INTERNATIONAL JOURNAL OF ENVIRONMENTAL HEALTH RESEARCH
https://doi.org/10.1080/09603123.2021.1937580

Taylor & Francis
Taylor & Francis Group

REVIEW ARTICLE

OPEN ACCESS Check for updates

Teaching health care students hand hygiene theory and skills: a systematic review

Edward Purssell[a] and Dinah Gould[b]

[a]Little Havens Children's Hospice, Benfleet, UK, Essex; [b]Independent Consultant in Infection Control, London, UK

ABSTRACT

Hand hygiene is the cornerstone of infection prevention but is poorly undertaken and under-appreciated by medical, nursing, and other health care students. This systematic review aimed to identify and describe strategies used to teach the theory and practice of hand hygiene, determine impact on knowledge and practice, and identify need for future education and research. Ten studies met the criteria for review. Health care students' theoretical knowledge of hand hygiene and their ability to practise are suboptimal and should be improved before they have contact with vulnerable patients. Educational input can increase knowledge and practice but the methodological heterogeneity of the studies and lack of rigour make it impossible to determine which interventions are most likely to be successful. The literature provides little evidence upon which to base educational practice in this area. There is a need for multi-centred longitudinal studies to measure effectiveness of teaching methods over time.

ARTICLE HISTORY
Received 3 March 2021
Accepted 28 May 2021

KEYWORDS
Aseptic technique; eduction; teaching

Introduction

Patients receiving health care are exposed to the risk of infection (World Health Organization 2009). Healthcare-associated infection is the most common untoward event reported among inpatients, resulting in considerable morbidity, mortality, distress, and decreased satisfaction with health care (National Institute for Health and Care Excellence 2018). It also results in increased costs, and treatment hastens the development of antimicrobial resistance. Exposure to micro-organisms able to cause nosocomial infection has also been documented in outpatient settings (Bingham et al. 2016). Community-associated infections pose an additional threat. Norovirus (Johnston et al. 2007), influenza (Salgado et al. 2002) and SARS-COV-2 (Morawaska et al. 2020) are among the many community-acquired pathogens transmissible in hospital. Infection control generally, and hand hygiene specifically, is therefore a vital part of maintaining the safety of patient and staff.

Hand hygiene can break the chain of infection, it is accepted as the cornerstone of all programmes of infection prevention and control (Pittet et al. 2006) and contributes to reducing the risks of antimicrobial resistance (Courtenay et al. 2019). The World Health Organization (World Health Organization 2009) has issued comprehensive guidelines and educational materials to promote hand hygiene. These recognise key points during patient care when hand hygiene should be undertaken based on "Five Moments for Hand Hygiene" (Sax et al. 2007). They also recommend a six-step technique to ensure that all hand surfaces receive adequate contact with the cleansing agent (Ayliffe et al. 1978). The World Health Organization (2009) guidelines have been widely disseminated and uptake is reported to be good (Allegranzi et al. 2013). Campaigns to promote hand hygiene can increase adherence to hand hygiene protocols (Gould et al. 2017) and in many countries health

CONTACT Edward Purssell edward.purssell@outlook.com Little Haven's Children's Hospice, Benfleet, UK

workers are required to undertake annual updating to sustain good practice. The same educational materials are suitable for medical, nursing and other students enrolled on health-related courses (World Health Organization 2009) but poor knowledge and performance are reported (Sundal et al. 2017; Kingston et al. 2018; Qasmi et al. 2018; Baier et al. 2020) and students consider hand hygiene less interesting than other curricular topics (Kaur et al. 2014). Even when adequate theoretical knowledge is displayed, students seem unable or unwilling to implement learning into clinical practice (Zimmerman et al. 2020). Heavy workload, poor access to alcohol-based handrubs and sinks, lack of effective role models and perceived need to model practice according to local custom, including a reticence to challenge those in more senior positions, and overconfidence in ones own ability have all been suggested as factors reducing students' adherence to hand hygiene protocols (Barrett and Randle 2008; Cresswell and Monrouxe 2018; Bushuven et al. 2020; Zimmerman et al. 2020).

Furthermore, there are a variety of similar terms, including antiseptic handwashing, hand antisepsis/decontamination/degerming, handwashing, hand cleansing, hand disinfection, and hygienic handwash, which may cause further confusion (World Health Organization 2009).

Health care students spend a significant part of their programmes delivering patient care in clinical settings, often from an early stage in their course and frequently move between different clinical areas, placing them at increased risk of acquiring and transmitting infection. Lack of knowledge, suboptimal performance, and poor motivation to undertake hand hygiene could increase infection risks. We undertook a systematic review of the literature to identify and describe strategies used to teach health care students the theory and practice of hand hygiene and determine its impact on knowledge and skills.

Materials and methods

All studies evaluating the impact of interventions to increase knowledge and practice and promote positive attitudes to hand hygiene were eligible to be included regardless of study design. Studies were eligible irrespective of whether hand hygiene was the main focus or was considered as part of a clinical procedure (e.g. dressing change) providing the necessary data could be analysed separately. Educational initiatives not based on WHO hand hygiene guidelines (World Health Organization 2009) were excluded because they do not reflect current policy and practice. There were no language restrictions. Pubmed and Embase were searched using the terms hand hygiene AND (teaching OR education) AND student (see supplementary file for full details); and hand searching of reference lists and an internet search was also conducted. Quantitative data were extracted by two authors, and forest plots drawn in the R package meta (Balduzzi et al. 2019); qualitative results were independently extracted and compared.

Results

The searches identified 476 papers (see supplementary file). Of these 13 appeared potentially eligible for inclusion. On detailed reading three were rejected. One study (Bloomfield et al. 2010) pre-dated publication of the World Health Organization (2009). Two (Fisher et al. 2010; Weber et al. 2016) were concerned with surgical scrubbing. Ten studies therefore met the review criteria. Two members of the research team read each paper to decide whether it met the inclusion criteria and undertook data extraction. Third party arbitration was available in cases of disagreement but was not necessary.

Included studies

Three studies were undertaken in the Far East (Fisher et al. 2010; Salmon et al. 2013; Suen et al. 2019), one in Germany (Scheithauer et al. 2012), two in the United States (Lavigne and Curran

2015; Kornicki and Miller 2016) and one each in Australia (Kaur et al. 2017), India (Chauhan et al. 2019), Finland (Korhonen et al. 2019) and Turkey (Kısacık et al. 2021). Four studies were undertaken with medical students (Fisher et al. 2010; Scheithauer et al. 2012; Kaur et al. 2017; Chauhan et al. 2019), five with nursing students, (Salmon et al. 2013; Kornicki and Miller 2016, Korhonen, Suen et al. 2019; Kısacık et al. 2021), and one with pharmacy students (Lavigne and Curran 2015). Some studies recruited students at the earliest possible stage in their course (Kornicki and Miller 2016), others recruited more senior students (Fisher et al. 2010), and some research teams included students at different points in their studies (Scheithauer et al. 2012).

Fisher et al. (2010) evaluated medical students' satisfaction with an educational initiative consisting of training then contributing to the work of hand hygiene audit teams on wards. There were no baseline data. In the other initiatives outcome measures included knowledge, excellence of practice, attitudes towards hand hygiene and satisfaction with the learning experience. Five publications reported uncontrolled before-and-after study designs (Scheithauer et al. 2012; Salmon et al. 2013; Lavigne and Curran 2015; Kaur et al. 2017; Chauhan et al. 2019). One reported a non-randomised trial (Korhonen et al. 2019). Three publications reported randomised controlled trials (Kornicki and Miller 2016; Suen et al. 2019; Kısacık et al. 2021) and of these one was double-blinded (Kısacık et al. 2021), one was a single-blinded trial in which data analysts were unaware of students' group allocation (Suen et al. 2019) and in the third trial details of blinding were not apparent (Kornicki and Miller 2016). Students recruited to the experimental groups in the trials received additional teaching and practice. Those in control groups received usual education for hand hygiene. In the other studies the novel education was received in addition to usual practice by student volunteers.

There was a move away from conventional, didactic teaching methods, fuelled by awareness of the need to avoid over-burdening an already full curriculum and need to engage students' interest. In five studies infection prevention teams helped develop the intervention (Fisher et al. 2010; Scheithauer et al. 2012; Salmon et al. 2013; Kornicki and Miller 2016; Chauhan et al. 2019). Two studies were described by the authors as feasibility studies intended to preface larger scale interventions (Fisher et al. 2010; Kornicki and Miller 2016).

Three initiatives provided input on both Five Moments (when to cleanse hands) and the six-step hand hygiene technique (Salmon et al. 2013; Lavigne and Curran 2015; Chauhan et al. 2019). Of the remainder, three initiatives concentrated on technique (Kornicki and Miller 2016; Suen et al. 2019; Kısacık et al. 2021) and one on Five Moments (Fisher et al. 2010). Three other research teams did not describe content of the intervention in detail (Scheithauer et al. 2012; Kaur et al. 2017; Korhonen et al. 2019). In one study the intervention consisted of a training session followed by practical experience auditing hand hygiene in wards (Fisher et al. 2010). In four studies hand hygiene technique was demonstrated with an ultra-violet (UV) light box and fluorescent dye (Scheithauer et al. 2012; Kornicki and Miller 2016; Suen et al. 2019; Kısacık et al. 2021). In four studies theoretical and practical teaching by video were followed by practice in classroom settings without the use of UV technology (Salmon et al. 2013; Lavigne and Curran 2015; Chauhan et al. 2019; Korhonen et al. 2019). In one of these studies students additionally identified hand hygiene opportunities and adherence on video-taped clinical scenarios (Salmon et al. 2013). Scenario-based learning with small group discussion was used to augment lectures in one initiative (Kaur et al. 2017) and in another study students' hands were cultured before and after hand hygiene to provide further visual evidence of the impact of hand hygiene (Kornicki and Miller 2016). Sample sizes ranged from 52 (Suen et al. 2019) to 400 students (Salmon et al. 2013). In one initiative students were recruited from two universities (Korhonen et al. 2019). In a second study recruitment was from three schools of nursing (Salmon et al. 2013). The remaining studies all took place in a single centre. One initiative (Kaur et al. 2017) formed part of a much larger investigation in which the intervention was based on considerable pre-pilot work to establish the approach to teaching most likely to be effective and to be acceptable to students (Kaur et al. 2014).

Two research teams (Kornicki and Miller 2016; Kısacık et al. 2021) used a validated scale to assess students' attitudes to hand hygiene and employed a validated questionnaire to determine which areas of the hands escaped contact with the cleansing agent. The other research teams using UV technology undertook simple counts of missed areas (Scheithauer et al. 2012; Suen et al. 2019). Salmon et al. (2013) assessed students' practice in simulations and in clinical settings. In four studies practice was observed with simulated data in classroom settings (Lavigne and Curran 2015; Kaur et al. 2017; Chauhan et al. 2019; Korhonen et al. 2019). In the remaining studies performance, knowledge, and attitudes were assessed by self-report questionnaires designed for rapid completion, usually employing tick-box Likert scales developed especially for the study. In seven studies knowledge and practice were assessed immediately after delivering the intervention or within 4–6 weeks (Fisher et al. 2010; Scheithauer et al. 2012; Lavigne and Curran 2015; Kornicki and Miller 2016; Chauhan et al. 2019; Suen et al. 2019; Kısacık et al. 2021). In one study follow-up data were collected 6 months post-intervention (Kaur et al. 2017) and in two studies monitoring continued over 2 years (Salmon et al. 2013; Korhonen et al. 2019). Knowledge and practice were generally low at baseline and in the non-randomised trial significantly greater knowledge was documented for students in the experimental group compared to the controls (Korhonen et al. 2019).

Post-intervention improvement in knowledge, practice and positive attitudes towards hand hygiene were reported in all publications except for the randomised controlled trial undertaken by Kornicki and Miller (2016). The students in this study were newly enrolled in the first year of the course. Lack of improvement in hand hygiene technique at follow-up was attributed to their high levels of anxiety and lack of familiarity with university IT systems. Ability to concentrate on the simulated exercise was compromised and they are reported difficulty responding to negatively-worded items on the data collection questionnaire.

Outcomes from the controlled trials that could reasonably be turned into standardised mean differences are shown in the forest plot in Figure 1. There was no attempt to pool results because the resultant pooled estimate would have no intuitive meaning, but there was significant heterogeneity between outcomes ($Q = 73.49$, $df = 4$, $p < 0.001$, $I^2 = 94.6\%$). Not all outcomes were improved by the interventions tested, although in most cases any change was not statistically significant; apart from the increase in hand hygiene skills in the study by Kısacık et al. (2021). The very wide confidence intervals are reflective of the small sample sizes of these studies. Perhaps of most interest here is the difference in length of hand hygiene after clinical and academic training. Another study found no significant difference between groups on knowledge (Kornicki and Miller 2016).

Data from the before and after studies are shown in Figure 2. Although most outcomes showed an increase after the intervention, the limitations associated with before and after studies on the same participants make the clinical significance of this harder to judge. Perhaps of particular interest is the finding that after the intervention, there was increased awareness that some clinical situations might make hand hygiene more difficult (Chauhan et al. 2019). Although there were differences in outcomes there was less heterogeneity than the comparative studies ($Q = 14.75$, $df = 6$, $p = 0.022$, $I^2 = = 59.3\%$), and the larger sample sizes in some of the studies has led to a more precise estimate of the population value.

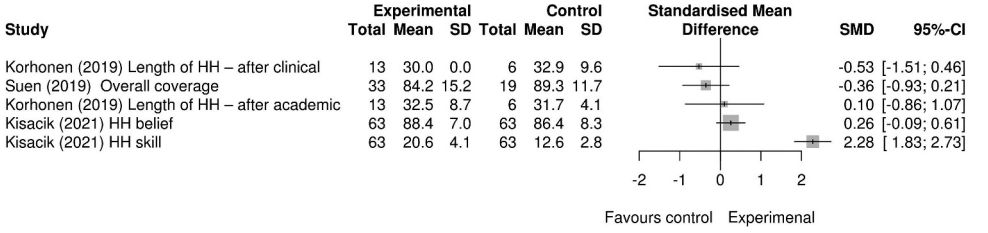

Figure 1. Summary statistics from controlled studies.

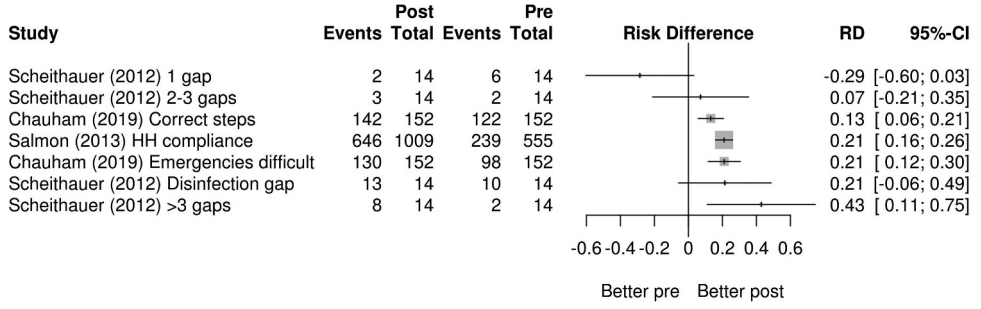

Figure 2. Summary statistics from before and after studies.

Discussion

Despite the importance of the topic, ours appears to be the first systematic review to explore how health care students are taught about hand hygiene. This lack of attention is surprising given the emphasis placed on hand hygiene globally (World Health Organization 2009; Allegranzi et al. 2013; Gould et al. 2017), its contribution to the containment of antimicrobial resistance (Courtenay et al. 2019) and the need to update clinicians regularly to ensure that knowledge, skills, and motivation are sustained (Drey et al 2020). There appears to be lack of appreciation of the risks associated with students' suboptimal hand hygiene performance and failure to appreciate that they are the future role models and custodians of good clinical practice. The included studies reported the low levels of baseline knowledge and performance previously identified in cross-sectional surveys (Sundal et al. 2017; Kingston et al. 2018; Qasmi et al. 2018; Baier et al. 2020; Zimmerman et al. 2020).

Considerable methodological heterogeneity was apparent in the ten included studies. The initiatives were reported from seven countries and involved different occupational groups and students at different stages in the course. Approaches to assessment and data collection varied. There was considerable variability in content and approach to education. Methodological quality of the studies was disappointing; with a large number being uncontrolled before and after studies and with very small numbers of participants. Reliance was placed on data drawn from single centres and small samples, jeopardising external validity while numerous threats to internal validity were also identified. Most initiatives were either uncontrolled or controlled inadequately. Participation was usually voluntary, recruitment was challenging in some cases, and in others retention was problematic. Even where whole cohorts were invited to participate, it may be that only those who were motivated to learn participated; it is impossible to know about the relevant motivations of those who did, and did not participate. Heavy reliance was placed on the use of self-reported scales to document practice although student report is a poor indicator of students' hand hygiene performance: over-confidence and tendency to inflate adherence are both well-established (Cole 2009; Bushuven et al. 2020). A scale to assess student health workers' knowledge and attitudes to hand hygiene has been developed (Van De Mortel 2009) and validated (Karadag et al. 2016) but was adopted by only two research teams and of these, one reported that students encountered difficulties with completion. The other research teams employed scales developed in-house with scant evidence of validation. Of the four studies reporting use of UV technology to assess hand hygiene technique, only two employed a validated instrument to document thoroughness. This is disappointing, bearing in mind that educational institutions profess to champion evidence-based practice; but appear unable to do so themselves.

The studies are insufficiently robust to be used as evidence to inform best educational policy and practice but collectively the authors highlight problems that need to be tackled immediately. These could be addressed without further research. As there is little doubt that students' poor hand hygiene performance can contribute to cross-infection, they should receive regular updates in the same way as qualified staff and be included in regular audits with performance feedback if they are

present on wards when audits are taking place. The barriers that students encounter in relation to hand hygiene (Barrett and Randle 2008; Cresswell and Monrouxe 2018; Zimmerman et al. 2020) are the same as those reported by qualified staff and if addressed at institutional level, would do much to promote hand hygiene adherence in qualified staff and those training (World Health Organization 2009).

Future research to explore the most effective ways of delivering hand hygiene education need to be more robust in terms of study design, approaches to sampling and assessment of performance. The studies reviewed represent practice in individual institutions. The United Kingdom and many other countries lack centrally mandated methods of teaching hand hygiene, probably leading to wide variation in methods. Small, single-centre studies provide an imprecise estimate of the effect of these interventions in the population and may actually measure the quality of educational excellence in the institution rather than the intervention *per se*. A multi-centred approach is needed to overcome this limitation. There is a need for future studies to be more comprehensive. Students need to know both when and how to undertake hand hygiene, with opportunity to practise safely in simulations early in the course before they begin to practice in busy wards and departments. Sound understanding of the theory underpinning hand hygiene and experience in simulations would allow them to develop the confidence necessary to challenge poor practice witnessed in clinical settings and to request better resources to undertake hand hygiene. The educational interventions employed had moved away from didactic teaching to more student-centred methods but none harnessed the potential of newer technology such as electronic hand hygiene monitoring systems (Srigley et al. 2015) and "gaming" programmes (Higgins and Hannan 2013) to promote hand hygiene adherence although evaluations with qualified practitioners are encouraging. However, evaluations of teaching often concentrates on student satisfaction rather than the effectiveness of the teaching. Further work could be undertaken to explore their potential with students in simulated wards. In particular it would be useful to understand the relative motivations of those who do, and do not perform hand hygiene in such situations. None of the research teams reported use of objective structured clinical examinations (OSCEs) although they are used routinely in medical and nursing education.

A recent review examining behavioural interventions to improve hand hygiene has noted a change in emphasis from direct measures such as providing alcohol hand-rub towards more motivational techniques. These include goal setting and planning, comparing individual and group behaviour, and provision of feedback (Sands et al. 2020). It may be that newer educational interventions are making a similar move from didactic teaching to a more reflective approach.

When considering educational interventions it is important to consider cognitive learning, psychomotor, and affective skills (World Health Organization 2009); and to work towards including the higher levels of a taxonomy such as that by Bloom which deal with synthesis and analysis; as well as the lower levels of knowledge, comprehension and application (Adams 2015). However, as with the behavioural change interventions, unpicking and identifying each of these in an individual educational intervention which forms part of a broader educational programme can be challenging (Sands et al. 2020). A more reflective approach might also elevate patient safety to the same level as that of personal protection, which may for some be a more compelling force for change (Borg et al. 2009).

Patient safety concerns are common, one study suggesting that 62% of doctors and 80% of nurses reported at least one safety concern in the last four weeks (Schwappach and Richard 2018). However, speaking-up in case of poor hand hygiene may be rare, particularly if there is a hierarchical imbalance (Bushuven et al. 2020). The negative impact of hierarchies on voicing safety concerns has been noted more broadly, along with the expected behaviours and socialisation of nurses within the care team (Morrow et al. 2016).

The main limitation of this review is the risk that potentially eligible studies were not identified by the searches. No research terms to identify the required publications exist. It is possible that in some organisations much of the input on hand hygiene is taught in relation to specific clinical procedures. None of the studies picked up in the searches described interventions taught in this

way, perhaps explaining why OSCEs were not mentioned. There may be locally held audit-data that could be of use, but which is not publicly available.

Published research in this area comes mainly from high income countries with advanced educational and health services. Although hand hygiene is important in all settings, benefits of its promotion might be most keenly felt in lower income countries where it has been shown to be among the most cost-effective public health interventions (The Global Handwashing Partnership. Economic Impact. 2021). Further research in these setting would be of immense value.

Conclusion

Health care students' theoretical knowledge of hand hygiene and their ability to practise may be suboptimal and it is important to ensure that they are competent before they have contact with vulnerable patients. The review indicates that educational input can increase knowledge and improve practice but the methodological heterogeneity of the studies and lack of rigour make it impossible to determine which interventions are most likely to be successful. Nevertheless, the review was able to highlight areas where improvements in practice could be made. The complexity of teaching a seemingly simple task needs to be addressed more rigorously, in particular the structural and hierarchical aspects, and the multidisciplinary nature of the subject which includes all of those working in healthcare settings.

Competing interest statement

There are no relevant financial or non-financial competing interests to report.

Funding

This project received no external funding.

References

Adams NE. 2015. Bloom's taxonomy of cognitive learning objectives. J Med Libr Assoc. 103(3):152–153. doi:10.3163/1536-5050.103.3.010.

Allegranzi B, Gayet-Ageron A, Damani N, Bengaly L, McLaws ML, Moro L, Memish Z, Urroz O, Richet H, Storr J, et al. 2013. Global implementation of WHO's multimodal strategy for improvement of hand hygiene: a quasi-experimental study. The Lancet Infectious Diseases. 13(10):843–851. doi:10.1016/S1473-3099(13)70163-4.

Ayliffe GAJ, Babb JR, Quoraishi S. 1978. A test for hygienic hand disinfection. Journal of Clinical Pathology. 31 (10):923–928. doi:10.1136/jcp.31.10.923.

Baier C, Albrecht UV, Ebadi E, Vonberg R, Schilke R. 2020. Knowledge about hand hygiene in the Generation Z: a questionnaire-based survey among dental students, trainee nurses and medical technical assistants in training. American Journal of Infection Control. 48(6):708–712. doi:10.1016/j.ajic.2020.02.002.

Balduzzi S, Rücker G, Schwarzer G. 2019. How to perform a meta-analysis with R: a practical tutorial. Evid Based Mental Health. 22(4):153–160. doi:10.1136/ebmental-2019-300117.

Barrett R, Randle J. 2008. Hand hygiene practices: nursing students' perceptions. J Clin Nurs. 17:1851–1857. doi:10.1111/j.1365-2702.2007.02215.x.

Bingham J, Abell G, Kienast L, Lerner L, Matuschek B, Mullins W, Parker A, Reynolds N, Salisbury D, Seidel J, et al. 2016. Health worker hand contamination at critical moments in outpatient care. Am J Infect Control. 44:1198–1202. doi:10.1016/j.ajic.2016.04.208.

Bloomfield S, Roberts J, While A. 2010. The effect of computer-assisted learning versus conventional teaching methods on the acquisition and retention of handwashing theory and skills in pre-qualification nursing students: a randomised controlled trial. Internat J Nurs Stud. 47:287–294. doi:10.1016/j.ijnurstu.2009.08.003.

Borg MA, Benbachir M, Cookson BD, Redjeb SB, Elnasser Z, Rasslan O, Gür D, Daoud Z, Bagatzouni DP. 2009. Self-protection as a driver for hand hygiene among healthcare workers. Infect Control Hosp Epidemiol. 30(6):578–580. doi:10.1086/597511.

Bushuven S, Dettenkofer M, Sippel S, Koenig S, Bushuven S, Schneider-Brachert W. 2020. Speaking up behavior and cognitive bias in hand hygiene: competences of German- speaking medical students. PLoS ONE. 15(9):e0239444. doi:10.1371/journal.pone.0239444.

Chauhan K, Pandey A, Thakuria B. 2019. Hand hygiene: an educational intervention targeting grass root level. J Infect Pub Health. 12:419–423. doi:10.1016/j.jiph.2018.12.014.

Cole M. 2009. Exploring the hand hygiene competence of student nurses: a flawed self-assessment. Nurs Ed Today. 29:380–388. doi:10.1016/j.nedt.2008.10.010.

Courtenay M, CastroSanchez E, Fitzpatrick M, Gallagher R, Lim R, Morris G. 2019. Tackling antimicrobial resistance 20192024 – the UK's five year national action plan. J Hosp Infect. 101:426–427. doi:10.1016/j.jhin.2019.02.019.

Cresswell P, Monrouxe LV. 2018. And you'll suddenly realise 'I've not washed my hands.: medical students', junior doctors' and medical educators' narratives of hand hygiene behaviours. BMJ Open. 8(3):e018156. doi:10.1136/bmjopen-2017-018156.

Drey N, Gould D, Purssell E, Chudleigh J, Moralejo D, Gallagher R, Jeanes A, Wigglesworth N, Pittet D. 2020. Applying thematic synthesis to interpretation and commentary in epidemiological studies: identifying what contributes to successful interventions to promote hand hygiene in patient care. BMJ Qual Saf. 29(9):756–763. https://doi.org/10.1136/bmjqs-2019-009833

Fisher D, Pereira L, Ng TM, Patlovitch K, Teo F, Hsu LY. 2010. Teaching hand hygiene to medical students using a hands-on approach. J Hosp Infect. 76:86–87. doi:10.1016/j.jhin.2010.04.007.

Gould DJ, Moralejo D, Drey NS, Chudleigh J, Taljaard M 2017. Interventions to improve hand hygiene compliance in patient care (second update). Cochrane Database of Systematic Reviews Cochrane Database of Systematic Reviews. 9:Art.No. CD005186. 10.1002/14651858.CD005186.pub4.

Higgins A, Hannan MM. 2013. Improved hand hygiene technique and adherence in healthcare workers using gaming technology. J Hosp Infect. 84:32–37. doi:10.1016/j.jhin.2013.02.004.

Johnston C, Qui H, Ticehurst J, Dickson C, Rosenbaum P, Lawson P, Stokes AB, Lowenstein CJ, Kaminsky M, Cogrove SE, et al. 2007. Outbreak management and implications of a nosocomial norovirus outbreak. Clin Infect Dis. 45:534–540. doi:10.1086/520666.

Karadag M, Yıldırım N, Iseri OP. 2016. The validity and reliability study of hand hygiene belief scale and hand hygiene practices inventory. Cukurova Med J. 41:271–284.

Kaur R, Razee H, Seale H. 2014. Facilitators and barriers around teaching concepts of hand hygiene to undergraduate medical students. Am J Infect Control. 88:28–33.

Kaur R, Razee H, Seale H. 2017. Setting the right foundations: improving the approach used to teach concepts of hand hygiene to medical students. J Hosp Infect. 95:355–358. doi:10.1016/j.jhin.2017.01.006.

Kingston L, O'Connell NH, Dunne CP. 2018. A comparative study of hand hygiene and alcohol-based hand rub use among Irish nursing and medical students. Nurs Ed Today. 63:112–118. doi:10.1016/j.nedt.2018.01.022.

Kısacık OG, Cig˘erci Y, Günes U. 2021. Impact of the fluorescent concretization intervention on effectiveness of hand hygiene in nursing students: a randomized controlled study. Nurs Ed Today. 97:104719. doi:10.1016/j.nedt.2020.104719.

Korhonen A, Vuori A, Lukkari A, Laitinen A, Perala M, Koskela T, Polkki T. 2019. Increasing nursing students' knowledge of evidence-based hand hygiene: a quasi-experimental study. Nurs Ed Today. 35:104–110.

Kornicki T, Miller E. 2016. Use of a simulation intervention to examine differences in nursing students' hand hygiene knowledge, beliefs, and behaviors. Nurs Ed Today. 45:96–101. doi:10.1016/j.nedt.2016.06.022.

Lavigne JE, Curran KM. 2015. Teaching the world health organization's how to handrub and five moments for hand hygiene in a health care delivery course at a new school of pharmacy. Curr Pharm Teach Learn. 7:207–213. doi:10.1016/j.cptl.2014.11.011.

Morawska L, Tang JW, Bahnfleth W, Bluyssen PM, Boerstra A, Buonanno G, Cao J, Dancer S, Floto A, Franchimon F, et al. 2020. How can airborne transmission of COVID-19 indoors be minimised? Environment International. 142:105832. https://doi.org/10.1016/j.envint.2020.105832

Morrow KJ, Gustavson AM, Jones J. 2016. Speaking up behaviours (safety voices) of healthcare workers: a metasynthesis of qualitative research studies. Int J Nurs Stud. 64:42–51. doi:10.1016/j.ijnurstu.2016.09.014.

National Institute for Health and Care Excellence. 2018. Healthcare associated infections: prevention and control in primary and community care (updated 2017). London: National Institute for Health and Care Excellence. www.nice.org.uk/guidance/cg139 .

Pittet D, Allegranzi B, Sax H, Dharan S, Pessoa-Silva CL, Donaldson L, Boyce J. 2006. Evidence-based model for hand transmission during patient care and the role of improved practices. Lancet Infect Dis. 6:641–652. doi:10.1016/S1473-3099(06)70600-4.

Qasmi SA, Mahmood SM, Iftikhar HY, Pirzada S. 2018. Guiding hand hygiene interventions among future healthcare workers: implications of knowledge, attitudes and social influences. Am J Infect Control. 46:1026–1031. doi:10.1016/j.ajic.2018.02.019.

Salgado CD, Farr B, Hall K, Hayden F. 2002. Influenza in the acute hospital setting. Lancet Infect Dis. 2:145–155. doi:10.1016/S1473-3099(02)00221-9.

Salmon S, Bei Wang X, Seetoh T, Lee SY, Fisher D. 2013. A novel approach to improve hand hygiene compliance in student nurses. Antimicob Res Infect Control. 2:16. doi:10.1186/2047-2994-2-16

Sands M, Aiken AM, Cumming O, Aunger R. 2020. The effect of behavioural interventions targeting hand hygiene practices among nurses in high-income hospital settings: a systematic review. Public Health Rev. 41(1):29. doi:10.1186/s40985-020-00141-6.

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. Infect Control Hosp Epidemiol. 67:9–21.

Scheithauer S, Haefner H, Schwanz T, Lopez-Gonzalez L, Bank C, Schulze-Röbbecke R, Weishoff-Houben M, Lemmen SW. 2012. Hand hygiene in medical students: performance, education and knowledge. Int J Hyg Environ Health. 215(5):536–539. doi:10.1016/j.ijheh.2012.02.009.

Schwappach D, Richard A. 2018. Speak up-related climate and its association with healthcare workers' speaking up and withholding voice behaviours: a cross-sectional survey in Switzerland. BMJ Qual Saf. 27(10):827–835. doi:10.1136/bmjqs-2017-007388.

Srigley JA, Gardam M, Fernie G, Lightfoot D, Lebovic G, Muller MP. 2015. Hand hygiene monitoring: a systematic review of efficacy. J Hosp Infect. 89:51–60. doi:10.1016/j.jhin.2014.10.005.

Suen LKP, Wong JWS, Lo KYK, Lai TKH. 2019. The use of hand scanner to enhance hand hygiene practice among nursing students: a single-blinded feasibility study. Nurs Ed Today. 76:137–147. doi:10.1016/j.nedt.2019.01.013.

Sundal JS, Aune, . AG, Stovig E, Aasland JK, Fjeldsaeter KL, Torjuul K. 2017. The hand hygiene compliance of student nurses during clinical placements. J Clin Nurs. 26:4646–4653. doi:10.1111/jocn.13811.

The Global Handwashing Partnership. Economic Impact. 2021. [accessed 2021 May 21]. https://globalhandwashing.org/about-handwashing/why-handwashing/economic-impact/ .

Van De Mortel TF. 2009. Development of a questionnaire to assess health care students' hand hygiene knowledge, beliefs and practices. Aust J Adv Nurs. 26:9–16.

Weber U, Constantinescu MA, Woermann. U, Schmitz F, Schnabel K. 2016. Video-based instructions for surgical hand disinfection as a replacement for conventional tuition? A randomised, blind comparative study. J Med Educ. 33:1–13.

World Health Organization. WHO guidelines on hand hygiene in healthcare, 2009. http://whqlibdoc.who.int/publications/2009/9789241597906_eng.pdf.2009. Accessed 2021 1 2

Zimmerman P-AP, Sladdin I, Shaban RZ, Gilbert J, Brown L. 2020. Factors influencing hand hygiene practice of nursing students: A descriptive, mixed-methods study. Nurse Educ Pract. 44:102746. https://doi.org/10.1016/j.nepr.2020.102746