciplinary approach and teamwork. *Middle East Journal of Anesthesiology*, 19:429-447.

5. Atack, L. & Luke, R. 2008. Impact of an online course on infection control and prevention competencies. *Journal of Advanced Nursing*, 63(2):175-180.

6. Babcock, H.M., Zack, J.E., Garrison, T., Trovillion, E., Jones, M. Fraser, V.J. & Kollef, M.H. 2004. An educational intervention to reduce ventilator-associated pneumonia in an integrated health system: A comparison of effects. *Chest*, 125(6):2224-22231.

7. Baldwin, N.S., Gilpin, D.F., Tunney, M.M., Kearney, M.P., Crymble, L. Cardwell, C. & Hughes, C.M. 2010. Cluster randomised controlled trial of an infection control education and training intervention programme focusing on methicillin-resistant *Staphylococcus aureus* in nursing homes for older people. *Journal of Hospital Infection*, 76(1):36-41.

8. Barsuk, J.H., Cohen, E.R., Feinglass, J., McGaghie, W.C. & Wayne, D.B. 2009. Use of simulation-based education to reduce catheter-related bloodstream infections. *Archives of Internal Medicine*, 169(15):1420-1423.

9. Berenholtz, S.M., Pronovost, P.J., Lipset, P.A., Hobson, D., Earsing, K., Farley, J.E., Milanovich, S., Garrett-Mayer, E., Winters, B.D., Rubin, H.R., Dorman, T. & Perl, T.M. 2004. Eliminating catheter-related bloodstream infections in the intensive care unit. *Critical Care Medicine*, 32(10):2014-2020.

10. Berg, D.E., Hershow, R.C., Ramirez, C.A. & Weinstein, R.A. 1995. Control of nosocomial infections in an intensive care unit in Guatemala City. *Clinical Infectious Diseases*, 21(3):588-593.

11. Bizzarro, M.J., Sabo, B., Noonan, M., Bonfiglio, M., Northrup, V. & Diefenbach, K. 2010. A quality improvement initiative to reduce central line-associated bloodstream infections

in a neonatal intensive care unit. *Infection Control and Hospital Epidemiology*, 31(3):241-248.

12. Bouadma, L., Mourvillier, B., Deiler, V., Le Corre, B., Lolom, I., Régnier, B., Wolff, M. & Lucet, J.C. 2010. A multifaceted program to prevent ventilator-associated pneumonia: Impact on compliance with preventive measures. *Critical Care Medicine*, 38(3):789-796.

13. Brown, S.M., Lubimova, A.V., Khrustalyeva, N.M., Shulaeva, S.V., Tekhova, I., Zueva, L.P., Goldmann, D. & O'Rourke, E.J. 2003. Use of an alcohol-based hand rub and quality improvement interventions to improve hand hygiene in a Russian neonatal intensive care unit. *Infection Control and Hospital Epidemiology*, 24(3):172-179.

14. Burden, A.R., Torjman, M.C., Dy, G.E., Jaffe, J.D., Littman, J.J., Nawar, F., Rajaram. S.S., Schorr, C., Staman, G.W. & Reboli, A.C. 2012. Prevention of central venous catheter-related bloodstream infections: Is it time to add simulation training to the prevention bundle? *Journal of Clinical Anesthesia*, 24:555-560.

15. Coignard, B., Grandbastien, B., Berrouane, Y., Krembel, C., Queverue, M., Salomez, J.L. & Martin, G. 1998. Handwashing quality: Impact of a special program. *Infection Control and Hospital Epidemiology*, 19(7):510-513.

16. Colombo, C., Giger, H., Grote, J., Deplazes, C., Pletscher, W., Lüthi, R. & Ruef, C. 2002. Impact of teaching interventions on nurse compliance with hand disinfection. *Journal of Hospital Infection*, 51:69-72.

17. Coopersmith, C.M. 2004. The impact of bedside behaviour on catheter-related bacteremia in the intensive care unit. *Archives of Surgery*, 139:131-136.

18. Coopersmith, C.M., Rebmann, T.L., Zack, J.E., Ward, M.R., Corcoran, R.M., Schallom, M.E., Sona, C.S., Buchman, T.G., Boyle, W.A., Polish, L.B. & Fraser, V.J. 2002. Effect of an education program on decreasing catheter-related bloodstream infections in the surgical intensive care unit. *Critical Care Medicine*, 30(1):59-64.

19. Costello, J.M., Morrow, D.F., Graham, D.A., Potter-Bynoe, G., Sandora, T.J. & Laussen, P.C. 2008. Systematic intervention to reduce central line-associated bloodstream infection rates in a pediatric cardiac intensive care unit. *Pediatrics*, 121(5):915-923.

20. Dierssen-Sotos, T., Brugos-Llamazares, V., Robles-Garcia, M., Rebollo-Rodrigo, H., Fariñas-Álvarez, C., Antolin-Juarez, F.M., Fernandez-Núñez, M.L., López, M. & Llorca, J. 2010. Evaluating the impact of a hand hygiene campaign on improving adherence. *American Journal of Infection Control*, 38(3):240-243.

21. Dubbert, P.M., Dolce, J., Richter, W. Miller, M. & Chapman, S.W. 1990. Increasing ICU staff handwashing: Effects of education and group feedback. *Infection Control and Hospital Epidemiology*, 11(4):191-193.

22. Duerink, D.O., Farida, H., Nagelkerke, N.J.D., Wahyono, H., Keuter, M. Lestari, E.S., Hadi, U. & Van den Broek, P.J. 2006. Preventing nosocomial infections: improving

compliance with standard precautions in an Indonesian teaching hospital. Journal of Hospital Infection, 64:36-43.

23. Eggimann, P., Harbarth, S., Constantin, M.N., Touveneau, S., Chevrolet, J.C. & Pittet, D. 2000. Impact of a prevention strategy targeted at vascular-access care on incidence of infections acquired in intensive care. The Lancet, 355:1864-1868.

24. Elkaradawy, S., Helaly, G. & Abdel Wahab, M.M. 2012. Effect of an infection control educational programme on anaesthetists' attitude and anaesthetic field bacterial contamination. *Egyptian Journal of Anaesthesia*, 28:149-156.

25. Goetz, A.M., Kedzuf, S., Wagener, M. & Muder, R.R. 1999. Feedback to nursing staff as an intervention to reduce catheter-associated urinary tract infections. *American Journal of Infection Control*, 27(5):402-404.

26. Guembe, M., Pérez-Parra, A., Gómez, E., Sánchez-Luna, M., Bustinza, A., Zamora, E., Carrillo-Álvarez, A., Cuenca, A., Padila, B., Martin-Rabadán, P. & Bouza, E. 2012. Impact on knowledge and practice of an intervention to control catheter infection in the ICU. *European Journal of Clinical Microbiology and Infectious Diseases*, 31:2799-2808.

27. Guerin, K., Wagner, J., Rains, K. & Bessesen, M. 2010. Reduction in central line-associated bloodstream infections by implementation of a postinsertion care bundle. American Journal of Infection Control, 38(6):430-433.

28. Helder, O.K., Brug, J., Looman, C.W.N., Van Goudoever, J.B. & Kornelisse, R.F. 2010. The impact of an education program on hand hygiene compliance and nosocomial infection incidence in an urban neonatal intensive care unit: 'An intervention study with before and after comparison. *International Journal of Nursing Studies*, 47:1245–1252.

29. Higuera, F., Rosenthal, V.D., Duarte, P., Ruiz, J. Franco, G. & Safdar, N. 2005. The effect of process control on the incidence of central venous catheter-associated bloodstream infections and mortality in intensive care units in Mexico. *Critical Care Medicine*, 33(9):2022-2027.

30. Holodnick, C.L. & Barkauskas, V. 2000. Reducing percutaneous injuries in the OR by educational methods. *AORN Journal*, 73(3):461-476.

31. Howard, D.P.J., Williams, C., Sen, S., Shah, A., Duarka, J., Bird, R., Loh, A. & Howard, A. 2009. A simple effective clean practice protocol significantly improves hand decontamination and infection control measures in the acute surgical setting. *Infection*, 37(1):34-38.

32. Huang, J., Jiang, D., Wang, X., Liu, Y. Fennie, K., Burgess, J. & Williams, A.B. 2002. Changing knowledge, behavior, and practice related to universal precautions among hospital nurses in China. *The Journal of Continuing Education in Nursing*, 33(5):217-224.

33. Huang, T.T. & Wu, S.C. 2008. Evaluation of a training programme on knowledge and compliance of nurse assistants' hand hygiene in nursing homes. *Journal of Hospital Infection*, 68:164-170.

34. Lam, B.C., Lee, J. & Lau, Y.L. 2004. Hand hygiene practices in a neonatal intensive care unit: A multimodal intervention and impact on nosocomial infection. *Pediatrics,* 114(5):e565-e571.

35. Lange, B.J., Weiman, M., Feuer, E.J., Jakobowski, D., Bilodeau, J., Stallings, V.A., Hirschl, R., Bell, L.M., Harper, J. & Cnaan, A. 1997. Impact of changes in catheter management on infectious complications among children with central venous catheters. *Infection Control and Hospital Epidemiology*, 18(5):326-332.

36. Larson, E.L., Bryan, J.L., Adler, L.M. & Blane, C. 1997. A multifaceted approach to changing handwashing behavior. *American Journal of Infection Control*, 25(1):3-10.

37. Lee, T.C., Moore, C., Raboud, J.M., Muller, M.P., Green, K., Tong, A., Dhailwal, J. & McGeer, A. 2009. Impact of a mandatory infection control education program on nosocomial acquisition of methicillin-resistant *Staphylocoocus aureus. Infection Control and Hospital Epidemiology*, 30(3):249-256.

38. Lobo, R.D., Levin, A.S., Oliveira, M.S., Gomes, L.M.B., Gobara, S., Park, M., Figueiredo, V.B., De Vasconcelos Santos, E. & Costa, S.F. 2010. Evaluation of interventions to reduce catheter-associated bloodstream infection: Continuous tailored education versus one basic lecture. *American Journal of Infection Control*, 38:440-448.

39. Lobo, R.D., Levin, A.S., Brasileiro-Gomes, L.M., Cursino, R., Park, M., Figueiredo, V.B., Taniguchi, L., Polido, C.G. & Costa, S.F. 2005. Impact of an educational program and policy changes on decreasing catheter-associated bloodstream infections in a medical intensive care unit in Brazil. *American Journal of Infection Control*, 33(2):83-87.

40. Makris, A.T., Morgan, L., Gaber, D.J., Richter, A. & Rubino, J.R. 2000. Effect of a comprehensive infection control program on the incidence of infections in long-term care facilities. *American Journal of Infection Control*, 28(1):3-7.

41. Marigliano, A., Barbadoro, P., Pennacchietti, L., D'Errico, M.M. & Prospero, E. 2012. Active training and surveillance: Two good friends to reduce urinary catheterization rate. *American Journal of Infection Control*, 40:692-695.

42. McHugh, S.M., Corrigan, M., Dimitrov, B., Cowman, S., Tierney, S., Humphreys, H. & Hill, A. 2010. A targeted e-learning program for surgical trainees to enhance patient safety in preventing surgical infection. *Journal of Continuing Education in the Health Professions*, 30(4):257-259.

43. McKee, C., Berkowitz, I., Cosgrove, S.E., Bradley, K., Beers, C., Perl, T.M., Winner, L., Pronovost, P.J. & Miller, M.R. 2008. Reduction of catheter-associated bloodstream infections in pediatric patients: Experimentation and reality. *Pediatric Critical Care Medicine*, 9(1):40-46.

44. Mestre, G., Berbel, C., Tortajada, P., Alarcia, M., Coca, R., Fernández, M.M., Gallemi, G., Garćia, I., Aguilar, M.C., Rodríguez-Baño, J. & Martinez, J. 2003. Successful multifaceted intervention aimed to reduce short peripheral venous catheter-related adverse events: A quasi-experimental cohort study. *American Journal of Infection Control*, 41:520-526.

45. Nguyen, K.V., Nguyen, P.T.M. & Jones, L.J. 2008. Effectiveness of an alcohol-based hand hygiene programme in reducing nosocomial infections in the urology ward of Binh Dan Hospital, Vietnam. *Tropical Medicine and International Health*, 13(10):1297-1302.

46. Parra, A.P., Menárguez, M.C., Granda, M.J.P., Tomey, M.J., Padilla, B. & Bouza, E. 2010. A simple educational intervention to decrease incidence of central line-associated bloodstream infection (CLABSI) in intensive care units with low baseline incidence of CLABSI. *Infection Control and Hospital Epidemiology*, 31(9):964-967.

47. Parras, F., Ena, J., Bouza, E. & Santiago, M. 1994. Impact of an educational program for the prevention of colonization of intravascular catheters. *Infection Control and Hospital Epidemiology*, 15(4):239-242.

48. Pessoa-Silva, C.L., Hugonnet, S., Pfister, R., Touveneau, S., Dharan, S., Posfay-Barbe, K. & Pittet, D. 2007. Reduction of health care-associated infection risk in neonates by successful hand hygiene promotion. *Pediatrics*, 120(2):e382-e390.

49. Picheansathian, W., Pearson, A. & Suchaxaya, P. 2008. The effectiveness of a promotion programme on hand hygiene compliance and nosocomial infections in a neonatal intensive care unit. *International Journal of Nursing Practice*, 14:315-321.

50. Pittet, D., Hugonnet, S., Harbarth, S., Mourouga, P., Sauvan, V., Touveneau, S. & Perneger, T.V. 2000. Effectiveness of a hospital-wide programme to improve compliance with hand hygiene. *The Lancet*, 356:1307-1312.

51. Rauk, P.N. 2010. Educational intervention, revised instrument sterilization methods, and comprehensive preoperative skin preparation protocol reduce caesarean section surgical site infection. *American Journal of Infection Control*, 38(4):319-323.

52. Richard, V.S., Kenneth, J., Ramaprabha, P., Kirupakaran, H. & Chandy, G.M. 2001. Impact of introduction of sharps containers and of education programmes on the pattern of needle stick injuries in a tertiary care centre in India. *Journal of Hospital Infection*, 47:163-165.

53. Rosenthal, V.D., Guzman, S. & Crnich, C. 2006. Impact of an infection control program on rates of ventilator-associated pneumonia in intensive care units in 2 Argentinean hospitals. *American Journal of Infection Control*, 34(2):58-63.

54. Rosenthal, V.D., Guzman, S. & Safdar, N. 2005. Reduction in nosocomial infection with improved hand hygiene in intensive care units of a tertiary care hospital in Argentina. *American Journal of Infection Control*, 33(7):392-397.

55. Rosenthal, V.D., Guzman, S. & Safdar, N. 2004. Effect of education and performance feedback on rates of catheter-associated urinary tract infection in intensive care units in Argentina. *Infection Control and Hospital Epidemiology*, 25(1):47-50.

56. Rosenthal, V.D., Guzman, S., Pezzotto, S.M. & Crnich, C.J. 2003. Effect of an infection control program using education and performance feedback on rates of intravascular device-associated bloodstream infections in intensive care units in Argentina. *American Journal of Infection Control,* 31(7):405-409.

57. Rosenthal, V.D., McCormick, R.D., Guzman, S., Villamayor, C. & Orellano, P.W. 2003. Effect of education and performance feedback on handwashing. The benefit of administrative support in Argentinean hospitals. *American Journal of Infection Control*, 31(2):85-92.

58. Ross, A. & Crumpler, J. 2007. The impact of an evidence-based practice education program on the role of oral care in the prevention of ventilator-associated pneumonia. *Intensive and Critical Care Nursing*, 23:132-136.

59. Salahuddin, N., Zafar, A., Sukhyani, L., Rahim, S. Noor, M.F., Hussain, K., Siddiqui, S. Islam, M. & Husain, S.J. 2004. Reducing ventilator-associated pneumonia rates through a staff education programme. *Journal of Hospital Infection,* 57:223-227.

60. Salaripour, M. & Perl, T.M. 2013. The effectiveness and the retention level of the competency-based training for infection prevention and control practices. *The Canadian Journal of Infection Control*, 28(1):13-16.

61. Sannoh, S., Clones, B., Munoz, J., Montecalvo, M. & Parves, B. 2010. A multimodal approach to central venous catheter hub care can decrease catheter-related bloodstream infection. *American Journal of Infection Control*, 38(6):424-429.

62. Santana, S.L., Furtado, G.H.C., Wey, S.B. & Medeiros, E.A.S. 2008. Impact of an education program on the incidence of central line-associated bloodstream infection in 2 medical-surgical intensive care units in Brazil. *Infection Control and Hospital Epidemiology*, 29(12):1171-1173.

63. Schoon, J. & Sudoma, C. 2013. Bridging the gap from knowledge to practice: Get tough! Clean your stuff! *The Canadian Journal of Infection Control*, 28(1):19-22.

64. Sharir, R., Teitler, N., Lavi, I. & Raz, R. 2001. High-level handwashing compliance in a community teaching hospital: A challenge that can be met! *Journal of Hospital Infection*, 49:55-58.

65. Shelenz, S., Tucker, D., Georgeu, C., Daly, S., Hill, M., Roxburgh, J. & French, G.L. 2005. Significant reduction of endemic MRSA acquisition and infection in cardiothoracic patients by means of an enhanced infection control programme. *Journal of Hospital Infection*, 60:104-110.

66. Sherertz, R.J., Ely, E.W., Westbrook, D.M., Gledhill, K.S., Streed, S.A., Kiger, B., Flynn, L., Hayes, S., Strong, S., Cruz, J., Bowton, D.L., Hulgan, T. & Haponik, E.F. 2000. Education of physicians-in-training can decrease the risk for vascular catheter infection. *Annals of Internal Medicine*, 132(8):641-648.

67. Singh, S., Kumar, R.K., Sundaram K.R., Kanjilal, B. & Nair, P. 2012. Improving outcomes and reducing costs by modular training in infection control in a resource-limited setting. *International Journal for Quality in Health Care*, 24:641-648.

68. Tolentino-DelosReyes, A., Ruppert, S.D. & Shiao, S.P.K. 2007. Evidence-based practice: Use of ventilator bundle to prevent ventilator-associated pneumonia. *American Journal of Critical Care*, 16(1):20-27.

69. Trick, W.E., Vernon, M.O., Welbel, S.F., DeMarais, P. Hayden, M.K. & Weinstein, R.A. 2007. Multicenter intervention program to increase adherence to hand hygiene recommendations and glove use and to reduce the incidence of antimicrobial resistance. *Infection Control and Hospital Epidemiology*, 28(1):42-49.

70. Warren, D.K., Cosgrove, S.E., Diekema, D.J., Zucotti, G., Climo, M.W., Bolon, M.K., Tokars, J.I., Noskin, G.A., Wong, E.S., Sepkowitz, K.A., Herwaldt, L.A., Perl, T.A., Solomon, S.L. & Fraser, V.J. 2006. A multicentre intervention to prevent catheter-associated bloodstream infections. *Infection Control and Hospital Epidemiology*, 27(7):662-669.

71. Warren, D.K., Zack, J.E., Mayfield, J.L., Chen, A., Prentice, D., Fraser, V.J. & Kollef, M.H. 2004. The effect of an education program on the incidence of central venous catheter-associated bloodstream infection in a medical ICU. *Chest*, 126:1612-1618.

72. Warren, D.K., Zack, J.E., Cox, M.J., Cohen, M.M. & Fraser, V.J. 2003. An educational intervention to prevent catheter-associated bloodstream infections in a nonteaching, community medical center. *Critical Care Medicine*, 31(7):1959-1963.

73. Wisniewski, M.F., Kim, S., Trick, W.E., Welbel, S.F. & Weinstein, R.A. 2007. Effect of education on hand hygiene beliefs and practices: A 5-year program. *Infection Control and Hospital Epidemiology*, 28(1):88-91.

74. Won, S.P., Chou, H.C., Hsieh, W.S., Chen, C Y., Huang, S.M., Tsou, K.I. & Tsao, P.N. 2004. Handwashing program for the prevention of nosocomial infections in a neonatal intensive care unit. *Infection Control and Hospital Epidemiology*, 25(9):742-746.

75. Zack, J.E., Garrison, T., Trovillion, E., Clinkscale, D., Coopersmith, C.M., Fraser, V.J. & Kollef, M.H. 2002. Effect of an education program aimed at reducing the occurrence of ventilator-associated pneumonia. *Critical Care Medicine*, 30(11):2407-2412.

76. Zingg, W., Imhof, A., Maggiorini, M., Stocker, R., Keller, E. & Ruef, C. 2009. Impact of a prevention strategy targeting hand hygiene and catheter care on the incidence of catheter-related bloodstream infections. *Critical Care Medicine,* 37(7):2167-2173.

Acronyms used in the text and database

AMSTAR	A Measurement Tool to Assess Systematic Reviews
APIC	Association for Professionals in Infection Control
CAUTI	Catheter-associated urinary tract infection
CCU	Coronary care unit
CDC	Centres for Disease Control and Prevention
CICU	Cardiac intensive care unit
CLABSI	Central line associated bloodstream infection
CVC	Central vascular catheter
ECDC	European Centre for Disease Prevention and Control
HAI	Healthcare-associated infection
HCW	Healthcare worker
ICU	Intensive care unit
IDSA	Infectious Diseases Society of America
IHI	Institute for Healthcare Improvement
IPC	Infection prevention and control
IV	Intravenous line
MICU	Medical intensive care unit
MSICU	Medical-surgical intensive care unit
NICU	Neonatal intensive care unit
PICU	Paediatric intensive care unit
PPE	Personal protective equipment
PRISMA	Preferred reporting items for systematic reviews and meta-analyses
SHEA	The Society for Healthcare Epidemiology of America
SSI	Surgical site infection
SICU	Surgical intensive care unit
VAP	Ventilator-associated pneumonia
WHO	World Health Organisation

ADDENDUM B

Database of education intervention studies used in the systematic review

See separate Excel file available in attached CD

ADDENDUM C

Methodological quality assessment of existing systematic reviews on IPC education

The AMSTAR checklist was used to do the assessment.

Assessment	SCORES				
	Review 1*	**Review 2***	**Review 3***	**Review 4***	**Review 5***
1. Was an 'a priori' design provided?	Yes	Yes	Yes	Yes	Yes
2. Was there duplicate study selection and data extraction?	Yes	No	Can't answer	Yes	Yes
3. Was a comprehensive literature search performed?	Yes	Yes	Yes	Yes	Yes
4. Was the status of the publication (i.e. grey literature) used as an inclusion criterion?	No	No	Yes	Can't answer	Yes
5. Was a list of studies (included and excluded) provided?	No (only included studies)	No (only included studies)	No (neither included or excluded studies)	No (only included studies)	Yes
6. Were the characteristics of the included studies provided?	Yes	Yes	No	Yes	Yes
7. Was the scientific quality of the included studies assessed and documented?	No	No	No	Yes	Yes
8. Was the scientific quality of the included studies used appropriately in formulating conclusions?	Not applicable	Not applicable	Not applicable	Yes	Yes
9. Were the methods used to combine the findings of studies appropriate?	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
10. Was the likelihood of publication bias assessed?	No	No	No	Yes	Yes
11. Was the conflict of interest included?	No	No	No	No	No
TOTAL SCORE	**4**	**3**	**3**	**7**	**9**

**See reference corresponding to the number below*

Review 1: Safdar & Abad, (2008:933-940)
Review 2: Ward's (2011:9-17)
Review 3: Naikoba & Hayward (2001:173-180)
Review 4: Cherry, Brown, Neal & Shaw (2010:198–218)
Review 5: Gould, Drey, Moralejo, Grimshaw & Chudleigh (2008:193-202)

ADDENDUM D

PRISMA CHECKLIST

Section/topic	#	Checklist item	Detail / Reported on page #
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	p. 2
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	pp. 4-5
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known.	p. 8
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	p. 22
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	Stellenbosch University Health Research Ethics Committee, registration number S13/02/028
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	pp. 23-24
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	p. 24
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	pp.24-25
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic	pp. 25-27

		review, and, if applicable, included in the meta-analysis).	
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	p. 27
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	pp. 25-29
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	p. 27
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	NA
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	pp. 27-28
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	p. 27
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	NA
RESULTS			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	p. 30
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	Addendum B
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	Not documented
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	Addendum B
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	NA
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	Not documented

Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	NA
DISCUSSION			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	pp. 30-44
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	pp. 28, 46
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	pp. 53-55
FUNDING			
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	NA

Adapted from: Moher, Liberati, Tetzlaff, Altman & PRISMA Group (2009: 264-269)