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REVIEW

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Undergraduate nursing students' education and training in aseptic technique: A mixed methods systematic review

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Abstract

Aim: To appraise and synthesize empirical studies exploring undergraduate nursing students' education and training in aseptic technique.

Design: Mixed methods, systematic literature review adopting Joanna Briggs Institute methodology.

Data sources: Thirteen electronic databases were searched 1996–2020, followed by searches with a general browser, hand-searching key journals and reviewing reference lists of retrieved papers.

Review methods: Potentially eligible papers were scrutinised by two reviewers. Those eligible were critically appraised and quality assessed using the Critical Appraisal Skills Programme and Specialist Unit for Review Evidence checklists.

Results: Of 538 potentially eligible studies, 27 met the inclusion criteria. There was limited evidence of the effectiveness of different teaching methods. Students' knowledge, understanding and competency varied and were often poor, although they reported confidence in their ability to perform aseptic technique. Students and qualified nurses perceived that education and training in aseptic techniques might be improved.

Conclusion: Education and training in aseptic technique might be improved but the review findings should be viewed cautiously because the studies lacked methodological rigour.

Impact: This appears to be the first systematic review to explore undergraduate nursing students' education and training in relation to aseptic technique. There was limited evidence to support the effectiveness of different teaching methods and scope for improving nursing students' knowledge, understanding and competency in aseptic technique. Students and qualified nurses suggested that education and training might be enhanced. More robust studies are required to support education, practice and policy.

KEYWORDS
aseptic technique, infection prevention, nursing education, nursing students, pre-registration, systematic review, undergraduate

1 | INTRODUCTION

Healthcare-associated infection (HCAI) is the most common adverse event reported in healthcare (World Health Organization, 2011). In Europe, over 4 million patients develop at least one HCAI per annum with 37,000 deaths (European Centre for Disease Prevention & Control, 2013), inflating the cost of health care (O'Neill, 2016) and increasing the global threat of antimicrobial resistance (World Health Organization, 2016a). Policy-makers identify three strategies to reduce these risks: improvements in infection prevention and guidelines to support practice and education (Department of Health, 2019; World Health Organization, 2016b, 2016c). Although aseptic technique is recognised as central to the prevention of infection in these guidelines, there is no international standard. Descriptions of the procedure differ (Aziz, 2009) and numerous variations in practice have been reported (Preston, 2005; Unsworth & Collins, 2011). Problems are compounded because there is no internationally agreed definition of aseptic technique. To further complicate this issue, the aims of aseptic technique differ across guidelines. For example, in the United Kingdom (UK), according to one set of official guidelines, the aim of aseptic technique is "To minimise the risks of exposing the person being cared for to pathogenic micro-organisms" (Antimicrobial Resistance and Healthcare Associated Infection Scotland (ARHAI Scotland) group, 2021), while in another guideline the aim is "To ensure that sites of the body susceptible to infection do not receive contact with contaminated equipment or fluid" (National Institute & for Clinical Excellence, 2017). Despite this lack of agreement, the ability to undertake aseptic technique is regarded as an important nursing skill, with the demonstration of competence, a requirement for registration in many countries, including the UK (Nursing and Midwifery Council (2018); Nursing & Midwifery Board of Australia, 2013).

2 | BACKGROUND

Over the years, approaches to teaching and assessing aseptic technique have changed in the UK to align with broader changes in nurse education. Until the mid-1990s, all nursing students were required to demonstrate competence in a single test before they were allowed to register. Throughout the mid-1990s pre-registration nursing courses moved from hospital-based schools of nursing to universities, with universities responsible for their own arrangements to assess competence. This lack of standardisation is one of the numerous problems affecting both the university-based teaching of aseptic technique and students' experiences during clinical placements. A recent survey, designed to explore teaching and assessment of aseptic technique in UK undergraduate nursing education, established a lack of consistency and inaccuracies relating to the principles of asepsis (Hawker et al., 2020). Additionally, more than one guideline was identified as underpinning teaching by 88% of the universities surveyed. These findings corroborate studies exploring other key infection prevention issues, notably hand hygiene (Sundal et al., 2017; Zimmerman et al., 2020) and probably contribute to the differences in practice described by Preston (2005) and Unsworth and Collins (2011). In the research by Hawker et al. (2020), there were marked variations in the number of hours devoted to teaching and assessing aseptic techniques. Aseptic technique was predominantly taught by university lecturers, with teaching approaches including classroom-based sessions, simulation in clinical skills laboratories and self-directed learning. Variations in the practice of aseptic technique have been identified by nursing students during clinical placements, with good clinical role models often unavailable (Gould & Drey, 2013; Ward, 2011). Opportunities for qualified nurses to update their knowledge and skills related to aseptic technique are limited, and their understanding of the underlying principles of asepsis has been reported to be suboptimal (Gould et al., 2018, 2021). As a result, nurse educators and mentors in clinical placements may be poorly equipped to teach and assess students.

No systematic reviews investigating undergraduate nursing students' education and training in aseptic technique appear to have been undertaken. A systematic review was undertaken to explore undergraduate nursing students' education and training in aseptic technique internationally and identify scope for improvement as stipulated in international policy (World Health Organization 2016a, 2016b, 2016c, Department of Health, 2019).

3 | THE REVIEW

3.1 | Aim

To appraise and synthesize evidence from empirical studies exploring undergraduate nursing students' education and training in aseptic technique internationally.

3.2 | Objectives

The objectives of the systematic review were as follows:

1. To establish the effectiveness of different teaching/learning methods for aseptic technique upon nursing students' knowledge and competence.
2. To examine reported levels/findings of nursing students' knowledge, competency and confidence in undertaking an aseptic technique as outcomes of learning.
3. To explore students', educators' and qualified nurses' perceptions of education and training in aseptic technique in undergraduate nursing programmes.

3.3 | Design

A mixed methods review was chosen to address the different objectives about effectiveness (quantitative) and experience (qualitative) to increase understanding of nursing students' education and

training in aseptic technique (Bressan et al., 2016). This review was informed by the Joanna Briggs Institute (JBI) methodology for mixed methods systematic reviews and adopted a convergent segregated approach to synthesis and integration (Hong et al., 2017; Lizarondo et al., 2020). This approach is characterised by an independent synthesis of qualitative and quantitative data followed by integration of quantitative and qualitative evidence (Lizarondo et al., 2020).

No reporting guidelines for mixed methods studies reviews exist (Fleming et al., 2008). The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) checklist (Moher et al., 2009), Template for Intervention Description and Replication (TIDier) checklist (Hoffman et al., 2014) for reporting of interventions and the enhancing transparency in the reporting the synthesis of qualitative research guidance (Tong et al., 2012) were followed.

3.4 | Search methods

The following databases were searched from January 1996 to April 2020 to identify eligible published papers (CINAHL, Medline, BNI, Scopus, Web of Science, Embase, Cochrane Library, ERIC, JBI and HMIC) and unpublished papers and 'grey' literature (Proquest Dissertations & Theses, Open SIGLE and the Grey literature report). A preliminary search identified that the earliest study exploring aseptic technique featuring nursing students was Davey (1997). MeSH terminology and keywords were used for aseptic technique, infection prevention, healthcare-associated infection, nursing students, nurse education, training and assessment (see File S1 for search strategy). Additional search strategies included: searching the internet with a general browser (Google Scholar); screening reference lists of papers already retrieved and hand-searching high-yield key journals (American Journal of Infection Control, Journal of Advanced Nursing, Journal of Infection Control, Nurse Education Today).

The inclusion criteria were as follows: (1) empirical studies (qualitative, quantitative or mixed methods); (2) focusing upon undergraduate nursing students' learning, teaching and assessment of aseptic technique in university or clinical placements; (3) exploring aseptic technique as a whole concept applied in any invasive procedure; (4) measuring nursing students' knowledge, competency, confidence in undertaking an aseptic technique (5) students', educators' or qualified nurses' perceptions of teaching, learning and assessment of aseptic technique in the university or clinical practice setting in undergraduate nursing programmes. Exclusion criteria were as follows: (1) non-empirical papers- literature reviews, opinion papers or editorials; (2) other healthcare students' learning, teaching and assessment of aseptic technique (3) individual components of an aseptic technique only, i.e., hand hygiene and (4) no outcome measures reported for aseptic technique.

3.5 | Search outcomes

The database searches located 1147 papers. The selection process is summarised in the PRISMA flow diagram (Moher et al., 2009) (see Figure 1). After the removal of duplicates, there were 538 papers for screening.

All studies were assessed for relevance by screening the titles and then abstracts and if a judgment could not be reached the full paper was retrieved for assessment. A screening tool was developed based on the inclusion criteria to ensure consistency throughout the screening process. All 56 potentially eligible papers were screened by two reviewers (CH, DJG) against the inclusion criteria using the screening tool. Arbitration from a third independent reviewer was available but not required. Of 538 potentially eligible papers, 27 met the inclusion criteria.

3.6 | Quality appraisal

The quality of studies included in the review was evaluated using different critical appraisal tools depending upon study design (see File S2). The Critical Appraisal Skills Programme (CASP) (2020) checklists for randomized trials and qualitative studies were used for assessing the methodological quality of intervention studies ($n = 6$) and qualitative studies ($n = 8$), respectively. The methodological quality of eight cross-sectional studies ($n = 8$) and quantitative, descriptive studies ($n = 5$) were assessed using the Specialist Unit for Review Evidence (SURE) (2018) critical appraisal checklist for cross-sectional studies. Two reviewers independently assessed the quality of each study and were in agreement. No studies were excluded following the quality appraisal. The quality assessment was used to identify the strengths and limitations of the evidence and inform assessment in the confidence of the review findings.

3.7 | Data extraction

Data were extracted from the included papers using a standardized data extraction table as described by guidance from the Centre for Reviews and Dissemination (2009). The extracted data included the following: (1) authors, year and country; (2) aim; (3) study design; (4) sample; (5) intervention where applicable; (6) data collection methods and (6) key findings – for nursing students' competency, knowledge and confidence levels and students' educators' or qualified nurses' perceptions of teaching, learning and assessment of aseptic technique (see Tables 1–3). Two reviewers involved in the screening and quality appraisal, independently extracted data and another reviewer cross-checked the data extraction table for accuracy (Lizarondo et al., 2020). Any disagreements in data extraction were resolved by discussion with a third reviewer (Lizarondo et al., 2020). Data extraction for thematic synthesis is described in the next section.

3.8 | Synthesis

A convergent segregated approach was used whereby independent synthesis of qualitative and quantitative data was followed by

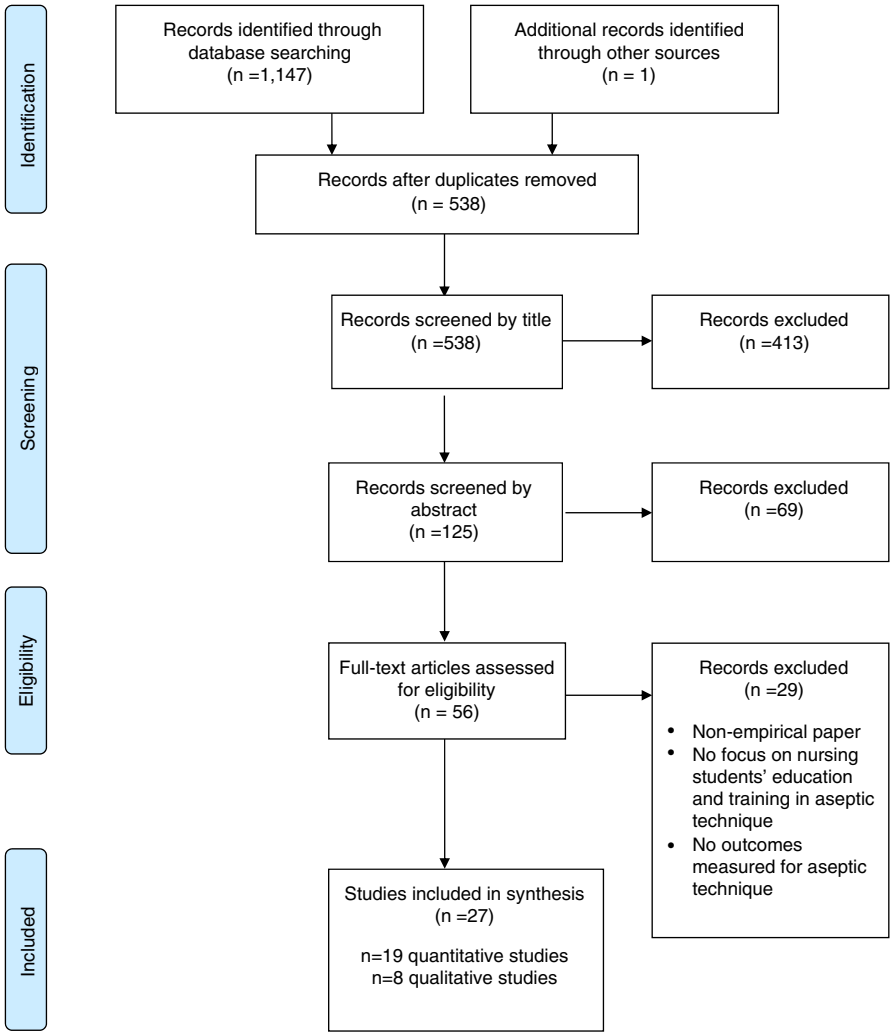

FIGURE 1 Study selection process based on the PRISMA diagram (Moher et al., 2009)

integration of quantitative and qualitative evidence (Hong et al., 2017; Lizarondo et al., 2020). A meta-analysis was not feasible to meet objective 1 because of the heterogeneity of the intervention studies. Therefore, a narrative synthesis was undertaken using the following tools and techniques identified under two elements of Popay et al.'s (2006) framework for narrative synthesis; tabulation, developing textual descriptions, grouping and clustering of studies to characterize the key outcomes and findings (competence and knowledge) across studies in developing a preliminary synthesis and concept mapping for exploring relationships in the data.

Quantitative evidence and qualitative evidence from observational studies were synthesized separately and then a narrative summary produced, which is presented under objective 2, linking and organizing the findings across the outcomes of interest which were as follows: (1) competency, (2) knowledge and (3) confidence to provide a configured analysis (Lizarondo et al., 2020). Narrative summaries allow for the juxtaposition of different types of evidence (Dixon-Woods et al., 2005). Quantitative evidence and qualitative evidence were integrated using configurative analysis. This involved constant comparison of the quantitative evidence and qualitative evidence, in order to organize/link the evidence into a line of argument (Lizarondo et al., 2020; Tong et al.,2012).

Thematic synthesis was undertaken in which findings from the observational studies (quantitative and qualitative evidence) were synthesized together (Harden et al., 2018) to address objective 3. Although more commonly associated with the synthesis of qualitative research, thematic synthesis was used as a pragmatic approach to the synthesis of qualitative and quantitative studies with a similar focus (Fleurke et al., 2020). Two stages of Thomas and Harden's (2008) three-staged approach to thematic synthesis were followed, which involved independent inductive coding and the development of descriptive codes and a coding framework followed by the generation of themes by the first reviewer. Only quantitative data relevant to perceptions or experiences of learning, teaching and assessment were extracted primarily from survey findings and assigned a textual description for coding to allow integration with qualitative data (Lizarondo et al., 2020). The second and the third reviewer checked the coding and thematic synthesis process. The findings are presented under the following key themes: (1) observing good and poor role models, (2) congruence between university teaching and clinical practice and (3) variations in opportunity for learning and assessment.

TABLE 1 Effectiveness of different teaching/learning methods – Intervention studies

Study, location & Aim	Study design	Sample	Intervention	Data collection	Key findings
Jeffries et al. (2002), *USA* To compare the effectiveness of two instructional methodologies in teaching skills in the skills laboratory	Pre- & post test	Nursing students ($n = 120$)	Traditional versus interactive learning	Observation of wound dressing performance & 20 item knowledge test	NS improvement in knowledge 100% passed AT test on 1st attempt
Melby et al. (2007), *Ireland* To investigate the importance of lecturer demonstration on psychomotor skill performance	RCT	Nursing students ($n = 16$)	30 min demonstration	Analysis of videotaped IM injection technique performance	Adherence to aseptic principles only in the student receiving a demonstration
O'Neill (2001), *UK* To investigate the effect of stimulated recall upon skill acquisition & competence in the simulated setting	RCT	Nursing students ($n = 47$)	Stimulated recall	Analysis of videotaped tracheostomy dressing performance using the checklist	Significant improvement in asepsis maintenance in stimulated recall group only ($p = .00001$). NS difference in correct evaluation of asepsis ($p = .4$)
Wright et al. (2008), *UK* To evaluate the effect of PETTLEP based imagery training on skill performance	RCT	Nursing students ($n = 18$)	Imagery training for AT dressing change	Movement Imagery Questionnaire-Revised & OSCE	NS differences in OSCE scores between control and imagery group *($p = .69$)*
Walsh et al. (2011), *Canada* To compare the effectiveness of EAL, PAL & CAL on skills acquisition, retention & transfer in the simulated setting.	Pre- & post test	Nursing students ($n = 25$)	PAL, EAL or CAL session U/C on female simulator x3	Analysis of videotaped performance – validated 25 item checklist & global rating scale	Significant reduction in breaks of AT & increase in checklist & global rating scale scores pre- to post-test ($p \leq .05$) NS differences between groups ($p > .05$)
Zhang (2015), *China* To explore the effect of standardized teaching ward rounds in preventing hospital-acquired infection	Non-randomised trial	Nursing students ($n = 240$)	2 wkly tandardized teaching ward round (AT)	Non-validated questionnaire Skills test	Significantly higher skills test pass rate ($p = .046$) & knowledge scores ($p = .006$) for AT in standardized than traditional ward round group

Abbreviations: AT, aseptic technique; CAL, Computer assisted learning; EAL, Expert assisted learning; IM; Intra, Muscular; NS, Non-significant; OSCE, Objective Structured Clinical Examination; PAL, Peer assisted learning; PETTLEP, Physical, Environment, Task, Timing, Learning, Emotion & Perspective; RCT, Randomised Controlled Trial; U/C, Urinary catheterisation.

TABLE 2 Knowledge, competency and confidence levels -observational studies

Study, location & Aim	Study design	Sample	Data collection	Key findings
Carter et al. (2017), *USA* To examine the relationship between hours of IPC education & students' knowledge, attitudes & practices in AT	Cross-sectional survey	Nursing students(n = 3678)	Online survey	99% understood AT.12% not confident in AT when inserting & maintaining invasive devices. Students who received simulation/clinical practice more confident (p = .003).
Cebeci et al. (2015), *Turkey* To determine the number & type of medication administration errors made by nursing students	Cross-sectional survey	Nursing students (n = 324)	Non-validated questionnaire	23.8% (96/420) of errors were deviations from AT
Davey (1997), *Australia* To explore nursing students' understanding of the concept of asepsis within the clinical skills laboratory	Qualitative	Nursing students (n = 18)	Written exercise & in-depth interviews	No student had a complete understanding of AT (n = 2 principles; n = 9 procedure; n = 7 aim)
Ferreira Batista et al. (2013), *Brazil* To investigate nursing students' understanding of infection prevention in ventilated intensive care patients	Exploratory survey	Nursing students (n = 30)	Non-validated questionnaire	23% (10) identified AT to prevent infections
Gonzalez & Sole (2014), *USA* To assess student competence on skill attainment in urinary catheter insertion & identify the most common AT breaches	Descriptive observational study (pilot)	Nursing students(n = 13)	Analysis of videotaped performance using checklist & confidence scale	77% (10/13) breached AT. Most common breach−89.4% (7/13) when cleaning urethral meatus. Mean confidence 3.6
Mackey et al. (2014), *Singapore* To determine the value of being a standardised patient on student learning outcomes	Qualitative	Nursing students (n = 15)	2 x focus groups	Students observed poor AT in wound care & compared students' performance with their own skill level
Mitchell et al. (2014), *Australia* To determine graduating nursing students' knowledge of & intentions towards IPC practices	Cross-sectional survey	Nursing students (n = 349)	Online survey	60% strongly agreed AT should be used when manipulating IV devices.
Rush et al. (2014), *UK* To establish students' experiences with 1st year OSCA	Cross-sectional survey	Nursing students(n = 180)	Online survey	89.4% (161/180) passed AT OSCA at first attempt
Simonetti et al. (2019), *Italy* To establish nursing students' knowledge of evidence-based guidelines on the prevention of peripheral venous catheter-related infection	Cross-sectional survey	Nursing students (n = 1056)	Adapted validated 10 item questionnaire	Second highest correct score−78.8% using AT when caring for IV lines
Uysal (2016), *Turkey* To determine nursing students common mistakes in NSLEs	Retrospective analytical study	Exam papers(n = 605)	Analysis of performance checklists & exam scores	Most common mistake-not following asepsis principles for IM & S/C injection & IV access
Watts et al. (2009), *Canada* To evaluate the use of self-assessment using videotaping in psychomotor skill development	Descriptive observational study	Nursing students (n = 40)	Analysis of videotaped dressing change performance using checklist	Educators identified 2–3 x higher no. of breaks in AT than students, 54% (45/83)-setting up the sterile field; 34% (28/83)-cleaning the wound

Abbreviations: AT, aseptic technique; IM; Intra-Muscular IV; Intravenous; IPC, Infection Prevention and Control; SC, Subcutaneous OSCA-Objective Structured Clinical Assessment.

TABLE 3 Perceptions/experiences of teaching/learning/assessment of aseptic technique -Observational studies

Study, location & Aim	Study design	Sample	Data collection	Key findings
Carter et al. (2017), *USA* To examine the relationship between hours of IPC education & students' knowledge, attitudes & practices in AT	Cross-sectional survey	Nursing students ($n = 3678$)	Online survey	34% reported 4–8 hrs of AT education-simulation (63%); lecture (21%); clinical setting (15%). 51% witnessed poor IPC practices including AT. 89% agreed what was taught in schools was observed in clinical practice
Cox et al. (2014), *Australia* To explore IPC nurses' perceptions of microbiology & IPC training in undergraduate nursing curricula & perceived transferability of knowledge	Qualitative	Infection control nurses ($n = 8$)	Semi-structured interviews	Theory practice gap in AT reported
Geller et al. (2010), *USA* To describe the frequency & types of IPC hazards & near misses reported by nursing students over 3 years	Retrospective analytical study	Nursing students ($n = 500$)	Analysis of 3yrs of students hazard/near miss database entries	886/3492 (25.4%) IPC practices comments, breaks in AT 3rd most common category (17.2%)
Gould & Drey (2013), *UK* To explore student nurses' experiences of IPC during clinical placements.	Descriptive survey	Nursing students($n = 488$)	Online survey	Nurses & doctors' AT practices criticised. Poor practice in community & long stay elderly facilities.
Ribu et al. (2003), *Norway* To obtain knowledge about leg & foot ulcer care by community nurses	Descriptive observational study	Nursing students($n = 30$)	7wks structured observation in pt's homes by students	21 (60%) washed their hands before & after aseptic procedure, n = 3 nurses wore hand jewellery & n = 3 breaches of AT
Stayt & Merriman (2013), *UK* To evaluate pre-registration student nurses' perceptions of clinical skill development in clinical placements	Cross-sectional survey	Nursing students ($n = 421$)	Online survey	73.7% never practise AT unsupervised, never/sometimes have opportunity to practice (44.4%) or for assessment (63.1%)
Ward (2010), *UK* To explore student's experience of IPC in clinical placements & how this affects learning.	Qualitative, descriptive	Nursing & midwifery students ($n = 40$)	Semi-structured interviews	Good (community nurses) & poor AT practices reported. Poor role models have positive & negative effects on learning
Ward (2011), *UK* To explore nursing students' & mentors' perceptions of student's IPC educational needs.	Qualitative, descriptive	Nursing students ($n = 31$) and mentors ($n = 32$)	As above	Students confused by conflicting ANTT practices. Students & mentors identified the need for assessment
Ward (2012a), *UK* To explore attitudes towards IPC perceived by nursing students & mentors.	Qualitative	As above	As above	Mentors perceived AT important but sometimes needed to cut corners
Ward (2012b), *UK* To investigate experiences/ education needs of students in relation to IPC in clinical placements	Qualitative, exploratory	As above	As above	Students stated that staff forget not just about hand-washing but AT
Westphal et al. (2014), *USA* To identify common workarounds & describe what influenced nurses to do this as observed by 4th year nursing students	Qualitative, descriptive	Nursing students' assignments ($n = 96$)	Analysis of written assignments	3 incidences of AT breaches; 1x urinary catheter 2x peripheral venous catheter insertion

Abbreviations: ANTT, Aseptic Technique Non-Touch Technique; AT, aseptic technique; IPC Infection Prevention and Control.

4 | RESULTS

4.1 | Description of studies

The review included 27 studies, a summary of each included study can be found in Tables 1–3, (for further information see File S3). There were eight qualitative studies and nineteen quantitative studies. Of the quantitative studies, six were intervention studies: Randomized controlled trials (RCTs) (n = 3), pre- and post-test designs (n = 2) and non-randomized trial (n = 1) and thirteen were observational studies: cross-sectional surveys (n = 8), analytical studies (n = 2) and descriptive studies (n = 3). Sample sizes ranged from 13 to 3678 for quantitative studies and 8–96 for qualitative studies. Studies came from a range of countries: UK (n = 9), USA (n = 5), Australia (n = 3), Canada (n = 2), Ireland (n = 1), Turkey (n = 2), Italy (n = 1), China (n = 1), Brazil (n = 1), Norway (n = 1) and Singapore (n = 1).

Only three studies evaluated nursing students' education and training in aseptic technique as the primary aim (Carter et al., 2017; Davey, 1997; Gonzalez & Sole, 2014). Five studies focused on the effectiveness of different teaching methods in the development of psychomotor skills requiring aseptic technique (Jeffries et al., 2002; Melby et al., 1997; O'Neill, 2001; Walsh et al., 2011; Wright et al., 2008). One study explored the effectiveness of a teaching intervention in clinical practice (Zhang, 2015). Ten studies explored nursing students' experiences/perceptions of infection prevention or skill development including aseptic technique in clinical placements (Carter et al., 2017; Geller et al., 2010; Gould & Drey, 2013; Ribu et al., 2003; Stayt & Merriman, 2013; Ward, 2010, 2011, 2012a, 2012b; Westphal et al., 2014). One study explored infection prevention nurses' perceptions of undergraduate infection prevention education including aseptic technique (Cox et al., 2014). Eleven studies reported findings upon nursing students' knowledge, competency and confidence in undertaking an aseptic technique (Carter et al., 2017; Cebeci et al., 2015; Davey, 1997; Ferreira Baptista et al., 2013; Gonzalez & Sole, 2014; Mackey et al., 2014; Mitchell et al., 2014; Rush et al., 2014; Simonetti et al., 2019; Uysal, 2016; Watts et al., 2009). None of the studies addressed all areas of interest in the review.

4.2 | Objective 1: Establish the effectiveness of different teaching/learning methods for aseptic technique upon nursing students' knowledge and competence.

Six intervention studies explored the effectiveness of different teaching/learning methods (see Table 1): RCTs (n = 3), pre- and post-test designs (n = 2) and non-randomized trial (n = 1). Five studies investigated different teaching/learning methods for aseptic technique as applied to different clinical procedures: injections (Melby et al., 1997); dressing changes (Jeffries et al., 2002; O'Neill, 2001; Wright et al., 2008) and urinary catheterization (Walsh et al., 2011). Five of the six studies were undertaken in the university setting (Jeffries et al., 2002; Melby et al., 1997; O'Neill, 2001; Walsh et al., 2011; Wright et al., 2008). One study (Zhang, 2015), took place in clinical practice.

There was heterogeneity in the teaching interventions explored in studies (see File S4 for a full description of each intervention using the [TIDier] checklist [Hoffman et al., 2014]). Each of the studies measured the effectiveness of different teaching/learning methods in terms of having a statistically significant effect upon students' knowledge and competence (see Table 4 for a summary).

Two studies, each testing intervention was designed to improve mental processes to enhance students' performance of aseptic technique during a wound dressing, produced conflicting findings (O'Neill, 2001; Wright et al., 2008). In O'Neill's (2001) RCT, students (n = 19) who received stimulated recall-facilitator-led review of their videotaped performance of aseptic technique during a tracheostomy dressing demonstrated significant improvements in asepsis maintenance from pre- to post-test *(p = .00001)*. These findings should be viewed cautiously given that students in the experimental group were reported undertaking significantly more activity *(p = .0002)* (reading) outside the intervention than the control group. In contrast, in Wright et al.'s (2008) RCT, students (n = 18) who received Physical, Environment, Task, Timing, Learning, Emotion and Perspective (PETTLEP) imagery training – a form of rehearsal of performing an aseptic technique during a wound dressing – demonstrated no significant improvement in competency *(p = .069)*.

TABLE 4 Different learning/teaching methods and effect on knowledge and competence

Study	Different learning/teaching methods	Outcomes
O'Neill (2001)	Stimulated recall	+Competence
Jeffries et al. (2002)	Traditional versus Interactive learning	−Competence −Knowledge
Melby et al. (2007)	Demonstration	+Competence
Wright et al. (2008)	Imagery training	−Competence
Walsh et al. (2011)	Peer, expert or computer-assisted learning	−Competence
Zhang (2015)	Standardised teaching versus traditional ward round	+ Competence + Knowledge

+, statistically significant effect (p < .05); −, Non statistically significant effect (p > .05).

Three studies, comparing the effectiveness of different instructional methods for aseptic technique in different clinical procedures in the simulated environment, yielded mixed findings (Jeffries et al., 2002; Melby et al., 2007; Walsh et al., 2011). A pre- and post-test study by Jefferies et al. (2002), identified no significant differences in knowledge (no *p*-value reported) between students who received didactic teaching of aseptic technique as applied to wound dressings ($n = 50$) or interactive, self-directed learning ($n = 70$). This finding might be explained by students in both groups demonstrating similarly high levels of knowledge at baseline. An RCT investigating the value of a demonstration in students' ($n = 16$) learning of intramuscular injection technique found that students who received a demonstration maintained asepsis. Asepsis was not maintained in those who did not receive the demonstration (Melby et al., 2007). However, this was based only on one students' videotaped performance. A pre- and post-test study by Walsh et al. (2011), comparing the effectiveness of peer, expert and computer-assisted learning of urinary catheterization in nursing ($n = 25$) and medical ($n = 35$) students, reported significant reductions in breaks in aseptic technique and increased checklist and global rating scores from pre- to post-test *($p < .05$)* but no significant differences between groups *($p > .05$)*.

Zhang's (2015) non-randomized trial investigated the effectiveness of standardized teaching ward rounds compared with traditional ward rounds in clinical practice. Nursing students ($n = 120$) who received standardized teaching ward rounds had significantly higher knowledge *($p = .006$)* and skills scores *($p = .046$)* for aseptic technique than students ($n = 120$) who received traditional ward rounds.

4.3 | Objective 2: Examine reported levels/ findings of nursing students' knowledge, competency and confidence in undertaking an aseptic technique as outcomes of learning.

Nine observational studies: six cross-sectional surveys, two qualitative studies and one descriptive study reported levels/ findings in relation to nursing students' knowledge (n = 5), competency (n = 4) and confidence to perform an aseptic technique (n = 2) (see Table 3).

4.4 | Knowledge

Five observational studies investigated nursing students' knowledge of aseptic technique and reported wide variation (Carter et al., 2017; Davey, 1997; Ferreira Baptista et al., 2013; Mitchell et al., 2014; Simonetti et al., 2019). Four cross-sectional studies explored nursing students' knowledge of when to apply aseptic technique during invasive procedures (Carter et al., 2017; Ferreira Baptista et al., 2013; Mitchell et al., 2014; Simonetti et al., 2019). (see Table 2). In Ferreira Batista et al. (2013) survey of nursing students' ($n = 30$) from one Brazilian university, 23% of students identified the use of aseptic technique to prevent infection in ventilated ICU patients. These findings should be viewed cautiously, given the small sample size and poor reporting of data. In contrast, in Mitchell et al. (2014) online survey of final-year nursing students' ($n = 349$) knowledge of infection prevention practices from six Australian universities, 60% of students strongly agreed aseptic technique should be used when manipulating intravenous lines or devices. Similarly, in Simonetti et al.'s (2019) survey of nursing students ($n = 1065$) from seven Italian universities, 78.8% identified using aseptic technique when caring for intravenous lines. In Carter et al.'s (2017) online survey of national students nursing association members ($n = 3678$) in the USA, 99% of students agreed they understood aseptic technique, and that it was required when inserting and maintaining invasive devices to prevent infection. There was no formal assessment of students' knowledge or definition offered to clarify their understanding. In contrast, in Davey et al.'s (1997) qualitative study, no student ($n = 18$) demonstrated a complete understanding of aseptic technique, students had a greater understanding of the aim or procedure of undertaking an aseptic technique than the principles.

4.5 | Competency

Six observational studies reported upon nursing students' competency (Cebeci et al., 2015; Gonzalez & Sole, 2014; Mackey et al., 2014; Rush et al., 2014; Uysal, 2016; Watts et al., 2009). Five studies identified errors or breaches in aseptic technique made by students, but errors were reported differently (Cebeci et al., 2015; Gonzalez & Sole, 2014; Mackey et al., 2014; Uysal, 2016; Watts et al., 2009). In Watts et al.'s (2009) descriptive study, evaluating nursing students' ($n = 86$) self-assessment of videotaped performance of aseptic technique during a wound dressing, educators identified 2–3 times higher the number of breaches in aseptic technique than first-year students. First-year students were also reported to breach aseptic technique when undertaking wound dressings by third-year nursing students ($n = 15$) in Mackey et al.'s (2014) qualitative study exploring their experience of being a simulated patient as illustrated by the following quote:

> "when these year one students came in and did the wound dressing for us I felt pretty scared, didn't want to be their patient because of all their non-aseptic technique and its really very bad"

In Watts et al.'s (2009) study, the majority of breaks in aseptic technique were made by students when setting up the sterile field (54%) and cleaning the wound (34%). Similar breaches in aseptic technique made by students were reported in Gonzalez and Soles' (2014) descriptive study, assessing nursing students' ($n = 13$) competency in urinary catheterization. Seventy-seven percent of students breached aseptic technique, with the majority 89.4% occurring when cleaning the urethral meatus.

Two studies reported breaches in aseptic technique to be the most common error made by students during medication administration (Cebeci et al., 2015; Uysal, 2016). In Cebeci et al.'s (2015) cross-sectional survey of nursing student's (n = 324) medication errors, deviation from aseptic technique was the most common error reported by students in 23.8% of cases. Similarly, in Uysal's (2016) retrospective, analytical study of nursing students' practical skills examination papers (n = 605), failure to adhere to the principles of asepsis was the most common mistake (21.3%, 18.9%, 45.3%) over a three-year period. The number of breaches in aseptic technique reported during different clinical procedures varied from 7 to 96 as reported by students and facilitators across studies (Cebeci et al.'s 2015; Uysal, 2016; Watts et al., 2009). Only Gonzalez and Sole's (2014) reported the total number of students, 73% (10/13) breaching aseptic technique as reported by educators.

In Rush et al.'s (2014) cross-sectional survey of first-year nursing students' (n = 180) experience of an Objective Structured Clinical Assessment (OSCA), 89.4% passed the aseptic technique OSCA at the first attempt. Similar high performance in Objective Structured Clinical Examinations (OSCEs) (77.56–91.67) (Rush et al., 2014; Uysal, 2016; Wright et al., 2008) or skill tests (91.7%–100%) (Jeffries et al., 2002; Zhang, 2015) by students was reported across other observational studies and intervention studies reported under objective 1.

4.6 | Confidence

Two observational studies reported students' confidence to undertake aseptic technique to be moderate to high (Carter et al., 2017; Gonzalez & Sole, 2014). In Gonzalez and Sole's (2014) descriptive study, nursing students' (n = 13) mean confidence was 3.6 on a 5-point scale, suggesting moderate confidence in their ability to perform urinary catheterization in the simulated environment despite the majority of students breaching aseptic technique. Likewise, in Carter et al.'s (2017) online survey of nursing students (n = 3678) described previously, only 12% reported not feeling confident in using aseptic technique when inserting and maintaining invasive devices.

4.7 | Objective 3: Explore students', educators' and qualified nurses' perceptions of education and training in aseptic technique in undergraduate nursing programmes

Eleven observational studies, three cross-sectional surveys; one descriptive study, one analytical study and six qualitative studies, focused upon students', educators' and qualified nurses' perceptions of the effectiveness of teaching and assessment of aseptic technique (see Table 3). Ten studies explored nursing students' perceptions/experiences of learning aseptic technique in clinical placements (Carter et al., 2017; Geller et al., 2010; Gould & Drey, 2013; Ribu et al.,2003; Stayt & Merriman, 2013; Ward, 2010, 2011, 2012a, 2012b; Westphal et al., 2014). One qualitative study explored infection prevention nurses' perceptions of aseptic technique education and training (Cox et al., 2014). Three qualitative studies also explored mentors' perceptions (Ward, 2011, 2012, 2012a). Half of these studies (n = 6) originated from the UK. Three themes emerged and included observing good and poor role models, congruence between university teaching and clinical practice, and variations in opportunity for learning and assessment.

4.8 | Observing good and poor role models

The first theme was observing good and poor role models. Nursing students reported observing both good and poor aseptic technique practices in different clinical placements (Carter et al., 2017; Geller et al., 2010; Gould & Drey, 2013; Ribu et al., 2003; Ward, 2010, 2012a, 2012b; Westphal et al., 2014). Opinions about aseptic technique practices in community settings were conflicting with criticisms of both nursing and medical practice (Gould & Drey, 2013; Ward, 2010). In Ward's (2010) qualitative study, nursing students (n = 40) some nurses were seen to have poor practices: "I saw someone…they re-used the stitch cutter on someone else" while community nurses were reported to have good practices: "district nurses were particularly good…do it in a proper aseptic non-touch manner". In comparison, nursing students (n = 488) in Gould and Drey's (2013) survey were highly critical of aseptic technique practices in community and long-stay settings.

In three studies, nursing students reported observing qualified nurses breaching aseptic technique by contaminating susceptible sites, equipment and the sterile field during different invasive procedures (Geller et al., 2010; Ribu et al., 2003; Westphal et al., 2014). In Ribu et al.'s (2003) descriptive study, nursing students (n = 30) reported only 60% of nurses washed their hands before and after wound dressing ulcers, and three incidences of breaches in aseptic technique. Similarly, in Westphal et al.'s (2014) qualitative study, analyzing student's (n = 96) assignments, students identified three incidences of breaches in aseptic technique during the insertion of invasive devices by qualified nurses, one incidence is captured in the following quote: "the nurse crossed her arm over the sterile field and used her non-sterile hand to adjust the gloves… and allowed the urinary catheter to fall against the patient's leg and continued to insert it". Students (n = 500) in Geller et al.'s (2010) retrospective, analytical study reported 17.2% breaks in aseptic technique observed in clinical practice over a three-year period, but were trained as part of their programme to report infection control hazards or near misses.

4.9 | Congruence between university teaching and clinical practice

The second theme described congruence between university teaching and clinical practice. Three studies provided conflicting findings of congruence between what is taught about aseptic technique in

university and what is observed in clinical practice (Carter et al., 2017; Cox et al., 2014; Ward 2011). In two qualitative studies, students (n = 31) and mentors (n = 32) (Ward 2011) and infection prevention nurses (n = 8) (Cox et al.'s 2014) reported conflicting practices and a theory-practice gap in aseptic technique as illustrated by the following quotes from infection prevention nurses: "universities seem teach something different to what's happening on the ground" and "those basic aseptic techniques are just missing" and a student: "setting up an intravenous line aseptically am I doing it right? Am I doing it wrong". By contrast, in Carter et al.'s (2017) survey, 89% of students (n = 3768) reported agreement between what was taught in university and observed in clinical practice.

4.10 | Variations in opportunity for learning and assessment

The final theme was about variations in opportunity for learning and assessment. Two studies provided insight concerning students' perceptions of how aseptic technique was taught in university (Carter et al., 2017; Ward 2011). In Ward's (2011) qualitative study, mentors (n = 32) and students (n = 31) perceived small group teaching to be more effective for learning than large lectures. The findings of Carter et al.'s (2017) survey suggested wide variation in the type and duration of aseptic technique education that students received. These authors speculated that the nature of the educational experience might influence the ability and confidence to practice.

Two studies reported that students might have variable or limited opportunities to practice and be assessed in their ability to undertake aseptic technique in university and clinical placements (Stayt and Merriman 2013; Ward 2011). In Ward's (2011) qualitative study, mentors (n = 32) and students (n = 31) identified the need for assessment of aseptic technique as shown by the following student quote "someone actually coming out on the wards to assess us, test us…". In Stayt and Merriman's (2013) survey of nursing students' (n = 421) perceptions of skills development in placements, 44% and 63.1% of students reported sometimes or never having the opportunity to practice and for assessment, respectively.

5 | DISCUSSION

The aims of this review were met by adopting a mixed methods, systematic convergent segregated approach. Integrating synthesized qualitative and quantitative findings achieved a great understanding of undergraduate nursing students' education and training in aseptic technique. The literature requires further development to be able to draw any firm conclusions; however, the review findings indicate that teaching and assessment of aseptic technique in undergraduate nursing programmes could be improved. The different learning/teaching methods for aseptic technique demonstrated limited effectiveness upon nursing students' knowledge and competency. Studies reported nursing students' knowledge to be variable, and competency levels suboptimal, despite high pass rates in practical examinations, and high levels of confidence in students with regards to their ability to undertake an aseptic technique. Students' and qualified nurses perceived dissonance between what was taught in university and witnessed in clinical placements. Students reported wide variation in education and limited opportunity for practice and assessment in university and clinical placements.

The review findings should be viewed cautiously given the poor methodological quality of studies. Intervention studies were of low quality, single-site studies using small convenience samples of students with a high risk of selection and measurement bias as well as confounding factors. The heterogeneity of interventions was tested, and the use of different non-validated measurement tools made comparisons of outcomes across studies difficult. The methodological limitations of intervention studies impact confidence in the findings with regards to the effectiveness of different teaching/learning methods for aseptic technique, and therefore, findings need to be viewed cautiously before any changes to educational practices are made.

Observational studies were mostly small, single-site studies using small non-probability samples, increasing the risk of selection and response bias. Observational studies that recruited larger samples of students from different universities through membership of an organization, introduced sampling bias. Some survey response rates were low. There was a heavy reliance on students' self-reported knowledge and understanding, and their perceptions of teaching and assessment of aseptic technique, without validation or the perspective of others. Poor reporting and insufficient detail of the research setting, sample and data collection processes affected the rigour and credibility of observational studies. Students were at different stages of their programme and undertaking aseptic technique in different clinical procedures, which made it difficult to compare learning outcomes across studies. Little information was presented about the criteria used to assess students. Differences in reporting of students' breaches of aseptic technique made it difficult to compare findings across studies. While these methodological limitations undermine overall confidence in the findings of observational studies, they do indicate that nursing students' education and training in aseptic technique and knowledge and competence levels could be improved.

Nursing students' suboptimal knowledge and competency and inflated confidence in their aseptic technique skills, together with discrepancies between what is taught in the university and seen in clinical practice, are of major concern for patient safety (DoH 2019; WHO 2016a, 2016b). Plausible reasons for these review findings might be that teaching is impaired by the lack of agreement amongst educators over definitions, principles and the aim of aseptic technique, with educators having limited opportunity to update their knowledge and skills (Gould et al., 2018, 2021). There is some support for this in Hawker et al.'s (2020) survey findings, which identified inconsistency and inaccuracies in aseptic technique principles identified by educators and taught to students.

As far as the authors are aware, this is the first systematic review undertaken in this area. It exposes the lack of research in an area considered by policy-makers (DoH 2019; WHO 2016a, WHO 2016b) and educators (Gonzalez and Sole 2014; Stayt and Merriman 2013) as a key clinical skill. Only three studies included in the review had the primary aim of exploring nursing students' education and training in aseptic technique (Carter et al., 2017; Davey, 1997; Gonzalez and Sole, 2014). The remaining studies largely focused upon teaching/learning and assessment of different clinical procedures, requiring an aseptic technique. More important issues such as the lack of agreement over the aim, definitions and principles of aseptic technique and the impact of this in undergraduate nursing programmes have been overlooked.

It is recommended that policy-makers should as a matter of priority reach a consensus about an internationally agreed definition of aseptic technique and produce international guidelines for aseptic technique including the aim and underlying principles. Recommendations for education and practice are to ensure that practitioners and educators are regularly updated in aseptic technique and reinforce the underlying principles of asepsis when teaching students. Students should be also provided with greater opportunities for learning, practice and assessment of aseptic technique.

The findings of this review confirm that the evidence required to enhance undergraduate education and training in the sphere of aseptic technique is weak (WHO 2016a). The ambition of policy-makers, to improve aseptic technique practices by enhancing education and training, will not be realized until there is greater investment in more robust research (DoH 2019; WHO 2016a). Robust intervention studies investigating the effectiveness of different teaching/learning methods with larger sample sizes and better outcome measures for competence, confidence and knowledge are required. Greater understanding is required of what and how nursing students are taught and assessed in aseptic technique in the university setting. Students' perceptions of the effectiveness of education and training have been widely explored in studies without gaining other perspectives. Nurse educators' opinions of the effectiveness of education and training have been overlooked. An in-depth case study exploring nursing students' education and training in aseptic technique, in both the university and clinical practice setting, from the multiple perspectives of educators, mentors, students and infection prevention and control nurses is recommended to address these gaps in understanding.

Further qualitative studies are needed to explore nursing students' understanding of aseptic technique. Only one much earlier study undertook an in-depth examination of nursing student's understanding of aseptic technique and deemed it to be poor (Davey 1997). Other studies either measured students' knowledge of when to apply an aseptic technique or accepted that students understood the meaning of aseptic technique without assessment (Carter et al., 2017; Ferreira Baptista et al., 2013; Mitchell et al., 2014; Simonetti et al., 2019). Nursing students need to know not only when to apply an aseptic technique, but also comprehend the principles of aseptic technique to ensure safe practice (NMC 2018).

6 | CONCLUSION

The findings of this systematic review suggest that education and training in aseptic technique could be improved, but should be viewed cautiously given the poor methodological quality of the studies. Although aseptic technique is a core skill with nursing students globally required to learn it, it has attracted very little research attention compared to other infection prevention practices such as hand hygiene. Suboptimal undergraduate nurse education and training in aseptic technique may impede the development of nursing students' knowledge, understanding and competency. Further research is required to explore how teaching and assessment of aseptic technique in undergraduate programmes might be enhanced.

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CONFLICT OF INTEREST

No conflict of interest has been declared by the author(s).

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

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