

Supplemental Digital Appendix 1

Search Strategy

We conducted the search in two stages. For the first stage, we've listed below the Ovid MEDLINE and EMBASE search process. The searches for Cochrane Library, and ERIC are not shown and used terms similar to the two below (last update: December 13, 2013). The second stage of our search of MEDLINE and EMBASE is also reported below (last update: April 13, 2015).

Search 1: Ovid MEDLINE

1. Anesthesiology/
2. Clinical Clerkship/
3. Emergency Medicine/
4. General Practitioners/
5. General Surgery/
6. Gastroenterology/
7. Hospitalists/
8. Internal Medicine/
9. Neurology/
10. Occupational Health Physicians/
11. Orthopedics/
12. Physicians, Family/
13. Physicians, Primary Care/
14. Pulmonary Medicine/
15. Radiology, Interventional/
16. Rheumatology/
17. Students, Medical/
18. Schools, Medical/
19. (general adj surg\$).tw.
20. (orthopedic? adj surg\$).tw.
21. specialist?.tw.
22. sub-specialist?.tw.
23. subspecialist?.tw.
24. an?esthesiaolog\$.tw.
25. clerkship?.tw.
26. (emergency adj medicine).tw.
27. (family adj physician?).tw.
28. (general adj practitioner?).tw.
29. gastroenterolog\$.tw.
30. hospitalist?.tw.
31. (interventional adj radiolog\$).tw.
32. internship?.tw.
33. intern.tw.
34. interns.tw.
35. internist\$.tw.
36. (internal adj medicine).tw.
37. (medical adj student?).tw.

- 38. (medical adj practitioner?).tw.
- 39. (medical adj trainee?).tw.
- 40. neurology.tw.
- 41. neurologist.tw.
- 42. neurologists.tw.
- 43. "primary care physician?" .tw.
- 44. pulmonolog\$.tw.
- 45. respirolog\$.tw.
- 46. rheumatolog\$.tw.
- 47. resident.tw.
- 48. residents.tw.
- 49. residency.tw.
- 50. residencies.tw.
- 51. fellow*.tw.
- 52. (clinic* adj1 fellow*).tw.
- 53. or/1-52
- 54. exp Education, Medical/
- 55. exp Curriculum/
- 56. Computer Simulation/
- 57. Computer-Assisted Instruction/
- 58. Credentialing/
- 59. exp Certification/
- 60. Games, Experimental/
- 61. Educational Measurement/
- 62. Learning/
- 63. Licensure, Medical/
- 64. Models, Anatomic/
- 65. Patient Simulation/
- 66. Programmed Instruction as Topic/
- 67. Role Playing/
- 68. Self-Evaluation Programs/
- 69. Self-Assessment/
- 70. Teaching/
- 71. (augmented adj reality).tw.
- 72. (anatomic adj model?).tw.
- 73. (bench\$ adj train\$).tw.
- 74. (box adj trainer?).tw.
- 75. curriculum.tw.
- 76. "computer assist\$ instruct\$".tw.
- 77. curricula.tw.
- 78. credential?ing.tw.
- 79. certification.tw.
- 80. ed.fs.
- 81. educat\$.tw.
- 82. e-learning.tw.
- 83. elearning.tw.
- 84. (enhanced adj reality).tw.

- 85. (experiment\$ adj game\$).tw.
- 86. learn\$.tw.
- 87. licensure.tw.
- 88. manikin?.tw.
- 89. mannequin?.tw.
- 90. moulage?.tw.
- 91. OSCE?.tw.
- 92. "objective structured clinical exam\$".tw.
- 93. (professional adj development).tw.
- 94. (practice adj scenario?).tw.
- 95. (predicted adj performance).tw.
- 96. (program\$ adj instruct\$).tw.
- 97. (role adj play\$).tw.
- 98. recertification.tw.
- 99. re-certification.tw.
- 100. (reflective and practice).tw.
- 101. (reflection and practice).tw.
- 102. (self adj (direct\$ or regulat\$)).tw.
- 103. (self adj assess\$).tw.
- 104. (self adj evaluat\$).tw.
- 105. simulat\$.tw.
- 106. (standardi?ed adj patient?).tw.
- 107. teach\$.tw.
- 108. train\$.tw.
- 109. (virtual adj reality).tw.
- 110. session*.tw.
- 111. workshop*.tw.
- 112. seminar?.tw.
- 113. forum?.tw.
- 114. symposi???.tw.
- 115. roundtable*.tw.
- 116. round-table*.tw.
- 117. convention?.tw.
- 118. meeting?.tw.
- 119. assessment?.tw.
- 120. (checklist? or check-list?).tw.
- 121. (criteria or criterion).tw.
- 122. Patient Safety/
- 123. Quality Improvement/
- 124. (refresh* adj1 course?).tw.
- 125. (retention adj2 skill?).tw.
- 126. (retain* adj2 skill?).tw.
- 127. testing?.tw.
- 128. or/54-127
- 129. Catheterization, Central Venous/
- 130. CVC.tw.
- 131. (central adj2 catheter\$).tw.

- 132. (central adj line?).tw.
- 133. PICC.tw.
- 134. (venous adj access).tw.
- 135. (venous adj cannul\$).tw.
- 136. (venous adj line?).tw.
- 137. arthrocent\$.tw.
- 138. (joint adj aspiration).tw.
- 139. (joint adj effusion).tw.
- 140. (joint adj sepsis).tw.
- 141. "synovial fluid aspiration".tw.
- 142. thoracentes\$.tw.
- 143. thoracocentes\$.tw.
- 144. (pleural adj tap\$).tw.
- 145. "pleural fluid aspiration?" .tw.
- 146. Paracentesis/
- 147. paracentes\$.tw.
- 148. (peritoneal adj tap\$).tw.
- 149. Spinal Puncture/
- 150. (lumbar adj puncture?).tw.
- 151. (lumbar adj tap\$).tw.
- 152. (spinal adj punctu\$).tw.
- 153. (spine adj punctur\$).tw.
- 154. (spinal adj tap\$).tw.
- 155. or/129-154
- 156. 53 and 128 and 155
- 157. ((procedur* or clinical or technical) adj2 (skill? or abilit\$ or competen\$ or aptitude or proficien\$)).tw.
- 158. 53 and 128 and procedur*2.tw. and (157 or clinical competence/ or st.fs.)
- 159. anesthesiology/ed or clinical clerkship/ed or emergency medicine/ed or general practitioners/ed or general surgery/ed or gastroenterology/ed or hospitalists/ed or internal medicine/ed or neurology/ed or occupational health physicians/ed or orthopedics/ed or physicians, family/ed or physicians, primary care/ed or pulmonary medicine/ed or radiology, interventional/ed or rheumatology/ed
- 160. or/17-50
- 161. (156 or 158) and (159 or 160)
- 162. remove duplicates from 161
- 163. exp Animals/ not (exp Animals/ and Humans/)
- 164. 162 not 163
- 165. limit 162 to humans
- 166. 164 or 165
- 167. Surgical Procedures, Operative/
- 168. Endovascular Procedures/
- 169. Endoscopy, Digestive System/
- 170. Gastroenterostomy/
- 171. Surgical Procedures, Minimally Invasive/
- 172. Surgical Procedures, Elective/
- 173. Laparoscopy/
- 174. (laparoscop* or "minimally invasive" or endoscop* or cholecystect*).tw.

Supplemental digital content for Brydges R, Stroud L, Wong BM, Holmboe ES, Imrie K, Hatala R.
Core competencies or a competent core? A scoping review and realist synthesis of
invasive bedside procedures training in internal medicine. Acad Med.

- 175. or/167-174
- 176. 166 not 175

Search 1: Ovid EMBASE

1. Anesthesiology/
2. anesthesiologist/
3. an?esthetist?.tw.
4. (clinical adj1 clerk*).tw.
5. emergency physician/
6. general practitioner/
7. general surgery/
8. surgeon/
9. Gastroenterology/
10. Internal Medicine/
11. internist/
12. medical specialist/
13. Neurology/
14. neurologist/
15. occupational physician/
16. Orthopedics/
17. orthopedic surgeon/
18. family doctor?.tw.
19. primary care doctor?.tw.
20. pulmonology/
21. interventional radiology/
22. radiologist/
23. Rheumatology/
24. medical student/
25. medical school/
26. resident/
27. (general adj surg\$).tw.
28. (orthopedic? adj surg\$).tw.
29. (orthopaedic? adj surg\$).tw.
30. orthopaedist?.tw.
31. specialist?.tw.
32. sub-specialist?.tw.
33. subspecialist?.tw.
34. an?esthesiolog\$.tw.
35. clerkship?.tw.
36. (emergency adj medicine).tw.
37. (family adj physician?).tw.
38. (general adj practitioner?).tw.
39. gastroenterolog\$.tw.
40. hospitalist?.tw.
41. (interventional adj radiolog\$).tw.
42. internship?.tw.
43. intern.tw.
44. interns.tw.
45. internist\$.tw.
46. (internal adj medicine).tw.

- 47. (medical adj student?).tw.
- 48. (medical adj practitioner?).tw.
- 49. (medical adj trainee?).tw.
- 50. neurology.tw.
- 51. neurologist.tw.
- 52. neurologists.tw.
- 53. "primary care physician?".tw.
- 54. pulmonolog\$.tw.
- 55. respirolog\$.tw.
- 56. rheumatolog\$.tw.
- 57. resident.tw.
- 58. residents.tw.
- 59. residency.tw.
- 60. residencies.tw.
- 61. fellow?.tw.
- 62. (clinic* adj1 fellow*).tw.
- 63. or/1-62
- 64. exp medical education/
- 65. curriculum/
- 66. curriculum development/
- 67. Computer Simulation/
- 68. Computer-Assisted Instruction?.tw.
- 69. exp accreditation/
- 70. exp competence/ [includes 'clinical competence' or 'professional competence' which started usage in 2006]
- 71. Credential*.tw.
- 72. professional standard/
- 73. game/
- 74. education program/
- 75. educational model/
- 76. educational technology/
- 77. in service training/
- 78. interdisciplinary education/
- 79. Learning/
- 80. learning environment/
- 81. lifelong learning/
- 82. outcome of education/
- 83. postgraduate education/
- 84. refresher course/
- 85. licensing/
- 86. anatomic model/
- 87. exp simulation/
- 88. simulator/
- 89. Program* Instruction?.tw.
- 90. residency education/
- 91. Role Playing/
- 92. self-evaluation/

- 93. "evaluation and follow up"/
- 94. Self-Assess*.tw.
- 95. exp teaching/
- 96. (augmented adj reality).tw.
- 97. (anatomic adj model?).tw.
- 98. (bench\$ adj train\$).tw.
- 99. (box adj trainer?).tw.
- 100. curriculum.tw.
- 101. "computer assist\$ instruct\$".tw.
- 102. curricula.tw.
- 103. credential?ing.tw.
- 104. certification.tw.
- 105. [ed.fs. ==> "education" as a floating subheading does not exist in Embase]
- 106. educat\$.tw.
- 107. e-learning.tw.
- 108. elearning.tw.
- 109. (enhanced adj reality).tw.
- 110. (experiment\$ adj game\$).tw.
- 111. learn\$.tw.
- 112. licensure.tw.
- 113. manikin?.tw.
- 114. mannequin?.tw.
- 115. moulage?.tw.
- 116. OSCE?.tw.
- 117. "objective structured clinical exam\$".tw.
- 118. (professional adj development).tw.
- 119. (practice adj scenario?).tw.
- 120. (predicted adj performance).tw.
- 121. (program\$ adj instruct\$).tw.
- 122. (role adj play\$).tw.
- 123. recertification.tw.
- 124. re-certification.tw.
- 125. (reflective and practice).tw.
- 126. (reflection and practice).tw.
- 127. (self adj (direct\$ or regulat\$)).tw.
- 128. (self adj assess\$).tw.
- 129. (self adj evaluat\$).tw.
- 130. simulat\$.tw.
- 131. (standardi?ed adj patient?).tw.
- 132. teach\$.tw.
- 133. train\$.tw.
- 134. (virtual adj reality).tw.
- 135. session*.tw.
- 136. workshop*.tw.
- 137. seminar?.tw.
- 138. forum?.tw.
- 139. symposi???.tw.

- 140. roundtable*.tw.
- 141. (round adj table*).tw.
- 142. convention?.tw.
- 143. meeting?.tw.
- 144. assessment?.tw.
- 145. (checklist? or check-list?).tw.
- 146. (criteria or criterion).tw.
- 147. Patient Safety/
- 148. Quality Improvement/
- 149. (refresh* adj1 course?).tw.
- 150. (retention adj2 skill?).tw.
- 151. (retain* adj2 skill?).tw.
- 152. testing?.tw.
- 153. or/64-152
- 154. central venous catheterization/
- 155. CVC.tw.
- 156. (central adj2 catheter\$).tw.
- 157. (central adj line?).tw.
- 158. peripherally inserted central venous catheter/
- 159. PICC.tw.
- 160. (venous adj access).tw.
- 161. (venous adj cannul\$).tw.
- 162. (venous adj line?).tw.
- 163. arthrocentesis/
- 164. arthrocent\$.tw.
- 165. joint aspiration/
- 166. (joint adj aspiration).tw.
- 167. (joint adj effusion).tw.
- 168. (joint adj sepsis).tw.
- 169. "synovial fluid aspiration".tw.
- 170. thoracocentesis/
- 171. thoracentes\$.tw.
- 172. thoracocentes\$.tw.
- 173. (pleural adj tap\$).tw.
- 174. "pleural fluid aspiration?" .tw.
- 175. Paracentesis/
- 176. paracentes\$.tw.
- 177. (peritoneal adj tap\$).tw.
- 178. lumbar puncture/
- 179. (lumbar adj puncture?).tw.
- 180. (lumbar adj tap\$).tw.
- 181. (spinal adj punctu\$).tw.
- 182. (spine adj punctur\$).tw.
- 183. (spinal adj tap\$).tw.
- 184. or/154-183
- 185. 63 and 153 and 184

- 186. ((procedur* or clinical* or technical*) adj2 (skill? or abilit\$ or competen\$ or aptitude or proficien\$)).tw. [truncation added to 'clinical' and 'technical']
- 187. 63 and 153 and procedur*2.tw. and (186 or exp competence/) [NB: .st.fs does not exist in Embase; clinical competence is from 2006 -]
- 188. (exp animals/ or exp animal experimentation/ or nonhuman/) not ((exp animals/ or exp animal experimentation/ or nonhuman/) and exp human/)
- 189. 63 or 153
- 190. (185 or 187) and 189
- 191. 190 not 188
- 192. remove duplicates from 191
- 193. limit 192 to embase
- 194. limit 193 to (book or book series or conference proceeding or "conference review")
- 195. 193 not 194
- 196. surgical procedures, operative/
- 197. Endovascular Procedures/
- 198. endoscopy, digestive system/
- 199. Gastroenterostomy/
- 200. Surgical Procedures, Minimally Invasive/
- 201. Surgical Procedures, Elective/
- 202. Laparoscopy/
- 203. (laparoscop* or "minimally invasive" or endoscop* or cholecystect*).tw.
- 204. or/196-203
- 205. 195 not 204

Search 2: Ovid MEDLINE

1. Anesthesiology/
2. Clinical Clerkship/
3. Emergency Medicine/
4. General Practitioners/
5. General Surgery/
6. Gastroenterology/
7. Hospitalists/
8. Internal Medicine/
9. Neurology/
10. Occupational Health Physicians/
11. Orthopedics/
12. Physicians, Family/
13. Physicians, Primary Care/
14. Pulmonary Medicine/
15. Radiology, Interventional/
16. Rheumatology/
17. Students, Medical/
18. Schools, Medical/
19. (general adj surg\$).tw.
20. (orthopedic? adj surg\$).tw.
21. specialist?.tw.
22. sub-specialist?.tw.
23. subspecialist?.tw.
24. an?esthesiaolog\$.tw.
25. clerkship?.tw.
26. (emergency adj medicine).tw.
27. (family adj physician?).tw.
28. (general adj practitioner?).tw.
29. gastroenterolog\$.tw.
30. hospitalist?.tw.
31. (interventional adj radiolog\$).tw.
32. internship?.tw.
33. intern.tw.
34. interns.tw.
35. internist\$.tw.
36. (internal adj medicine).tw.
37. (medical adj student?).tw.
38. (medical adj practitioner?).tw.
39. (medical adj trainee?).tw.
40. neurology.tw.
41. neurologist.tw.
42. neurologists.tw.
43. "primary care physician?" .tw.
44. pulmonolog\$.tw.
45. respirolog\$.tw.
46. rheumatolog\$.tw.

- 47. resident.tw.
- 48. residents.tw.
- 49. residency.tw.
- 50. residencies.tw.
- 51. fellow*.tw.
- 52. (clinic* adj1 fellow*).tw.
- 53. or/1-52
- 54. exp Education, Medical/
- 55. exp Curriculum/
- 56. Computer Simulation/
- 57. Computer-Assisted Instruction/
- 58. Credentialing/
- 59. exp Certification/
- 60. Games, Experimental/
- 61. Educational Measurement/
- 62. Learning/
- 63. Licensure, Medical/
- 64. Models, Anatomic/
- 65. Patient Simulation/
- 66. Programmed Instruction as Topic/
- 67. Role Playing/
- 68. Self-Evaluation Programs/
- 69. Self-Assessment/
- 70. Teaching/
- 71. (augmented adj reality).tw.
- 72. (anatomic adj model?).tw.
- 73. (bench\$ adj train\$).tw.
- 74. (box adj trainer?).tw.
- 75. curriculum.tw.
- 76. "computer assist\$ instruct\$".tw.
- 77. curricula.tw.
- 78. credential?ing.tw.
- 79. certification.tw.
- 80. ed.fs.
- 81. educat\$.tw.
- 82. e-learning.tw.
- 83. elearning.tw.
- 84. (enhanced adj reality).tw.
- 85. (experiment\$ adj game\$).tw.
- 86. learn\$.tw.
- 87. licensure.tw.
- 88. manikin?.tw.
- 89. mannequin?.tw.
- 90. moulage?.tw.
- 91. OSCE?.tw.
- 92. "objective structured clinical exam\$".tw.
- 93. (professional adj development).tw.

- 94. (practice adj scenario?).tw.
- 95. (predicted adj performance).tw.
- 96. (program\$ adj instruct\$).tw.
- 97. (role adj play\$).tw.
- 98. recertification.tw.
- 99. re-certification.tw.
- 100. (reflective and practice).tw.
- 101. (reflection and practice).tw.
- 102. (self adj (direct\$ or regulat\$)).tw.
- 103. (self adj assess\$).tw.
- 104. (self adj evaluat\$).tw.
- 105. simulat\$.tw.
- 106. (standardi?ed adj patient?).tw.
- 107. teach\$.tw.
- 108. train\$.tw.
- 109. (virtual adj reality).tw.
- 110. session*.tw.
- 111. workshop*.tw.
- 112. seminar?.tw.
- 113. forum?.tw.
- 114. symposi???.tw.
- 115. roundtable*.tw.
- 116. round-table*.tw.
- 117. convention?.tw.
- 118. meeting?.tw.
- 119. assessment?.tw.
- 120. (checklist? or check-list?).tw.
- 121. (criteria or criterion).tw.
- 122. Patient Safety/
- 123. Quality Improvement/
- 124. (refresh* adj1 course?).tw.
- 125. (retention adj2 skill?).tw.
- 126. (retain* adj2 skill?).tw.
- 127. testing?.tw.
- 128. or/54-127
- 129. Catheterization, Central Venous/
- 130. CVC.tw.
- 131. (central adj2 catheter\$).tw.
- 132. (central adj line?).tw.
- 133. PICC.tw.
- 134. (venous adj access).tw.
- 135. (venous adj cannul\$).tw.
- 136. (venous adj line?).tw.
- 137. arthrocent\$.tw.
- 138. (joint adj aspiration).tw.
- 139. (joint adj effusion).tw.
- 140. (joint adj sepsis).tw.

- 141. "synovial fluid aspiration".tw.
- 142. thoracentes\$.tw.
- 143. thoracocentes\$.tw.
- 144. (pleural adj tap\$).tw.
- 145. "pleural fluid aspiration?".tw.
- 146. Paracentesis/
- 147. paracentes\$.tw.
- 148. (peritoneal adj tap\$).tw.
- 149. Spinal Puncture/
- 150. (lumbar adj puncture?).tw.
- 151. (lumbar adj tap\$).tw.
- 152. (spinal adj punctu\$).tw.
- 153. (spine adj punctur\$).tw.
- 154. (spinal adj tap\$).tw.
- 155. or/129-154
- 156. 53 and 128 and 155
- 157. ((procedur* or clinical or technical) adj2 (skill? or abilit\$ or competen\$ or aptitude or proficien\$)).tw.
- 158. 53 and 128 and procedur*2.tw. and (157 or clinical competence/ or st.fs.)
- 159. anesthesiology/ed or clinical clerkship/ed or emergency medicine/ed or general practitioners/ed or general surgery/ed or gastroenterology/ed or hospitalists/ed or internal medicine/ed or neurology/ed or occupational health physicians/ed or orthopedics/ed or physicians, family/ed or physicians, primary care/ed or pulmonary medicine/ed or radiology, interventional/ed or rheumatology/ed
- 160. or/17-50
- 161. (156 or 158) and (159 or 160)
- 162. remove duplicates from 161
- 163. exp Animals/ not (exp Animals/ and Humans/)
- 164. 162 not 163
- 165. limit 162 to humans
- 166. 164 or 165
- 167. Surgical Procedures, Operative/
- 168. Endovascular Procedures/
- 169. Endoscopy, Digestive System/
- 170. Gastroenterostomy/
- 171. Surgical Procedures, Minimally Invasive/
- 172. Surgical Procedures, Elective/
- 173. Laparoscopy/
- 174. (laparoscop* or "minimally invasive" or endoscop* or cholecystect*).tw.
- 175. or/167-174
- 176. 166 not 175
- 177. limit 176 to yr="2014 -Current"
- 178. 177 not 5
- 179. 178 not 11
- 180. 179 not 19-20.mp. [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier]
- 181. 179 not 19

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182. 181 not 20

183. (embol* or biopsy or intraoss* or dentis* or dental* or resuscit* or hysteroscop* or peripheral* or
PICC or surg* or anastomosis).tw.

184. 182 not 183

Search 2: Ovid EMBASE

1. Anesthesiology/
2. anesthesiologist/
3. an?esthetist?.tw.
4. (clinical adj1 clerk*).tw.
5. emergency physician/
6. general practitioner/
7. general surgery/
8. surgeon/
9. Gastroenterology/
10. Internal Medicine/
11. internist/
12. medical specialist/
13. Neurology/
14. neurologist/
15. occupational physician/
16. Orthopedics/
17. orthopedic surgeon/
18. family doctor?.tw.
19. primary care doctor?.tw.
20. pulmonology/
21. interventional radiology/
22. radiologist/
23. Rheumatology/
24. medical student/
25. medical school/
26. resident/
27. (general adj surg\$).tw.
28. (orthopedic? adj surg\$).tw.
29. (orthopaedic? adj surg\$).tw.
30. orthopaedist?.tw.
31. specialist?.tw.
32. sub-specialist?.tw.
33. subspecialist?.tw.
34. an?esthesiaolog\$.tw.
35. clerkship?.tw.
36. (emergency adj medicine).tw.
37. (family adj physician?).tw.
38. (general adj practitioner?).tw.
39. gastroenterolog\$.tw.
40. hospitalist?.tw.
41. (interventional adj radiolog\$).tw.
42. internship?.tw.
43. intern.tw.
44. interns.tw.
45. internist\$.tw.

- 46. (internal adj medicine).tw.
- 47. (medical adj student?).tw.
- 48. (medical adj practitioner?).tw.
- 49. (medical adj trainee?).tw.
- 50. neurology.tw.
- 51. neurologist.tw.
- 52. neurologists.tw.
- 53. "primary care physician?".tw.
- 54. pulmonolog\$.tw.
- 55. respirolog\$.tw.
- 56. rheumatolog\$.tw.
- 57. resident.tw.
- 58. residents.tw.
- 59. residency.tw.
- 60. residencies.tw.
- 61. fellow?.tw.
- 62. (clinic* adj1 fellow*).tw.
- 63. or/1-62
- 64. exp medical education/
- 65. curriculum/
- 66. curriculum development/
- 67. Computer Simulation/
- 68. Computer-Assisted Instruction?.tw.
- 69. exp accreditation/
- 70. exp competence/ [includes 'clinical competence' or 'professional competence' which started usage in 2006]
- 71. Credential*.tw.
- 72. professional standard/
- 73. game/
- 74. education program/
- 75. educational model/
- 76. educational technology/
- 77. in service training/
- 78. interdisciplinary education/
- 79. Learning/
- 80. learning environment/
- 81. lifelong learning/
- 82. outcome of education/
- 83. postgraduate education/
- 84. refresher course/
- 85. licensing/
- 86. anatomic model/
- 87. exp simulation/
- 88. simulator/
- 89. Program* Instruction?.tw.
- 90. residency education/
- 91. Role Playing/

- 92. self-evaluation/
- 93. "evaluation and follow up"/
- 94. Self-Assess*.tw.
- 95. exp teaching/
- 96. (augmented adj reality).tw.
- 97. (anatomic adj model?).tw.
- 98. (bench\$ adj train\$).tw.
- 99. (box adj trainer?).tw.
- 100. curriculum.tw.
- 101. "computer assist\$ instruct\$".tw.
- 102. curricula.tw.
- 103. credential?ing.tw.
- 104. certification.tw.
- 105. [ed.fs. ==> "education" as a floating subheading does not exist in Embase]
- 106. educat\$.tw.
- 107. e-learning.tw.
- 108. elearning.tw.
- 109. (enhanced adj reality).tw.
- 110. (experiment\$ adj game\$).tw.
- 111. learn\$.tw.
- 112. licensure.tw.
- 113. manikin?.tw.
- 114. mannequin?.tw.
- 115. moulage?.tw.
- 116. OSCE?.tw.
- 117. "objective structured clinical exam\$".tw.
- 118. (professional adj development).tw.
- 119. (practice adj scenario?).tw.
- 120. (predicted adj performance).tw.
- 121. (program\$ adj instruct\$).tw.
- 122. (role adj play\$).tw.
- 123. recertification.tw.
- 124. re-certification.tw.
- 125. (reflective and practice).tw.
- 126. (reflection and practice).tw.
- 127. (self adj (direct\$ or regulat\$)).tw.
- 128. (self adj assess\$).tw.
- 129. (self adj evaluat\$).tw.
- 130. simulat\$.tw.
- 131. (standardi?ed adj patient?).tw.
- 132. teach\$.tw.
- 133. train\$.tw.
- 134. (virtual adj reality).tw.
- 135. session*.tw.
- 136. workshop*.tw.
- 137. seminar?.tw.
- 138. forum?.tw.

- 139. symposi???.tw.
- 140. roundtable*.tw.
- 141. (round adj table*).tw.
- 142. convention?.tw.
- 143. meeting?.tw.
- 144. assessment?.tw.
- 145. (checklist? or check-list?).tw.
- 146. (criteria or criterion).tw.
- 147. Patient Safety/
- 148. Quality Improvement/
- 149. (refresh* adj1 course?).tw.
- 150. (retention adj2 skill?).tw.
- 151. (retain* adj2 skill?).tw.
- 152. testing?.tw.
- 153. or/64-152
- 154. central venous catheterization/
- 155. CVC.tw.
- 156. (central adj2 catheter\$).tw.
- 157. (central adj line?).tw.
- 158. peripherally inserted central venous catheter/
- 159. PICC.tw.
- 160. (venous adj access).tw.
- 161. (venous adj cannul\$).tw.
- 162. (venous adj line?).tw.
- 163. arthrocentesis/
- 164. arthrocent\$.tw.
- 165. joint aspiration/
- 166. (joint adj aspiration).tw.
- 167. (joint adj effusion).tw.
- 168. (joint adj sepsis).tw.
- 169. "synovial fluid aspiration".tw.
- 170. thoracocentesis/
- 171. thoracentes\$.tw.
- 172. thoracocentes\$.tw.
- 173. (pleural adj tap\$).tw.
- 174. "pleural fluid aspiration?".tw.
- 175. Paracentesis/
- 176. paracentes\$.tw.
- 177. (peritoneal adj tap\$).tw.
- 178. lumbar puncture/
- 179. (lumbar adj puncture?).tw.
- 180. (lumbar adj tap\$).tw.
- 181. (spinal adj punctu\$).tw.
- 182. (spine adj punctur\$).tw.
- 183. (spinal adj tap\$).tw.
- 184. or/154-183
- 185. 63 and 153 and 184

- 186. ((procedur* or clinical* or technical*) adj2 (skill? or abilit\$ or competen\$ or aptitude or proficien\$)).tw. [truncation added to 'clinical' and 'technical']
- 187. 63 and 153 and procedur*2.tw. and (186 or exp competence/) [NB: .st.fs does not exist in Embase; clinical competence is from 2006 -]
- 188. (exp animals/ or exp animal experimentation/ or nonhuman/) not ((exp animals/ or exp animal experimentation/ or nonhuman/) and exp human/)
- 189. 63 or 153
- 190. (185 or 187) and 189
- 191. 190 not 188
- 192. limit 192 to embase
- 193. limit 193 to (book or book series or conference proceeding or "conference review")
- 194. 193 not "194".mp. [mp=title, abstract, subject headings, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword]
- 195. surgical procedures, operative/
- 196. Endovascular Procedures/
- 197. endoscopy, digestive system/
- 198. Gastroenterostomy/
- 199. Surgical Procedures, Minimally Invasive/
- 200. Surgical Procedures, Elective/
- 201. Laparoscopy/
- 202. (laparoscop* or "minimally invasive" or endoscop* or cholecystect*).tw.
- 203. or/196-203
- 204. 195 not "204".mp. [mp=title, abstract, subject headings, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword]
- 205. limit 191 to embase
- 206. remove duplicates from 205
- 207. limit 206 to (book or book series or conference proceeding or "conference review")
- 208. 206 not 207
- 209. or/195-202
- 210. 208 not 209
- 211. limit 210 to yr="2014 -Current"
- 212. 211 not 7
- 213. 212 not 8
- 214. 213 not (or/16-17)
- 215. 214 not (or/27-30)
- 216. 215 not 195
- 217. (hysteroscop* or peripheral*).tw.
- 218. 216 not 217
- 219. (PICC or surg* or anastomosis).tw.
- 220. 218 not 219
- 221. (embol* or biopsy or intraoss* or dentis* or dental* or resuscit*).tw.
- 222. 220 not 221

Supplemental Digital Appendix 2

Data Extraction Form for Realist Synthesis

Context	Mechanism	Outcome
<ul style="list-style-type: none"> • Reasons for the training intervention? (e.g., complication rates too high, local trainee need assessment, external drivers like ABIM or RCSPC). • Who was there? learner(s) / instructor(s) / patient(s) • What were trainees taught about the procedure (e.g., technical skills, indications, resource utilization, communication skills)? • Where did training take place? (i.e., setting) • When did training occur? (e.g., at what stage of training?) • How were resources acquired? How was faculty/educator buy-in generated? • Was the training standalone, or part of a larger system-level change (e.g., CLABSI bundles etc.)? • Was the training stand-alone or integrated with other parts of the curriculum (e.g., academic half-day vs. ongoing course vs. just-in time training)? • What role is the trainee expected to play in the procedure after training (e.g., primary operator vs. referral to other services)? 	<ul style="list-style-type: none"> • What are the underlying assumptions about how this intervention is supposed to improve competence? <ul style="list-style-type: none"> ◦ Hypothesized educational mechanisms of intervention? ◦ What are the hunches/expectations/rationales and rationalizations for why this was supposed to work? • Was any theory mentioned as inspiring the intervention? <ul style="list-style-type: none"> ◦ If so, only note if they actually used the theory to design the intervention (i.e., didn't just name a theory) 	<ul style="list-style-type: none"> • To what degree do you believe the mechanism(s) was well implemented and tested by the outcome measures/design of this study? • Do the measured outcomes “fit with” the proposed mechanism (e.g., intervention aimed at changing behaviour but measures knowledge outcomes)? • Did the outcomes follow the hypothesized effect? Why or why not? • Did the intervention ‘misfire’ or work differently than expected (e.g., participant follow up was problematic, lots of drop outs, etc.)? How so? • Do the authors provide a list of barriers and/or facilitators? What are they? • Can you suggest anything else that may be driving the outcomes other than those stated by the authors?

Supplemental Digital Appendix 3

Study Characteristics of 91 Full-Text Articles Included Prior to Realist Synthesis

Study characteristic	No. of studies (n = 91)*	No. of participants (n = 6201)
Study design		
Single group cross-sectional	3	309
Single group pre-test, post-test	43	3475
Nonrandomized, multiple groups	24	1306
Qualitative	1	11
Randomized, controlled trial	20	1100
Geographical location		
USA	70	4848
Canada	11	698
America	1	75
United Kingdom	1	30
Europe	4	82
Asia	2	74
Oceania	2	394
Study setting		
Non-clinical setting (incl. simulation, computer-based, etc.)	61	3938
Practice setting (hospital, field, clinic)	9	219
Both	21	2044
Procedural skill studied**		
Lumbar puncture	26	2293
Arthrocentesis	9	655
Paracentesis	12	871
Thoracentesis	13	483
Central line insertion	62	4434
Ultra-sound guidance used in training?		
Yes	42	1774
No	46	4266
Could not tell	3	161
Patient demographics reported?		
Yes	22	1689
No	26	1721
N/A	43	2791
Participants**		
Medical students	18	965
Physicians, postgraduate training	64	4288
Physicians in practice	11	666
Nurse students	1	25
Nurses in practice	64	4288
Other	2	56
Mix of healthcare professionals, without breakdown	13	76

Clinical specialty**		
Anesthesia	10	653
Critical care	16	1659
Emergency medicine	23	1603
Internal medicine, general or subspecialty	45	3176
Family medicine	3	94
Lab medicine/pathology/radiology	2	430
Obstetrics/gynecology	1	242
Pediatrics	19	1588
Surgery	11	480
Other	1	428
Trainee class captured above	8	320
Could not tell	1	74
Outcomes**		
Reaction	44	3679
Knowledge	26	1928
Skill, time	9	311
Skill, non-time process	37	1900
Skill, product	6	259
Behavior, time	6	222
Behavior, non-time	27	2358
Patient outcome	42	3263
Study quality (MERSQI score, out of 18)		
All studies, grand mean = 12.1 ± 2.6 (STDEV)	90	6201
MERSQI > 12.7 points	42	3046

* 19 of 91 studies did not report sample size, this effects sample size estimates in all other categories.

** The number of studies and learners in some subgroups may sum to more than the number for all studies, because several studies included >1 procedure, >1 learner group, fit within >1 clinical specialty, or reported multiple outcomes.

Supplemental Digital Appendix 4

Study Characteristics of 58 Abstracts Included Prior to Realist Synthesis

Study characteristic	No. of studies (n = 58)*	No. of participants (n = 1625)
Geographical location		
USA	15	593
Canada	1	Undefined
Europe	2	Undefined
Asia	1	20
Could not tell	39	1012
Study setting		
Non-clinical setting (incl. simulation, computer-based, etc.)	36	1312
Practice setting (hospital, field, clinic)	8	53
Both	9	123
Could not tell	5	137
Procedural skill studied**		
Lumbar puncture	14	233
Arthrocentesis	7	251
Paracentesis	4	79
Thoracentesis	5	12
Central line insertion	39	1131
Ultra-sound guidance used in training?		
Yes	20	600
No	27	859
Could not tell	11	166
Patient demographics reported?		
Yes	3	76
No	21	430
N/A	33	1090
Could not tell	1	29
Participants**		
Medical students	6	136
Physicians, postgraduate training	37	1386
Physicians in practice	1	21
Nursing students	1	25
Nurses in practice	0	0
Mix of healthcare professionals, without breakdown†	14	Undefined
Clinical specialty**		
Anesthesia	2	37
Critical care	13	346
Emergency medicine	24	337
Internal medicine, general or subspecialty	22	763
Family medicine	1	Undefined
Lab medicine/pathology/radiology	1	Undefined

Pediatrics	4	101
Trainee class captured above	1	23
Could not tell	3	121
Outcomes**		
Reaction	25	827
Knowledge	13	505
Skill, time	4	166
Skill, non-time process	19	609
Skill, product	3	124
Behavior, time	2	Undefined
Behavior, non-time	11	182
Patient outcome	21	433

* 26 of 58 abstracts did not report sample size, this effects sample size estimates in all other categories.

** The number of abstracts and learners in some subgroups may sum to more than the number for all abstracts, because several studies included >1 procedure, >1 learner group, fit within >1 clinical specialty, or reported multiple outcomes.