

**Online Supplemental Material for:
Cook, et al.
Comparative Effectiveness of Technology-Enhanced Simulation vs
Other Instructional Methods: A Systematic Review and Meta-Analysis**

Appendix 1. Full search strategy and detailed methods

A. Base search: July 30, 2010, updated May 11, 2011

MEDLINE, EMBASE, and CINAHL

The following search was run on MEDLINE, EMBASE, and CINAHL. The EMBASE search was modified to use Emtree subject headings.

1. exp education, medical/ or exp education, nursing/ or exp students, health occupations/ or exp students, nursing/ or exp students, medical/
2. exp faculty/ or exp schools/ or educational, professional/ or "internship and residency".mp. or ed.fs. [mp=title, original title, abstract, name of substance word, subject heading word, unique identifier]
3. curricul*.mp. or teaching methods/ or learn*.mp. or train*.mp. or skill*.mp. [mp=title, original title, abstract, name of substance word, subject heading word, unique identifier]
4. (simulat* or virtual).mp. or computer simulation/ or patient simulation/ or manikin*.mp. or mannikin*.mp. or mannequin*.mp. or cadaver*.mp. or animals/ or harvey.mp. or (sim adj man).mp. or laerdal.mp. or vrmist.mp. or (vr adj mist).mp. [mp=title, original title, abstract, name of substance word, subject heading word, unique identifier]
5. exp education, medical/ or exp education, nursing/ or exp students, health occupations/ or exp students, nursing/ or exp students, medical/
6. exp faculty/ or exp schools/ or educational, professional/ or "internship and residency"/ or ed.fs.
7. 5 or 6
8. exp *surgical procedures, operative/
9. exp *"Diagnostic Techniques and Procedures"/
10. 7 and (8 or 9)
11. computer simulation/ or simulat*.ti,ab. or manikin*.mp. or mannikin*.mp. or mannequin*.mp. or models, anatomic/ or virtual.mp. or (bench adj2 model*).mp. [mp=title, original title, abstract, name of substance word, subject heading word, unique identifier]
12. 7 and 11
13. (8 or 9) and 12
14. 12 or 13
15. (evaluat* or assess* or compar* or impact* or effect* or validat* or improv* or measure* or reliab* or random* or control* or pretest* or chang* or cohort*).mp. [mp=title, original title, abstract, name of substance word, subject heading word, unique identifier]
16. 14 and (15 or educational measurement/)
17. limit 14 to (clinical trial, all or clinical trial, phase i or clinical trial, phase ii or clinical trial, phase iii or clinical trial, phase iv or clinical trial or comparative study or controlled clinical trial or evaluation studies or meta analysis or multicenter study or randomized controlled trial or "research support, american recovery and reinvestment act" or research support, nih, extramural or research support, nih, intramural or research support, non us gov't or research support, us gov't, non phs or research support, us gov't, phs or validation studies)
18. 16 or 17

PsycINFO

1 exp graduate education/

2 "Professional Education & Training ".cc.

3 "Curriculum & Programs & Teaching Methods ".cc.

4 exp computer simulation/ or exp simulation/

5 exp health personnel/

6 (1 or 5) and (2 or 3) and simulation*.mp. [mp=title, abstract, heading word, table of contents, key concepts]

7 (1 or 5) and 4

8 6 or 7

ERIC

ERIC results for: (kw: healthcare or kw: medical or kw: nursing OR kw: nurses or kw: surgical) AND (kw: simulat* or kw: virtual or kw: manikin* or kw: mannikin or kw: cadaver*) AND (kw: education or kw: teach OR kw: teaching or kw: learn* or kw: training or kw: train or kw: curricul*) AND (kw: competenc* OR kw: skills or kw: skill or kw: assessment or kw: compare OR kw: comparative or kw: comparison or kw: measure* or kw: evaluat*)

Scopus

((TITLE-ABS-KEY((simulat* OR virtual OR manikin* OR mannikin* OR "sim man" OR harvey OR laerdal OR "vr mist" OR cadaver*) AND (medical OR surgical OR clinician* OR resident OR physician* OR nurs* OR "health care"))) AND TITLE-ABS-KEY((educat* OR train* OR student*) AND (performance OR proficien* OR mastery OR skill* OR competen*))) AND TITLE(simulat* OR virtual OR manikin* OR mannikin* OR "sim man" OR harvey OR laerdal OR "vr mist" OR cadaver*) AND TITLE-ABS-KEY(outcome* OR trial* OR program* OR evaluat* OR assess* OR measure* OR compar*) AND NOT ("standardized patients" OR "human standardized") AND NOT SRCTYPE("article in press") AND NOT PMID(1* OR *2 OR 3* OR 4* OR *5 OR 6* OR 7* OR 8* OR 9*)

Web of Science

1 Topic=((medical or nurse* or nursing or clinical or hospital* or physician* or surgical) SAME (educat* or student* OR interns* or train* or residency) AND (simulat* or virtual or cadaver* or manikin* or mannikin* or mannequin* or "sim man" or harvey or laerdal or "vr mist")) AND Topic=(competenc* or skill* or mastery or measure* or compar* or proficien* or quality)
Databases=SCI-EXPANDED Timespan=1993-2009

2 TI=((medical or nurse* or nursing or clinical or hospital* or physician* or surgical) SAME (educat* or student* OR interns* or train* or residency))
Databases=SCI-EXPANDED Timespan=1993-2009

3 #2 AND #1
Databases=SCI-EXPANDED Timespan=1993-2009

4 #2 AND #1
Refined by: Document Type=(ARTICLE)
Databases=SCI-EXPANDED Timespan=1993-2009

B. Full index search August 3, 2010, updated May 11, 2011

We included the entire index (since volume 1) of the journals *Simulation in Healthcare* and *Clinical Simulation in Nursing*.

C. Bibliography search

We included full bibliography from the following review articles:

2005

Aucar JA, Groch NR, Troxel SA, Eubanks SW. A review of surgical simulation with attention to validation methodology. *Surg Laparosc Endosc Percutan Tech*. 2005 Apr;15(2):82-9.

Hamilton R. Nurses' knowledge and skill retention following cardiopulmonary resuscitation training: a review of the literature. *J Adv Nurs*. 2005 Aug;51(3):288-97.

Issenberg SB, McGaghie WC, Petrusa ER, Lee Gordon D, Scalese RJ. Features and uses of high-fidelity medical simulations that lead to effective learning: a BEME systematic review. *Med Teach*. 2005 Jan;27(1):10-28.

2006

Sutherland LM, Middleton PF, Anthony A, Hamdorf J, Cregan P, Scott D, Maddern GJ. Surgical simulation: a systematic review. *Ann Surg*. 2006 Mar;243(3):291-300.

2008

Gurusamy KS, Aggarwal R, Palanivelu L, Davidson BR. Virtual reality training for surgical trainees in laparoscopic surgery. *Cochrane Database Syst Rev*. 2009 Jan 21;(1):CD006575. and Systematic review of randomized controlled trials on the effectiveness of virtual reality training for laparoscopic surgery. *Br J Surg*. 2008 Sep;95(9):1088-97.

McLaughlin S, Fitch MT, Goyal DG, Hayden E, Kauh CY, Laack TA, Nowicki T, Okuda Y, Palm K, Pozner CN, Vozenilek J, Wang E, Gordon JA; SAEM Technology in Medical Education Committee and the Simulation Interest Group. Simulation in graduate medical education 2008: a review for emergency medicine. *Acad Emerg Med*. 2008 Nov;15(11):1117-29.

Salas E, DiazGranados D, Klein C, Burke CS, Stagl KC, Goodwin GF, Halpin SM. Does team training improve team performance? A meta-analysis. *Hum Factors*. 2008 Dec;50(6):903-33.

Sturm LP, Windsor JA, Cosman PH, Cregan P, Hewett PJ, Maddern GJ. A systematic review of skills transfer after surgical simulation training. *Ann Surg*. 2008 Aug;248(2):166-79.

2010

Cant RP, Cooper SJ. Simulation-based learning in nurse education: systematic review. *Adv Nurs*. 2010 Jan;66(1):3-15.

McGaghie WC, Issenberg SB, Petrusa ER, Scalese RJ. A critical review of simulation-based medical education research: 2003-2009. *Med Educ*. 2010 Jan;44(1):50-63.

Merién AE, van de Ven J, Mol BW, Houterman S, Oei SG. Multidisciplinary team training in a simulation setting for acute obstetric emergencies: a systematic review. *Obstet Gynecol*. 2010 May;115(5):1021-31.

D. Extended search Sept. 22, 2010 (SCOPUS) updated May 11, 2011

((TITLE-ABS-KEY((simulator* OR simulation* OR manikin* OR mannikin* OR mannequin* OR virtual OR multimedia) AND (medicine OR medical OR pediatric* OR paediatric* OR surgery OR surgical OR surgeon* OR internist* OR orthopedic* OR orthopaedic* OR cardiovasc* OR endoscop* OR laparoscop* OR anesthes* OR anaesthet* OR emergency OR trauma OR dental OR dentist* OR nursing OR nurse* OR endovascular OR colonoscop* OR sigmoidoscop* OR intravenous OR arterial OR gastroenterology OR "minimally invasive" OR suture* OR diagnostic* OR ultrasound*) AND (resident* OR residenc* OR internship OR trainee OR student* OR professional* OR practitioner* OR "health care" OR physician* OR nurse OR nursing OR clinical OR bedside) AND (acquisition* OR training OR teaching OR curricul* OR mastery OR skill* OR retention OR learn* OR educat* OR expert* OR competen* OR "high fidelity" OR "low fidelity" OR competen* OR novice* OR proficien* OR adverse OR error*)))) AND ((random* OR blind* OR valid* OR outcome* OR controlled))

Appendix Table 2. List of all included studies

Legend

Trainees: MS=medical student, PG=postgraduate physician trainee, MD=practicing physician, RN=nurse or nursing student, EMT=emergency medical technician / paramedic / first responder or EMT student, D=dentist or dental student, V=veterinarian or veterinary student, C=chiropractor or student, O=other / mixed.

N: Number of outcome observations (group 1, group 2); this is usually the number of trainees, but in some cases reflects the number of teams observed or the number of patient observations. X=Crossover.

RCT=randomized controlled trial.

Comp (Comparison intervention): C=computer assisted instruction (including virtual patients); FL=face-to-face lecture; FS=face-to-face small group; P=paper/textbook; SP=standardized patients or real patients; V=video instruction.

Instructional design: Codes indicate the relative between-intervention differences in key instructional methods; namely, did the simulation intervention have more (S>C), less (S<C), or the same (S=C) amount of selected instructional design enhancements; blank cells indicate we were unable to determine intensity.

Outcomes: Sa=Satisfaction, K=knowledge, ST=skill-time, SPc=skill-process, SPd=skill-product, BT=behavior-time, BP=behavior-process, P=patient effects.

Quality: MERSQI=Medical Education Research Study Quality Instrument (maximum score 18); NOS=modified Newcastle-Ottawa scale (maximum score 6).

Citation (sorted by year then author)	Participants			Topic	Instructional design					Outcomes	Quality	
	Trainee	N	RCT		Comp.	Cognitive load	Feedback	Group work	Time learning		MERSQI	NOS
Nelson LH. Use of professional patients in teaching pelvic examinations. <i>Obstet Gynecol.</i> 1978; 52:630-3.	MS	15,15	Yes	Physical exam	SP	S=C	S=C	S=C		SPc	12.5	4
Lefcoe DL, et al. Simulated models: a mode for instruction in root planing procedures. <i>Educ Dir Dent Aux.</i> 1979; 3:20-4.	O	5,7	Yes	Dental cleaning	SP	S=C	S<C	S=C		P	13.5	5
Salvendy G, et al. The development and validation of an analytical training program for medical suturing. <i>Hum Factors.</i> 1980; 22:153-170.	MS	9,9	Yes	Open surgery/suturing	V	S=C	S=C	S>C		ST, SPc	13.5	4
Ovassapian A, et al. Learning fiberoptic intubation: use of simulators v. traditional teaching. <i>Br J Anaesth.</i> 1988; 61:217-20.	PG	16,16	Yes	Intubation	FL	S=C	S>C	S>C	S>C	P	14	3
Waugh RA, et al. Multimedia computer-assisted instruction in cardiology. <i>Arch Intern Med.</i> 1995; 155:197-203.	MS	111,71		Physical exam	V	S=C	S=C	S=C	S=C	K	9.5	1
Jiang XM. Effects of simulated teaching in the delivery room [Chinese]. <i>Chinese Journal of Nursing [Zhonghua Hu Li Za Zhi]</i> . 1997; 32:220-1.	O	32,30	Yes	Obstetrics	FL		S>C	S>C		K, SPc	12.5	3
Limpaphayom K, et al. The effectiveness of model-based training in accelerating IUD skill acquisition. A study of midwives in Thailand. <i>Br J Fam Plann.</i> 1997; 23:58-61.	O	148,137		Obstetrics	FL		S=C	S>C	S=C	Sa, K, BP, P	14	4

Citation (sorted by year then author)	Participants			Topic	Comp.	Instructional design				Outcomes	Quality	
	Trainee	N	RCT			Cognitive load	Feedback	Group work	Time learning		MERSQI	NOS
Peugnet F, et al. Virtual reality versus conventional training in retinal photocoagulation: a first clinical assessment. <i>Comput Aided Surg.</i> 1998; 3:20-6.	PG	5,3	Yes	Microsurgery/Ophthalmology	SP	S=C	S=C	S=C	S=C	BP	14	4
Young TJ, et al. A cervical manikin procedure for chiropractic skills development. <i>J Manipulative Physiol Ther.</i> 1998; 21:241-5.	C	6,14	Yes	Chiropractic manipulation	SP	S=C	S=C	S=C		SPc	12.5	5
Gilbart MK, et al. A computer-based trauma simulator for teaching trauma management skills. <i>Am J Surg.</i> 2000; 179:223-228.	MS	41,41	Yes	Resuscitation (BLS,ACLS,ATLS)	FS	S<C	S=C	S=C	S=C	Sa, SPc	12.5	5
Knudson MM, et al. Training residents using simulation technology: experience with ultrasound for trauma. <i>Journal of Trauma: Injury Infection & Critical Care.</i> 2000; 48:659-65.	PG	37,37		Radiology/other noninvasive dx	SP	S=C	S=C	S=C	S=C	K	12	2
Naik VN, et al. Fiberoptic orotracheal intubation on anesthetized patients: Do manipulation skills learned on a simple model transfer into the operating room? <i>Anesthesiology.</i> 2001; 95:343-348.	PG	12,12	Yes	Intubation	FL	S=C	S>C	S>C	S=C	BT, BP, P	16	4
Ost D, et al. Assessment of a bronchoscopy simulator. <i>Am J Respir Crit Care Med.</i> 2001; 164:2248-55.	PG	3,3	Yes	Endoscopy (GI,Urology,Bronch.)	SP	S=C	S>C	S=C	S=C	BT, BP	13	4
Pugh CM, et al. Use of a mechanical simulator to assess pelvic examination skills. <i>Journal of the American Medical Association.</i> 2001; 286:1021-3.	MS	30,23	Yes	Physical exam	FL			S=C		ST, SPc, SPd	11.5	4
Salen P, et al. Fast education: a comparison of teaching models for trauma sonography. <i>J Emerg Med.</i> 2001; 20:421-5.	PG, MD	10,10	Yes	Radiology/other noninvasive dx	SP	S=C	S=C	S=C	S=C	Sa, K	11.5	3
Tsai M-D, et al. Virtual reality orthopedic surgery simulator. <i>Comput Biol Med.</i> 2001; 31:333-51.	PG, MD	16X		Open surgery/suturing	P	S<C	S=C	S=C		Sa	6	1
Matsumoto ED, et al. The effect of bench model fidelity on endourological skills: a randomized controlled study. <i>J Urol.</i> 2002; 167:1243-7.	MS	17,7	Yes	Endoscopy (GI,Urology,Bronch.)	FL	S=C	S>C	S>C	S=C	ST, SPc, SPd	14.5	5
Modell JH, et al. Using the human patient simulator to educate students of veterinary medicine. <i>Journal of Veterinary Medical Education.</i> 2002; 29:111-6.	V	20,20	Yes	Anesthesia	P	S<C		S>C	S=C	K	11.5	2

Citation (sorted by year then author)	Participants			Topic	Comp.	Instructional design				Outcomes	Quality	
	Trainee	N	RCT			Cognitive load	Feedback	Group work	Time learning		MERSQI	NOS
Morgan PJ, et al. Simulation technology: a comparison of experiential and visual learning for undergraduate medical students. <i>Anesthesiology</i> . 2002; 96:10-6.	MS	72,72	Yes	Anesthesia	V	S<C	S=C	S=C	S=C	Sa, K, SPc	12.5	6
Multak N, et al. Human patient simulation: a preliminary report of an innovative training tool for physician assistant education. <i>Perspective on Physician Assistant Education</i> . 2002; 13:103-105.	O	28,28		Physical exam,Critical care	FS	S=C	S=C	S=C	S=C	K	9.5	2
Nyssen A-S, et al. A comparison of the training value of two types of anesthesia simulators: computer screen-based and mannequin-based simulators. <i>Anesth Analg</i> . 2002; 94:1560-5.	PG	10,10		Anesthesia	C	S<C	S=C	S>C		ST, SPc	13.5	3
Gerson LB, et al. A prospective randomized trial comparing a virtual reality simulator to bedside teaching for training in sigmoidoscopy. <i>Endoscopy</i> . 2003; 35:569-575.	PG	9,7		Endoscopy (GI,Urology,Bronch.)	SP	S<C	S=C	S=C	S<C	BT, BP, P	13.5	2
Jeffries PR, et al. Technology-based vs. traditional instruction. A comparison of two methods for teaching the skill of performing a 12-lead ECG. <i>Nurs Educ Perspect</i> . 2003; 24:70-4.	RN	30,43	Yes	Radiology/other noninvasive dx	C	S=C	S<C	S>C	S=C	Sa, K, SPc	14.5	5
Nackman GB, et al. Effective use of human simulators in surgical education. <i>J Surg Res</i> . 2003; 115:214-8.	MS	54,27		Critical care	FS	S<C	S=C	S=C	S=C	K, SPc	12.5	3
Curran VR, et al. Evaluation of the effect of a computerized training simulator (ANAKIN) on the retention of neonatal resuscitation skills. <i>Teach Learn Med</i> . 2004; 16:157-164.	MS	16,15	Yes	Resuscitation (BLS,ACLS,ATLS)	V		S>C	S=C		K, SPc	14	3
Grober ED, et al. Laboratory based training in urological microsurgery with bench model simulators: a randomized controlled trial evaluating the durability of technical skill. <i>J Urol</i> . 2004; 172:378-381.	PG	13,5	Yes	Microsurgery/Ophthalmology	FL	S=C	S>C	S=C	S>C	SPc, SPd	12.5	5
Grober ED, et al. The educational impact of bench model fidelity on the acquisition of technical skill: the use of clinically relevant outcome measures. <i>Ann Surg</i> . 2004; 240:374-381.	PG	21,10	Yes	Microsurgery/Ophthalmology	FL	S=C	S>C	S>C	S>C	ST, SPc, SPd	13.5	5
Hariri S, et al. Evaluation of a surgical simulator for learning clinical anatomy. <i>Med Educ</i> . 2004; 38:896-902.	MS	15,14	Yes	Min. invasive surg.	P	S=C	S=C	S=C	S=C	Sa, K	12.5	3

Citation (sorted by year then author)	Participants			Topic	Comp.	Instructional design				Outcomes	Quality	
	Trainee	N	RCT			Cognitive load	Feedback	Group work	Time learning		MERSQI	NOS
Velmahos GC, et al. Cognitive task analysis for teaching technical skills in an inanimate surgical skills laboratory. The American Journal of Surgery. 2004; 187:114-119.	PG	12,14	Yes	Venous access	SP	S>C	S=C	S=C		K, BT, BP, P	16	5
Hall RE, et al. Human patient simulation is effective for teaching paramedic students endotracheal intubation. Acad Emerg Med. 2005; 12:850-855.	EMT	18,18	Yes	Intubation	SP	S=C	S=C	S>C		ST, SPd	12.5	5
Leopold SS, et al. Impact of educational intervention on confidence and competence in the performance of a simple surgical task. Journal of Bone & Joint Surgery American Volume. 2005; 87:1031-7.	MD, RN, O	31,31	Yes	Percutaneous proc.	P	S=C	S>C	S=C	S=C	SPc	12.5	4
Mabry RL. Use of a hemorrhage simulator to train military medics. Mil Med. 2005; 170:921-5.	EMT	38,45		Resuscitation (BLS,ACLS,ATLS)	SP		S=C	S=C		ST, SPd	11.5	2
Mueller MP, et al. Teaching antiarrhythmic therapy and ECG in simulator-based interdisciplinary undergraduate medical education. Br J Anaesth. 2005; 95:300-4.	MS	111,107	Yes	Resuscitation (BLS,ACLS,ATLS)	C	S=C	S=C	S=C	S=C	Sa	10	5
Stitik TP, et al. Injections in patients with osteoarthritis and other musculoskeletal disorders: use of synthetic injection models for teaching physiatry residents. Am J Phys Med Rehabil. 2005; 84:550-9.	PG	15,15	Yes	Percutaneous proc.	P	S=C	S=C	S>C	S=C	K, SPc, BP	12	5
Tanoue K, et al. Effectiveness of training for endoscopic surgery using a simulator with virtual reality: Randomized study. International Congress Series. 2005; 1281:515-520.	MS	20,15	Yes	Min. invasive surg.	V	S=C	S>C	S=C	S>C	ST, SPc	12.5	4
Chen J-S, et al. Validation of a computer-based bronchoscopy simulator developed in Taiwan. J Formos Med Assoc. 2006; 105:569-576.	O	10,10	Yes	Endoscopy (GI,Urology,Bronch.)	V	S<C		S>C		Sa	10	3
Descarreux M, et al. Learning spinal manipulation: the importance of augmented feedback relating to various kinetic parameters. Spine J. 2006; 6:138-145.	C	15,16	Yes	spinal manipulation	SP	S=C	S>C	S=C	S=C	SPc	12.5	4

Citation (sorted by year then author)	Participants			Topic	Comp.	Instructional design				Outcomes	Quality	
	Trainee	N	RCT			Cognitive load	Feedback	Group work	Time learning		MERSQI	NOS
Gordon JA, et al. A randomized controlled trial of simulation-based teaching versus traditional instruction in medicine: a pilot study among clinical medical students. <i>Adv Health Sci Educ Theory Pract.</i> 2006; 11:33-39.	MS	38X	Yes	Communication skill,Physiology:physiology and pharmacology	FL			S>C	S=C	K	13.5	5
Kimura T, et al. Usefulness of a virtual reality simulator or training box for endoscopic surgery training. <i>Surg Endosc.</i> 2006; 20:656-659.	MS	6,4		Min. invasive surg.	V	S=C	S>C	S>C		ST, SPc	11.5	2
Makinen M, et al. Teaching basic life support to nurses. <i>Eur J Anaesthesiol.</i> 2006; 23:327-31.	RN	16,20	Yes	Resuscitation (BLS,ACLS,ATLS)	C	S=C	S=C	S>C	S>C	SPc	13.5	4
Steadman RH, et al. Simulation-based training is superior to problem-based learning for the acquisition of critical assessment and management skills. <i>Crit Care Med.</i> 2006; 34:151-7.	MS	15,16	Yes	Resuscitation (BLS,ACLS,ATLS)	FS	S<C	S>C	S>C	S=C	SPc	13.5	5
Birch L, et al. Obstetric skills drills: evaluation of teaching methods. <i>Nurse Educ Today.</i> 2007; 27:915-922.	PG, O	2,2	Yes	Obstetrics	FL	S<C	S>C	S>C	S=C	SPc	13.5	5
Nilsson TA, et al. A randomized trial of simulation-based versus conventional training of dental student skill at interpreting spatial information in radiographs. <i>Simul Healthc.</i> 2007; 2:164-9.	D	28,29	Yes	Radiology/other noninvasive dx,Dentistry	C	S=C	S=C		S=C	K	12.5	5
Scherer YK, et al. A comparison of clinical simulation and case study presentation on nurse practitioner students' knowledge and confidence in managing a cardiac event. <i>International Journal of Nursing Education Scholarship.</i> 2007; 4:Article 22.	RN	13,10	Yes	Resuscitation (BLS,ACLS,ATLS)	FS	S<C	S=C	S<C	S<C	Sa, K, SPc	12.5	6
Schwartz LR, et al. A randomized comparison trial of case-based learning versus human patient simulation in medical student education. <i>Acad Emerg Med.</i> 2007; 14:130-7.	MS	50,52	Yes	Acute chest pain	FS	S<C	S=C	S>C	S=C	SPc	13.5	5
Shepherd IA, et al. Enhancing graduate nurses' health assessment knowledge and skills using low-fidelity adult human simulation. <i>Simul Healthc.</i> 2007; 2:16-24.	RN	23,26	Yes	Resuscitation (BLS,ACLS,ATLS)	FS	S<C	S=C	S=C	S=C	SPc	14.5	4

Citation (sorted by year then author)	Participants			Topic	Comp.	Instructional design				Outcomes	Quality	
	Trainee	N	RCT			Cognitive load	Feedback	Group work	Time learning		MERSQI	NOS
Wong G, et al. A trend toward improved learning of cardiovascular pathophysiology in medical students from using a human patient simulator: results of a pilot study. <i>Adv Physiol Educ.</i> 2007; 31:372.	MS	10,9	Yes	Physiology:CV pathophysiology	FL	S=C	S>C	S>C	S=C	K	11.5	4
Alverson DC, et al. Medical students learn over distance using virtual reality simulation. <i>Simul Healthc.</i> 2008; 3:10-15.	MS	18,18		Physical exam,Critical thinking	FS	S<C	S=C	S=C		Sa	9.5	2
Brannan JD, et al. Simulator effects on cognitive skills and confidence levels. <i>J Nurs Educ.</i> 2008; 47:495-500.	RN	54,53		Physiology:pathophysiology of acute MI	FL	S=C	S>C	S>C	S=C	K, SPc	13.5	5
Gillett B, et al. Simulation in a disaster drill: comparison of high-fidelity simulators versus trained actors. <i>Acad Emerg Med.</i> 2008; 15:1144-1151.	PG, MD, RN, O	78X		Resuscitation (BLS,ACLS,ATLS),mass casualty drills	SP	S=C	S=C	S=C		SPc	10	1
Johnson PL, Jr. Multiple comparisons among mechanical lung simulators using differences in pre-and post scores of allied health students. <i>Respiratory Care Education Annual.</i> 2008; 17:23-33.	O	9,8	Yes	Intubation,lung mechanics	C		S=C	S=C		K	14.5	3
Knudson MM, et al. Trauma training in simulation: translating skills from SIM time to real time. <i>Journal of Trauma, Injury, Infection, and Critical Care.</i> 2008; 64:255-63.	PG	6,4	Yes	Resuscitation (BLS,ACLS,ATLS)	FL	S<C	S=C	S>C	S=C	K, SPc	14	4
Ravert P. Patient simulator sessions and critical thinking. <i>J Nurs Educ.</i> 2008; 47:557-62.	RN	12,13	Yes	Critical thinking	FS		S=C	S=C	S=C	K	12.5	3
Tsai S-L, et al. The use of virtual reality computer simulation in learning Port-A cath injection. <i>Adv Health Sci Educ Theory Pract.</i> 2008; 13:71-87.	RN	37,40	Yes	Venous access	FL	S<C	S=C	S>C	S=C	K, SPc	14.5	5
Verdaasdonk EGG, et al. Transfer validity of laparoscopic knot-tying training on a VR simulator to a realistic environment: A randomized controlled trial. <i>Surg Endosc.</i> 2008; 22:1636-1642.	PG	9,10	Yes	Min. invasive surg.	V	S=C	S>C	S=C		ST, SPc	13.5	5
Wang EE, et al. Resident response to integration of simulation-based education into emergency medicine conference. <i>Acad Emerg Med.</i> 2008; 15:1207-10.	PG	42X		Various topics emergency medicine (lecture series)	FL			S>C	S=C	Sa, K	7.5	2
Youngblood P, et al. Design, development, and evaluation of an online virtual emergency department for training trauma teams. <i>Simul Healthc.</i> 2008; 3:146-53.	MS, PG	14,16	Yes	Resuscitation (BLS,ACLS,ATLS)	C	S=C	S=C	S=C	S=C	Sa, SPc	15	3

Citation (sorted by year then author)	Participants			Topic	Comp.	Instructional design				Outcomes	Quality	
	Trainee	N	RCT			Cognitive load	Feedback	Group work	Time learning		MERSQI	NOS
Youngquist ST, et al. Paramedic self-efficacy and skill retention in pediatric airway management. Acad Emerg Med. 2008; 15:1295-303.	EMT	66,52		Intubation	V			S>C		SPd	13.5	3
Ali J, et al. The standardized live patient and mechanical patient models--their roles in trauma teaching. Journal of Trauma, Injury, Infection, and Critical Care. 2009; 66:98-102.	MS	24,24	Yes	Resuscitation (BLS,ACLS,ATLS)	SP		S=C	S=C		Sa, K, SPc	13.5	4
Hallikainen J, et al. Teaching anaesthesia induction to medical students: comparison between full-scale simulation and supervised teaching in the operating theatre. Eur J Anaesthesiol. 2009; 26:101-104.	MS	23,18	Yes	Anesthesia,Intubation	SP	S=C	S=C		S=C	SPc	13.5	4
Keegan R, et al. Use of the virtual ventilator, a screen-based computer simulation, to teach the principles of mechanical ventilation. Journal of Veterinary Medical Education. 2009; 36:436-443.	V	52,57	Yes	Anesthesia	C	S<C	S=C	S=C	S=C	Sa, K	12.5	4
Narra P, et al. Videoscopic phantom-based angiographic simulation: effect of brief angiographic simulator practice on vessel cannulation times. J Vasc Interv Radiol. 2009; 20:1215-23.	MS, PG	20,20	Yes	Endovascular proc.	C	S=C		S>C	S=C	ST, SPc, SPd	12.5	4
Nunnink L, et al. In situ simulation-based team training for post-cardiac surgical emergency chest reopen in the intensive care unit. Anaesth Intensive Care. 2009; 37:74-8.	PG, MD, RN	24,24		Open surgery/suturing,Critical thinking	V	S<C	S>C	S>C	S=C	K, SPc	11.5	3
Sotto JAR, et al. Exporting simulation technology to the Philippines: a comparative study of traditional versus simulation methods for teaching intravenous cannulation. Stud Health Technol Inform. 2009; 142:346-51.	MS	20,20	Yes	Venous access	SP	S=C	S>C	S=C	S>C	BT, BP, P	16.5	4
Ten Eyck RP, et al. Improved medical student satisfaction and test performance with a simulation-based emergency medicine curriculum: a randomized controlled trial. Ann Emerg Med. 2009; 54:684-91.	MS	90X	Yes	Critical thinking,Emerg topics	FS	S=C	S>C	S=C	S=C	K	12.5	5

Citation (sorted by year then author)	Participants			Topic	Comp.	Instructional design				Outcomes	Quality	
	Trainee	N	RCT			Cognitive load	Feedback	Group work	Time learning		MERSQI	NOS
Wenk M, et al. Simulation-based medical education is no better than problem-based discussions and induces misjudgment in self-assessment. <i>Adv Health Sci Educ Theory Pract.</i> 2009; 14:159-171.	MS	16,16	Yes	Critical thinking	FS	S=C	S>C	S<C	S=C	Sa, K, SPc	14.5	6
de Giovanni D, et al. Relative effectiveness of high- versus low-fidelity simulation in learning heart sounds. <i>Med Educ.</i> 2009; 43:661-668.	MS	18,19	Yes	Physical exam	C	S=C	S=C	S=C	S=C	SPd	14.5	4
Andreatta PB, et al. Virtual reality triage training provides a viable solution for disaster-preparedness. <i>Acad Emerg Med.</i> 2010; 17:870-876.	PG	7,7	Yes	mass casualty triage	SP	S=C	S=C	S=C	S=C	K, SPc, SPd	12.5	2
Bonnetain E, et al. Benefits of computer screen-based simulation in learning cardiac arrest procedures. <i>Med Educ.</i> 2010; 44:716-722.	MS	14,14	Yes	Resuscitation (BLS,ACLS,ATLS)	C		S=C	S>C	S=C	ST, SPc	13.5	3
Bruppacher HR, et al. Simulation-based training improves physicians' performance in patient care in high-stakes clinical setting of cardiac surgery. <i>Anesthesiology.</i> 2010; 112:985-992.	PG	10,10	Yes	weaning from bypass	FL	S<C	S>C	S=C	S=C	BP	15	5
Corbridge SJ, et al. Online learning versus simulation for teaching principles of mechanical ventilation to nurse practitioner students. <i>International Journal of Nursing Education Scholarship.</i> 2010; 7:1-10.	RN	10,10	Yes	mechanical ventilation	C	S<C		S>C		Sa, K	12.5	3
Daniels K, et al. Prospective randomized trial of simulation versus didactic teaching for obstetrical emergencies. <i>Simul Healthc.</i> 2010; 5:40-45.	PG, RN	4,4	Yes	Obstetrics	FL	S<C		S=C	S=C	K, SPc	14.5	5
Delasobera BE, et al. Evaluating the efficacy of simulators and multimedia for refreshing ACLS skills in India. <i>Resuscitation.</i> 2010; 81:217-223.	EMT	39,38		Resuscitation (BLS,ACLS,ATLS)	C		S>C	S>C	S=C	K, SPc	13.5	4
Ford DG, et al. Impact of simulation-based learning on medication error rates in critically ill patients. <i>Intensive Care Med.</i> 2010; 36:1526-1531.	RN	12,12		medication errors	FL	S<C		S=C	S=C	BP	13	3
Garg A, et al. Modern moulage: evaluating the use of 3-dimensional prosthetic mimics in a dermatology teaching program for second-year medical students. <i>Arch Dermatol.</i> 2010; 146:143-146.	MS	49,41	Yes	Physical exam	FL	S=C	S=C	S=C	S=C	SPc	11.5	3

Citation (sorted by year then author)	Participants			Topic	Comp.	Instructional design				Outcomes	Quality	
	Trainee	N	RCT			Cognitive load	Feedback	Group work	Time learning		MERSQI	NOS
Haycock A, et al. Training and transfer of colonoscopy skills: a multinational, randomized, blinded, controlled trial of simulator versus bedside training. <i>Gastrointest Endosc.</i> 2010; 71:298-307.	PG, RN, O	18,18	Yes	Endoscopy (GI,Urology,Bronch.)	SP		S<C	S=C	S=C	ST, SPc, BT, BP, P	15	5
Hobgood C, et al. Teamwork training with nursing and medical students: Does the method matter? Results of an interinstitutional, interdisciplinary collaboration. <i>Qual Saf Health Care.</i> 2010; 19:e25	MS, RN	14,20	Yes	Resuscitation (BLS,ACLS,ATLS)	FL	S<C	S>C	S>C	S=C	K, SPc	14	5
Howard VM, et al. Human patient simulators and interactive case studies: a comparative analysis of learning outcomes and student perceptions. <i>Comput Inform Nurs.</i> 2010; 28:42-48.	RN	25,24	Yes	Critical thinking	FS	S<C	S>C	S=C	S=C	Sa, K	15	3
Liaw SY, et al. Developing clinical competency in crisis event management: an integrated simulation problem-based learning activity. <i>Adv Health Sci Educ Theory Pract.</i> 2010; 15:403-413.	RN	31X		Team training	FS	S<C	S>C	S=C	S=C	SPc	12.5	3
Patel M, et al. Use of a beef tongue model and instructional video for teaching residents fourth-degree laceration repair. <i>International Urogynecology Journal.</i> 2010; 21:353-8.	PG	11,13	Yes	Open surgery/suturing	V	S=C	S>C	S>C	S=C	K, SPc	13.5	6
Reynolds A, et al. Simulation for teaching normal delivery and shoulder dystocia to midwives in training. <i>Education for Health: Change in Learning & Practice.</i> 2010; 23:1-8.	O	25,24	Yes	Obstetrics	FL	S=C	S>C	S>C	S=C	Sa, K	12.5	6
Ruessler M, et al. Simulation training improves ability to manage medical emergencies. <i>Emerg Med J.</i> 2010; 27:734-738.	MS	22,22		Resuscitation (BLS,ACLS,ATLS)	SP		S>C	S>C	S=C	SPc	13.5	2
Siassakos D, et al. Exploratory randomized controlled trial of hybrid obstetric simulation training for undergraduate students. <i>Simul Healthc.</i> 2010; 5:193-198.	MS	11,9	Yes	Obstetrics	FS	S=C	S>C			SPc, SPd	15.5	4
Ten Eyck RP, et al. Improved fourth-year medical student clinical decision-making performance as a resuscitation team leader after a simulation-based curriculum. <i>Simul Healthc.</i> 2010; 5:139-145.	MS	34,34	Yes	Resuscitation (BLS,ACLS,ATLS), Team training, ER resuscitation	FS	S<C	S=C	S=C	S=C	ST, SPc	13.5	5

Citation (sorted by year then author)	Participants			Topic	Comp.	Instructional design				Outcomes	Quality	
	Trainee	N	RCT			Cognitive load	Feedback	Group work	Time learning		MERSQI	NOS
Yang LY, et al. The use of human patient simulator in enhancing medical students understanding of crisis recognition and resuscitation. International Medical Journal. 2010; 17:209-211.	MS	37,40	Yes	Resuscitation (BLS,ACLS,ATLS)	FL			S=C	S=C	K	12.5	5
Beddingfield S, et al. The effect of high-fidelity simulation on examination performance. Teaching and Learning in Nursing. 2011; 6:46-49.	RN	24X		Postoperative nursing	SP	S=C	S>C	S>C		K	11.5	4
Campos JH, et al. Training in placement of the left-sided double-lumen tube among non-thoracic anaesthesiologists: Intubation model simulator versus computer-based digital video disc, a randomised controlled trial. Eur J Anaesthesiol. 2011; 28:169-174.	PG, MD	12,11	Yes	Intubation	C	S<C	S>C	S=C	S=C	BT, P	14	5
Damewood S, et al. Comparison of a multimedia simulator to a human model for teaching FAST exam image interpretation and image acquisition. Acad Emerg Med. 2011; 18:413-419.	MS	39,48	Yes	Radiology/other noninvasive dx	SP		S=C	S=C		K, SPc	13.5	5
McCoy CE, et al. Prospective randomized crossover study of simulation vs. didactics for teaching medical students the assessment and management of critically ill patients. J Emerg Med. 2011; 40:448-55.	MS	28X	Yes	Critical thinking	FL			S>C	S=C	SPc	12.5	4
Parker RA, et al. Pediatric clinical simulation: a pilot project. J Nurs Educ. 2011; 50:105-111.	RN	18,23	Yes	Nursing tasks	SP		S=C	S>C	S=C	K	12.5	4
Petscavage JM, et al. Cost analysis and feasibility of high-fidelity simulation based radiology contrast reaction curriculum. Acad Radiol. 2011; 18:107-112.	PG	23,21	Yes	Resuscitation (BLS,ACLS,ATLS)	FL		S>C	S>C	S>C	Sa, K	8.5	2
Swanson EA, et al. Comparison of selected teaching strategies incorporating simulation and student outcomes. Clinical Simulation in Nursing. 2011; 7(3):e81-e90.	RN	48,48	Yes	Critical thinking	FS	S<C	S=C	S=C	S=C	SPc	14.5	4

Appendix Table 3. Comparative costs of simulation vs other instruction

Citation	Simulation Cost	Traditional Cost	Comment	Other outcomes and effect size
Limpaphayom K, et al. Br. J. Fam. Plann. 1997;23:58-61.	\$134,783 (\$7583)	\$384,894 (\$3294)	Overall Simulation training cost was half that of Traditional because of course duration (2 week vs 6 week on site course). If exclude travel costs, then cost (in parentheses) of Traditional was half the cost of Simulation.	Satisfaction 0.8 Knowledge 0.5 Behaviors 2.8 Patient effects 0.25
de Giovanni D, et al. Med. Educ. 2009;43:661-668.	\$75,000	\$130	Initial cost of Harvey simulator vs cost of training CD.	Skill product 0.4
Nunnink L, et al. Anaesth. Intensive Care. 2009;37:74-78.	60 min.	0 min.	Staff supervisory time per simulation session (30 min x 2 people) vs stand-alone video (no supervision).	Knowledge 0.6 Skill process 0.6
Delasobera BE, et al. Resuscitation. 2010;81:217-223.	\$23,463	\$119	Total cost for simulation equipment vs software multi-user license.	Knowledge 0.1 Skill process 0.5
Petscavage JM, et al. Acad. Radiol. 2011;18:107-112.	\$5975 + 7 days	\$100 + 2 days	Detailed cost of training including faculty time for development and implementation.	Satisfaction 1.3 Knowledge 1.2