**Title:** Educational interventions to improve compliance with disinfection practices of non-critical portable medical equipment: A systematic review

**Running Title:** Education for LLD of PME

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**SUPPLEMENT**

**Search Strategies**

**Database:**  
Ovid MEDLINE(R) Epub Ahead of Print, In-Process & Other Non-Indexed Citations, Ovid MEDLINE(R) Daily, Ovid MEDLINE and Versions(R) 1946 to Present

|  |  |
| --- | --- |
| **#** | **Query** |
| 1 | (Disinfect\* or clean or cleaning or "infection control" or decontaminat\* or "cross transmission" or "cross contamination" or hygiene).ti,ab. |
| 2 | Disinfection/ |
| 3 | Infection Control/mt [Methods] |
| 4 | Cross Infection/pc [Prevention & Control] |
| 5 | 1 or 2 or 3 or 4 |
| 6 | ((Portable or noncritical or "non critical" or "point of care" or mobile) adj2 (equipment or radiograph or ultrasound or "medical device\*")).ti,ab. |
| 7 | (Stethoscope\* or "blood pressure cuff\*" or " sphygmomanometer cuff\*" or "surface ultrasound\*" or "ultrasound probe\*" or "ultrasound transducer\*" or glucometer\* or "pulse oximeter\*" or defibrillator\* or thermometer\* or "vital signs machine\*" or "vital signs monitor\*" or "bladder scanner\*").ti,ab. |
| 8 | exp sphygmomanometers/ or Stethoscopes/ or Electrodes/ or Defibrillators/ or transducers/ |
| 9 | (reusable adj2 (lead or leads or electrode\*)).ti,ab. |
| 10 | 6 or 7 or 8 or 9 |
| 11 | 5 and 10 |
| 12 | limit 11 to yr="2006 -Current" |
| 13 | exp africa/ or exp caribbean region/ or exp central america/ or exp latin america/ or exp canada/ or exp greenland/ or exp mexico/ or exp south america/ or exp antarctic regions/ or exp arctic regions/ or exp asia/ or exp europe/ or exp islands/ or exp oceania/ or exp "oceans and seas"/ |
| 14 | exp United States/ |
| 15 | 13 not 14 |
| 16 | 12 not 15 |
| 17 | (Implement\* or Improv\* or Intervention\* or Bundle\* or Program\* or Reduc\* or Decreas\* or Increas\* or Change\* or Protocol\* or Initiati\* or impact\*).ti,ab. |
| 18 | (Educat\* or Train\* or Feedback or Remind\*or Communicat\* or Alert\*).ti,ab. |
| 19 | Inservice training/ or Ed.fs. or Feedback/ or exp communication/ |
| 20 | Quality improvement/ or exp clinical trial/ or comparative study/ or Cross over studies/ or evaluation study/ or exp clinical trials as topic/ or exp cohort studies/ or exp evaluation studies as topic/ or exp epidemiologic studies/ or (random\* or control\* or "experimental study" or trial or trials or repeat\* or compar\* or "pre post" or versus or "before and after" or "interrupted time series").ti,ab. |
| 21 | ((control and (group\* or study)) or (time and factors) or survey\* or ci or cohort or comparative stud\* or evaluation studies or follow-up\*).mp. |
| 22 | 17 or 18 or 19 or 20 or 21 |
| 23 | 16 and 22 |

**Database:**  
Cochrane CENTRAL via Ovid

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| --- | --- |
| **#** | **Query** |
| 1 | (Disinfect\* or clean or cleaning or "infection control" or decontaminat\* or "cross transmission" or "cross contamination" or hygiene).ti,ab. |
| 2 | Disinfection/ |
| 3 | Infection Control/mt [Methods] |
| 4 | Cross Infection/pc [Prevention & Control] |
| 5 | 1 or 2 or 3 or 4 |
| 6 | ((Portable or noncritical or "non critical" or "point of care" or mobile) adj2 (equipment or radiograph or ultrasound or "medical device\*")).ti,ab. |
| 7 | (Stethoscope\* or "blood pressure cuff\*" or " sphygmomanometer cuff\*" or "surface ultrasound\*" or "ultrasound probe\*" or "ultrasound transducer\*" or glucometer\* or "pulse oximeter\*" or defibrillator\* or thermometer\* or "vital signs machine\*" or "vital signs monitor\*" or "bladder scanner\*").ti,ab. |
| 8 | exp sphygmomanometers/ or Stethoscopes/ or Electrodes/ or Defibrillators/ or transducers/ |
| 9 | (reusable adj2 (lead or leads or electrode\*)).ti,ab. |
| 10 | 6 or 7 or 8 or 9 |
| 11 | 5 and 10 |
| 12 | limit 11 to yr="2006 -Current" |
| 13 | exp africa/ or exp caribbean region/ or exp central america/ or exp latin america/ or exp canada/ or exp greenland/ or exp mexico/ or exp south america/ or exp antarctic regions/ or exp arctic regions/ or exp asia/ or exp europe/ or exp islands/ or exp oceania/ or exp "oceans and seas"/ |
| 14 | exp United States/ |
| 15 | 13 not 14 |
| 16 | 12 not 15 |
| 17 | (Implement\* or Improv\* or Intervention\* or Bundle\* or Program\* or Reduc\* or Decreas\* or Increas\* or Change\* or Protocol\* or Initiati\* or impact\*).ti,ab. |
| 18 | (Educat\* or Train\* or Feedback or Remind\*or Communicat\* or Alert\*).ti,ab. |
| 19 | Inservice training/ or Ed.fs. or Feedback/ or exp communication/ |
| 20 | Quality improvement/ or exp clinical trial/ or comparative study/ or Cross over studies/ or evaluation study/ or exp clinical trials as topic/ or exp cohort studies/ or exp evaluation studies as topic/ or exp epidemiologic studies/ or (random\* or control\* or "experimental study" or trial or trials or repeat\* or compar\* or "pre post" or versus or "before and after" or "interrupted time series").ti,ab. |
| 21 | ((control and (group\* or study)) or (time and factors) or survey\* or ci or cohort or comparative stud\* or evaluation studies or follow-up\*).mp. |
| 22 | 17 or 18 or 19 or 20 or 21 |
| 23 | 16 and 22 |

CINAHL

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| **#** | **Query** |
| S1 | TI ( Disinfect\* or clean or cleaning or "infection control" or decontaminat\* or "cross transmission" or "cross contamination" or hygiene) ) OR AB ( Disinfect\* or clean or cleaning or "infection control" or decontaminat\* or "cross transmission" or "cross contamination" or hygiene). ) |
| S2 | (MH "Sterilization and Disinfection") OR (MH "Infection Control/MT") OR (MH "Cross Infection/PC") OR (MH "Microbial Contamination/PC") OR (MH "Bacterial Contamination/PC") |
| S3 | S1 OR S2 |
| S4 | TI ( ((Portable or noncritical or "non critical" or "point of care" or mobile) N2 (equipment or radiograph or ultrasound or "medical device\*")) ) OR AB ( ((Portable or noncritical or "non critical" or "point of care" or mobile) N2 (equipment or radiograph or ultrasound or "medical device\*")) ) |
| S5 | TI ( (Stethoscope\* or "blood pressure cuff\*" or " sphygmomanometer cuff\*" or "surface ultrasound\*" or "ultrasound probe\*" or "ultrasound transducer\*" or glucometer\* or "pulse oximeter\*" or defibrillator\* or thermometer\* or "vital signs machine\*" or "vital signs monitor\*" or "bladder scanner\*") ) OR AB ( (Stethoscope\* or "blood pressure cuff\*" or " sphygmomanometer cuff\*" or "surface ultrasound\*" or "ultrasound probe\*" or "ultrasound transducer\*" or glucometer\* or "pulse oximeter\*" or defibrillator\* or thermometer\* or "vital signs machine\*" or "vital signs monitor\*" or "bladder scanner\*") ) |
| S6 | TI ( (reusable N2 (lead or leads or electrode\*)) ) OR AB ( (reusable N2 (lead or leads or electrode\*)) ) |
| S7 | (MH "Portable Equipment+") OR (MH "Stethoscopes") OR (MH "Blood Pressure Cuffs") OR (MH "Transducers") OR (MH "Pulse Oximeters") OR (MH "Electrodes+") OR (MH "Blood Glucose Meters") |
| S8 | S4 OR S5 OR S6 OR S7 |
| S9 | S3 AND S8 |
| S10 | S3 AND S8 2006-Present |
| S11 | (MH "Africa+") OR (MH "Central America+") OR (MH "Latin America") OR (MH "South America+") OR (MH "West Indies+") OR (MH "Canada") OR (MH "Greenland") OR (MH "Mexico") OR (MH "Antarctic Regions") OR (MH "Arctic Regions") OR (MH "Asia+") OR (MH "Australia+") OR (MH "Europe+") OR (MH "Indian Ocean Islands+") OR (MH "Pacific Islands+") |
| S12 | (MH "United States+") |
| S13 | S11 NOT S12 |
| S14 | S10 NOT S13 |
| S15 | TI ( (Implement\* or Improv\* or Intervention\* or Bundle\* or Program\* or Reduc\* or Decreas\* or Increas\* or Change\* or Protocol\* or Initiati\* or impact\*) ) OR AB ( (Implement\* or Improv\* or Intervention\* or Bundle\* or Program\* or Reduc\* or Decreas\* or Increas\* or Change\* or Protocol\* or Initiati\* or impact\*) ) |
| S16 | TI ( (Educat\* or Train\* or Feedback or Remind\*or Communicat\* or Alert\*) ) OR AB ( (Educat\* or Train\* or Feedback or Remind\*or Communicat\* or Alert\*) ) |
| S17 | TI ( ((control and (group\* or study)) or (time and factors) or survey\* or ci or cohort or comparative stud\* or evaluation studies or follow-up\*) ) OR AB ( ((control and (group\* or study)) or (time and factors) or survey\* or ci or cohort or comparative stud\* or evaluation studies or follow-up\*) ) OR MW ( ((control and (group\* or study)) or (time and factors) or survey\* or ci or cohort or comparative stud\* or evaluation studies or follow-up\*) ) |
| S18 | TI ( (random\* or control\* or "experimental study" or trial or trials or repeat\* or compar\* or "pre post" or versus or "before and after" or "interrupted time series") ) OR AB ( (random\* or control\* or "experimental study" or trial or trials or repeat\* or compar\* or "pre post" or versus or "before and after" or "interrupted time series") ) |
| S19 | (MH "Education, Continuing+") OR (MH "Feedback") OR (MH "Reminder Systems") OR (MH "Communication") OR (MH "Persuasive Communication") OR (MH "Quality Improvement") OR (MH "Clinical Trials+") OR (MH "Comparative Studies+") OR (MH "Cross Sectional Studies") OR (MH "Experimental Studies+") OR (MH "Prospective Studies+") OR (MH "Evaluation Research+") OR (MH "Epidemiological Research+") |
| S20 | S15 OR S16 OR S17 OR S18 OR S19 |
| S21 | S14 AND S20 |

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| **#** | **Query** |
| #1 | 'disinfection'/de |
| #2 | disinfect\*:ab,ti OR clean:ab,ti OR cleaning:ab,ti OR 'infection control':ab,ti OR decontaminat\*:ab,ti OR 'cross transmission':ab,ti OR 'cross contamination':ab,ti OR hygiene:ab,ti |
| #3 | #1 OR #2 |
| #4 | 'portable equipment'/exp OR 'stethoscope'/exp OR 'blood pressure cuff'/exp OR 'ultrasound transducer'/de OR 'blood glucose meter'/de OR 'pulse oximeter'/exp OR 'thermometer'/exp |
| #5 | ((portable OR noncritical OR 'non critical' OR 'point of care' OR mobile) NEAR/2 (equipment OR radiograph OR ultrasound OR 'medical device\*')):ab,ti |
| #6 | (reusable NEAR/2 (lead OR leads OR electrode\*)):ab,ti |
| #7 | stethoscope\*:ab,ti OR 'blood pressure cuff\*':ab,ti OR 'sphygmomanometer cuff\*':ab,ti OR 'surface ultrasound\*':ab,ti OR 'ultrasound probe\*':ab,ti OR 'ultrasound transducer\*':ab,ti OR glucometer\*:ab,ti OR 'pulse oximeter\*':ab,ti OR defibrillator\*:ab,ti OR thermometer\*:ab,ti OR 'vital signs machine\*':ab,ti OR 'vital signs monitor\*':ab,ti OR 'bladder scanner\*':ab,ti |
| #8 | #4 OR #5 OR #6 OR #7 |
| #9 | #3 AND #8 |
| #10 | #3 AND #8 AND [2006-2023]/py |
| #11 | 'canada'/exp OR 'mexico'/exp OR 'south and central america'/exp OR 'eastern hemisphere'/exp OR 'arctic and antarctic'/exp |
| #12 | 'united states'/exp |
| #13 | #11 NOT #12 |
| #14 | #10 NOT #13 |
| #15 | 'program evaluation'/exp OR 'clinical study'/exp OR 'in service training'/exp OR 'continuing education'/exp OR 'interprofessional education'/exp OR 'education program'/exp OR 'feedback system'/de OR 'positive feedback'/de OR 'negative feedback'/de OR 'reminder system'/de OR 'total quality management'/de OR 'comparative study'/de OR 'comparative effectiveness'/de OR 'crossover procedure'/de |
| #16 | implement\*:ab,ti OR improv\*:ab,ti OR intervention\*:ab,ti OR bundle\*:ab,ti OR program\*:ab,ti OR reduc\*:ab,ti OR decreas\*:ab,ti OR increas\*:ab,ti OR change\*:ab,ti OR protocol\*:ab,ti OR initiati\*:ab,ti OR impact\*:ab,ti |
| #17 | (educat\*:ab,ti OR train\*:ab,ti OR feedback:ab,ti OR remind\*or:ab,ti) AND communicat\*:ab,ti OR alert\*:ab,ti |
| #18 | random\*:ab,ti OR control\*:ab,ti OR 'experimental study':ab,ti OR trial:ab,ti OR trials:ab,ti OR repeat\*:ab,ti OR compar\*:ab,ti OR 'pre post':ab,ti OR versus:ab,ti OR 'before and after':ab,ti OR 'interrupted time series':ab,ti |
| #19 | ((control:ab,ti AND (group\*:ab,ti OR study:ab,ti) OR (time:ab,ti AND factors:ab,ti) OR survey\*:ab,ti OR ci:ab,ti OR cohort:ab,ti OR comparative:ab,ti) AND stud\*:ab,ti OR evaluation:ab,ti) AND studies:ab,ti OR 'follow up':ab,ti |
| #20 | #15 OR #16 OR #17 OR #18 OR #19 |
| #21 | #14 AND #20 |

Web of Science

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| **#** | **Query** |
| #1 | Disinfect\* or clean or cleaning or "infection control" or decontaminat\* or "cross transmission" or "cross contamination" or hygiene (Topic) |
| #2 | ((Portable or noncritical or "non critical" or "point of care" or mobile) NEAR/2 (equipment or radiograph or ultrasound or "medical device\*")). (Topic) |
| #3 | (Stethoscope\* or "blood pressure cuff\*" or " sphygmomanometer cuff\*" or "surface ultrasound\*" or "ultrasound probe\*" or "ultrasound transducer\*" or glucometer\* or "pulse oximeter\*" or defibrillator\* or thermometer\* or "vital signs machine\*" or "vital signs monitor\*" or "bladder scanner\*") (Topic) |
| #4 | (reusable NEAR/2 (lead or leads or electrode\*)) (Topic) |
| #5 | (Implement\* or Improv\* or Intervention\* or Bundle\* or Program\* or Reduc\* or Decreas\* or Increas\* or Change\* or Protocol\* or Initiati\* or impact\*) (Topic) |
| #6 | (Educat\* or Train\* or Feedback or Remind\*or Communicat\* or Alert\*) (Topic) |
| #7 | (random\* or control\* or "experimental study" or trial or trials or repeat\* or compar\* or "pre post" or versus or "before and after" or "interrupted time series") (Topic) |
| #8 | ((control and (group\* or study)) or (time and factors) or survey\* or ci or cohort or comparative stud\* or evaluation studies or follow-up\*) (Topic) |
| #9 | #2 OR #3 OR #4 |
| #10 | #5 OR #6 OR #7 OR #8 |
| #11 | #10 AND #9 AND #1 |
| #12 | #10 AND #9 AND #1 and 2023 or 2022 or 2021 or 2006 or 2007 or 2008 or 2009 or 2010 or 2011 or 2020 or 2019 or 2018 or 2017 or 2016 or 2015 or 2014 or 2013 or 2012 (Publication Years) |
| #13 | #10 AND #9 AND #1 and 2023 or 2022 or 2021 or 2006 or 2007 or 2008 or 2009 or 2010 or 2011 or 2020 or 2019 or 2018 or 2017 or 2016 or 2015 or 2014 or 2013 or 2012 (Publication Years) and USA (Countries/Regions) |

*Methods of Critical Appraisal*

Using the Johanna Briggs Institute (JBI) nine-question critical appraisal tool1, quality assessment was conducted on nine studies.2-10 Prior to assessing, reviewers (AB, CVG) determined that papers that received a “no” vote on any one of four specific questions from the tool would automatically be excluded, while those that had a “no” or “unsure” to the remaining criteria, it would be placed under consideration for exclusion with arbitration by the reviewers (AB, CVG). If a paper received a “no” to three or more criteria, then it would also be excluded from this review. Papers were excluded automatically if the answer was “no” to any of the following single questions in the quality review:

* Is it clear in the study what is the ‘cause’ and what is the ‘effect’ (i.e. there is no confusion about which variable comes first)?
* Were the participants included in any comparisons similar?
* Were the participants included in any comparisons receiving similar treatment/care, other than the exposure or intervention of interest?
* Were the outcomes of participants included in any comparisons measured in the same way?

*Results of Critical Appraisal*

The results of the critical appraisal are shown (Supplement 2). As per the methodology determined prior to assessment, one paper was excluded10, as the researchers did not report measurements taken or data collected before the intervention. One paper required further analysis before determining inclusion.5 Two of the authors (AB and CVG) contacted the corresponding author of this paper and confirmed that statistical analysis of outcomes was not completed due to the diversity of unique POCUS machines and the paper was included.5 All other papers were appraised for inclusion, as they adhered to the inclusion criteria.2-9 All papers that had undergone critical appraisal answered “no” to the question regarding a control group, due to the ubiquity of the pre-post intervention design in this cohort of articles. The reliability of outcome measurements was unclear in three papers.2,4,5 The outcomes in these papers were observed disinfection events, and authors either did not describe inter-rater reliability assessment or other methods of ensuring consistency in observations or in one case stated explicitly that they did not assess the inter-rater reliability of the observations.5 However,the articles were included due to their meeting the additional quality inclusion criteria.

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Reference** | **Is it clear in the study what is the ‘cause’ and what is the ‘effect’ (i.e. there is no confusion about which variable comes first)?** | **Were the participants included in any comparisons similar?** | **Were the participants included in any comparisons receiving similar treatment/care, other than the exposure or intervention of interest?** | **Was there a control group?** | **Were there multiple measurements of the outcome both pre and post the intervention/exposure?** | **Was follow up complete and if not, were differences between groups in terms of their follow up adequately described and analyzed?** | **Were the outcomes of participants included in any comparisons measured in the same way?** | **Were outcomes measured in a reliable way?** | **Was appropriate statistical analysis used?** | **Overall Appraisal** |
| 2 | Yes | Yes | Yes | No | Yes | NA | Yes | Unclear | Yes | Include |
| 3 | Yes | Yes | Yes | No | Yes | NA | Yes | Yes | Yes | Include |
| 4 | Yes | Yes | Yes | No | Yes | NA | Yes | Unclear | Yes | Include |
| 5 | Yes | Unclear | Yes | No | Yes | NA | Yes | Unclear | Unclear | Seek further info |
| 6 | Yes | Yes | Yes | No | Yes | NA | Yes | Yes | Yes | Include |
| 7 | Yes | Yes | Yes | No | No | NA | Yes | Yes | Yes | Include |
| 8 | Yes | Yes | Yes | No | Yes | NA | Yes | Yes | Yes | Include |
| 9 | Yes | Yes | Yes | No | Yes | NA | Yes | Yes | Yes | Include |
| 10 | Yes | Yes | Yes | No | No | Yes | Yes | No | Yes | Exclude |

References

1. Aromataris E, Fernandez R Fau - Godfrey CM, Godfrey Cm Fau - Holly C, Holly C Fau - Khalil H, Khalil H Fau - Tungpunkom P, Tungpunkom P. Summarizing systematic reviews: methodological development, conduct and reporting of an umbrella review approach. (1744-1609 (Electronic))

2. Holleck JL, Campbell S, Alrawili H, et al. Stethoscope hygiene: Using cultures and real-time feedback with bioluminescence-based adenosine triphosphate technology to change behavior. *American journal of infection control*. 2020;48(4):380-385. doi:<https://dx.doi.org/10.1016/j.ajic.2019.10.005>

3. Zaghi J, Zhou J, Graham DA, Potter-Bynoe G, Sandora TJ. Improving stethoscope disinfection at a children's hospital. *Infection control and hospital epidemiology*. 2013;34(11):1189-93. doi:<https://dx.doi.org/10.1086/673454>

4. Holleck JL, Merchant N, Lin S, Gupta S. Can education influence stethoscope hygiene? *American journal of infection control*. 2017;45(7):811-812. doi:<https://dx.doi.org/10.1016/j.ajic.2017.02.004>

5. Prats MI, Nelson BP, Gold DL, Branditz LD, Boulger CT, Bahner DP. CLEAR: A Novel Approach to Ultrasound Equipment Homeostasis. (1550-9613 (Electronic))

6. Van Kalsbeek DA-O, Enroth K, Lyden E, Rupp ME, Smith CJ. Improving hospital-based point-of-care ultrasound cleaning practices using targeted interventions: a pre-post study. (2524-8987 (Electronic))

7. Pessin YJ, Matthews EP. Glow Powder: See the Germs? An Innovative Teaching Technique in a Student Sonography Laboratory. *Journal of Diagnostic Medical Sonography*. 2019;35(5):363-372. doi:10.1177/8756479319855006

8. Reese SM, Knepper BC, Kurtz J, et al. Implementation of cleaning and evaluation process for mobile patient equipment using adenosine triphosphate. *Infection control and hospital epidemiology*. 2019;40(7):798-800. doi:<https://dx.doi.org/10.1017/ice.2019.115>

9. Crowley P, Chatterjee P, Coppin JD, et al. Effect of a "feedback prompt" from a disinfection tracking system on portable medical equipment disinfection. (1527-3296 (Electronic))

10. Jordan K, Barrett J, Murney S, Whipp A, Elliott JO. Educational programme to enhance stethoscope hygiene behaviour. (1532-2939 (Electronic))