

Online Supplementary Document

George et al. Online eLearning for undergraduates in health professions: A systematic review of the impact on knowledge, skills, attitudes and satisfaction
J Glob Health 2014;4:010406

1: Definition of the six eLearning categories

Six broad categories of eLearning interventions, based on the technologies employed. The categories were defined as follows:

- Offline computer-based eLearning: standalone applications where internet or intranet connections are not required for the delivery of the learning activities. The main tasks of the eLearning software in this category are usually performed on a PC or laptop. The delivery channels are usually CD-ROM or USB memory sticks. Alternatively, the delivery mode of the software can be via a networked connection, as long as the learning activities do not rely on this connection.
- Online and local area network-based eLearning: interventions that use the transmission control protocol (TCP) and the internet protocol (IP) to provide the full functionalities of the educational intervention. As implied by the terminology used, the delivery channels are usually the internet or a local area network.
- Psychomotor skills trainer: technology that will develop fine motor coordination skills and techniques in education, such as the precise use of instruments of tools.
- Virtual reality environments: computer-generated representations of a real or artificial environment. This can be interacted with by external involvement, allowing for a first-person active learning experience.
- Digital game-based learning: the application of game principles and mechanics in non-game contexts to engage users in solving problems and improve their engagement, attitudes, motivation and knowledge.
- mLearning: any eLearning intervention that uses handheld, mobile devices to deliver educational content such as a mobile phone, iPod or tablet.

2: Fields included in the data extraction form

1. Study ID

2.1. Journal where the study was published

2.2. Type of publication

2.3. Authors' affiliation

3.1. Study design as specified in the report

3.2. Study aims & objectives

3.3. Countries where the study was conducted

3.4. WHO region

3.5. World Bank income category

3.6. Study start date

3.7. Study end date

3.8. Method of comparison

4.1. Total number of participants invited to take part in the study

4.2. Total number of participants who agreed to take part in the study

4.3. Total number of participants meeting the inclusion criteria for participation in the study

4.4. Total number of participants included in the study

4.5. If cluster RCT, total number of clusters initially included in the study

4.6. If cluster RCT, total number of clusters randomised

4.7. Inclusion criteria

4.8. Exclusion criteria

5.1. Total number of experimental groups (including the control group)

5.2. Were groups tested for baseline differences?

5.2.1. If there were baseline differences, please specify what the difference was

5.3. Indicate the type of degree or qualification that participants were pursuing

If other, please specify:

5.4. Year of study within the anticipated degree or qualification

5.5. Control group

5.5.1. Total number of participants/clusters allocated to the control group

5.5.2. Mean age (standard deviation) of the participants in the control group

5.5.3. Name of educational intervention used as control

5.5.4. Description of the control condition

5.5.5. Field of study

5.6.6. Exposure to the control condition during the whole study

5.5.7. Total exposure time to the intervention

5.5.8. Type of technology/devices used to deliver the intervention

5.5.9. Delivery approach of the intervention

If other, please specify:

5.5.10. Was the usual delivery mode of the assessment changed?

5.5.11. If yes, please specify

5.5.12. Was the delivery mode of the assessment uniform across all the experimental groups?

5.6. Intervention group I

5.6.1. Total number of participants/clusters allocated to this intervention group.

5.6.2. Mean age (standard deviation) of the participants in this intervention group

5.6.3. Name of educational intervention used in this intervention group

5.6.4. Description of this intervention condition

5.6.5. Field of study

5.6.6. Exposure to this intervention condition during the whole study

5.6.7. Total exposure time to the intervention

5.6.8. Type of technology/devices used to deliver the intervention

5.6.9. Delivery approach of the intervention

If other, please specify:

5.6.10. Was the usual delivery mode of the assessment changed?

5.6.11. If yes, please specify

5.6.12. Was the delivery mode of the assessment uniform across all the experimental groups?

5.7. Intervention group II

5.7.1. Total number of participants/clusters allocated to this intervention group.

5.7.2. Mean age (standard deviation) of the participants in this intervention group

5.7.3. Name of educational intervention used in this intervention group

5.7.4. Description of this intervention condition

5.7.5. Field of study

5.7.6. Exposure to this intervention condition during the whole study

5.7.7. Total exposure time to the intervention

5.7.8. Type of technology/devices used to deliver the intervention

5.7.9. Delivery approach of the intervention

If other, please specify:

5.7.10. Was the usual delivery mode of the assessment changed?

5.7.11. If yes, please specify

5.7.12. Was the delivery mode of the assessment uniform across all the experimental groups?

5.8. Intervention group III

5.8.1. Total number of participants/clusters allocated to this intervention group.

5.8.2. Mean age (standard deviation) of the participants in this intervention group

5.8.3. Name of educational intervention used in this intervention group

5.8.4. Description of this intervention condition

5.8.5. Field of study

5.8.6. Exposure to this intervention condition during the whole study

5.8.7. Total exposure time to the intervention

5.8.8. Type of technology/devices used to deliver the intervention

5.8.9. Delivery approach of the intervention

If other, please specify:

5.8.10. Was the usual delivery mode of the assessment changed?

5.8.11. If yes, please specify

5.8.12. Was the delivery mode of the assessment uniform across all the experimental groups?

If more than 4 intervention groups (including the control group), please copy and paste the relevant cells as needed

6.1. Was 'Knowledge' measured? - If not, please go to section 6.2.

6.1.1. Instrument or measure used to assess knowledge - as specified by the study authors

6.1.2. Is this a validated instrument?

6.2. Were 'Skills' measured? - If not, please go to section 6.3.

6.2.1. Instrument or measure used to assess skills - as specified by the study authors

6.2.2. Is this a validated instrument?

6.3. Were 'Attitudes' measured? - If not, please go to section 6.4.

6.3.1. Instrument or measure used to assess attitudes - as specified by the study authors

6.3.2. Is this a validated instrument?

6.4. Was 'Student satisfaction' measured? - If not, please go to section 6.5.

6.4.1. Instrument or measure used to assess student satisfaction - as specified by the study authors

6.4.2. Is this a validated instrument?

6.5. Was an economic evaluation of the eLearning intervention performed?

6.5.1. Were quantitative indicators like costs, investments, hardware, software, license fees and benefits/savings of the eLearning intervention measured?

6.5.2. Was the urgency of the eLearning intervention (i.e., due to a new regulation or organisational demand) mentioned?

6.5.3. Were qualitative-strategic indicators of the eLearning intervention like quality and performance improvements measured?

6.5.4. Were external factors of the eLearning intervention like synergy effects or economies of scope measured?

6.5.5. Please list any additional economic indicators that were measured

7.1. Selection bias

7.1.1. Random sequence generation

7.1.1.1. Describe the method used to generate the allocation sequence in sufficient detail to allow an assessment of whether it should produce comparable groups

7.1.1.2. Please indicate your judgement

7.1.2. Allocation concealment

7.1.2.1. Describe the method used to conceal the allocation sequence in sufficient detail to determine whether intervention allocations could have been foreseen in advance of, or during, enrolment

7.1.2.2. Please indicate your judgement

7.2. Performance bias

7.2.1. Blinding of participants and personnel

7.2.1.1. Describe all measures used, if any, to blind study participants and personnel from knowledge of which intervention a participant received. Provide any information relating to whether the intended blinding was effective

7.2.1.2. Please indicate your judgement

7.3. Detection bias

7.3.1. Blinding of outcome assessment

7.3.1.1. Describe all measures used, if any, to blind outcome assessors from knowledge of which intervention a participant received. Provide any information relating to whether the intended blinding was effective

7.3.1.2. Please indicate your judgement

7.4. Attrition bias

7.4.1. Incomplete outcome data

7.4.1.1. Describe the completeness of outcome data for each main outcome, including attrition and exclusions from the analysis. State whether attrition and exclusions were reported, the numbers in each intervention group (compared with total randomized participants), reasons for attrition/exclusions where reported, and any re-inclusions in analyses performed by the review authors

7.4.1.2. Please indicate your judgement

7.5. Reporting bias

7.5.1. Selective reporting

7.5.1.1. State how the possibility of selective outcome reporting was examined by the review authors, and what was found.

7.5.1.2. Please indicate your judgement

7.6. Other bias

7.6.1. Other source of bias

7.6.1.1. State any important concerns about bias not addressed in the other domains in the tool

7.6.1.2. Please indicate your judgement

8.1. Recruitment bias

8.1.1. Please describe any evidence of recruitment bias.

8.2. Baseline imbalances

8.2.1. Please describe any evidence of baseline imbalances.

8.3. Loss of clusters

8.3.1. Please indicate any evidence of risk of bias due to loss of clusters.

8.4. Incorrect analysis

8.4.1. Please indicate any evidence of incorrect analysis.

9.1. Control group

9.1.1. Outcome reported

9.1.2. Measure of effect size (as measured by the study authors)

9.1.3. Measure of dispersion (as measured by the study authors)

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9.1.1. Outcome reported

9.1.2. Measure of effect size (as measured by the study authors)

9.1.3. Measure of dispersion (as measured by the study authors)

If more than one outcome was reported, please insert more cells here and copy and paste the relevant data entry boxes.

9.2. Intervention I group

9.2.1. Outcome reported

9.2.2. Measure of effect size (as measured by the study authors)

9.2.3. Measure of dispersion (as measured by the study authors)

9.2.1. Outcome reported

9.2.2. Measure of effect size (as measured by the study authors)

9.2.3. Measure of dispersion (as measured by the study authors)

9.2.1. Outcome reported

9.2.2. Measure of effect size (as measured by the study authors)

9.2.3. Measure of dispersion (as measured by the study authors)

9.2.1. Outcome reported

9.2.2. Measure of effect size (as measured by the study authors)

9.2.3. Measure of dispersion (as measured by the study authors)

If more than one outcome was reported, please insert more cells here and copy and paste the relevant data entry boxes.

9.3. Intervention II group

9.3.1. Outcome reported

9.3.2. Measure of effect size (as measured by the study authors)

9.3.3. Measure of dispersion (as measured by the study authors)

9.3.1. Outcome reported

9.3.2. Measure of effect size (as measured by the study authors)

9.3.3. Measure of dispersion (as measured by the study authors)

9.3.1. Outcome reported

9.3.2. Measure of effect size (as measured by the study authors)

9.3.3. Measure of dispersion (as measured by the study authors)

9.3.1. Outcome reported

9.3.2. Measure of effect size (as measured by the study authors)

9.3.3. Measure of dispersion (as measured by the study authors)

If more than one outcome was reported, please insert more cells here and copy and paste the relevant data entry boxes.

9.4. Intervention III group

9.4.1. Outcome reported

9.4.2. Measure of effect size (as measured by the study authors)

9.4.3. Measure of dispersion (as measured by the study authors)

9.4.1. Outcome reported

9.4.2. Measure of effect size (as measured by the study authors)

9.4.3. Measure of dispersion (as measured by the study authors)

9.4.1. Outcome reported

9.4.2. Measure of effect size (as measured by the study authors)

9.4.3. Measure of dispersion (as measured by the study authors)

If more than one outcome was reported, please insert more cells here and copy and paste the relevant data entry boxes.

9.5. Comparison I

9.5.1. Please indicate the intervention groups being compared

9.5.2. Please indicate the outcomes being compared

9.5.3. Statistical test used for the comparison

9.5.4. Result of the test

9.5.5. P value / Confidence intervals

9.6. Comparison II

9.6.1. Please indicate the intervention groups being compared

9.6.2. Please indicate the outcomes being compared

9.6.3. Statistical test used for the comparison

9.6.4. Result of the test

9.6.5. P value / Confidence intervals

9.7. Comparison III

9.7.1. Please indicate the intervention groups being compared

9.7.2. Please indicate the outcomes being compared

9.7.3. Statistical test used for the comparison

9.7.4. Result of the test

9.7.5. P value / Confidence intervals

9.8. Comparison IV

9.8.1. Please indicate the intervention groups being compared

9.8.2. Please indicate the outcomes being compared

9.8.3. Statistical test used for the comparison

9.8.4. Result of the test

9.8.5. P value / Confidence intervals

9.9. Comparison V

9.9.1. Please indicate the intervention groups being compared

9.9.2. Please indicate the outcomes being compared

9.9.3. Statistical test used for the comparison

9.9.4. Result of the test

9.9.5. P value / Confidence intervals

9.9. Comparison V

9.9.1. Please indicate the intervention groups being compared

9.9.2. Please indicate the outcomes being compared

9.9.3. Statistical test used for the comparison

9.9.4. Result of the test

9.9.5. P value / Confidence intervals

9.9. Comparison V

9.9.1. Please indicate the intervention groups being compared

9.9.2. Please indicate the outcomes being compared

9.9.3. Statistical test used for the comparison

9.9.4. Result of the test

9.9.5. P value / Confidence intervals

For each comparison conducted in the study, please copy and paste the cells as appropriate

10.1. Organisational setting

10.2. Technological infrastructure

10.3. Instructional Systems Design and Curriculum development

10.4. Delivery

10.5. Advantages of eLearning - as reported by the study authors

10.6. Disadvantages of eLearning - as reported by the study authors

11.1. Source of financing - as reported by the study authors

11.2. Did the intervention undergo a formal accreditation process within the host institution?

11.3. If yes, please describe

11.4. Was the eLearning intervention developed for this study consequently adopted as a formal method for the delivery of education at the host institution?

11.5. If yes, please specify

12.1. Study conclusions - as stated by the study authors

12.2. Limitations of the study - as reported by the study authors

12.3. Was contact with the study authors sought? - If No, please go to section 12.5

12.4. Please indicate the nature of the information requested from the study authors

12.5. Please indicate the results of the request for information

12.6. Additional notes

3: Results of electronic searches

Number of citations yielded by the electronic searches for each bibliographic database

Database	Results	
	Before de-duplication	After de-duplication
MEDLINE	941	806
EMBASE	3206	3123
PsycINFO	334	334
Web of Knowledge	6993	4099
ERIC	146	146
CENTRAL	588	584
Total	12208	9092

4: Characteristics of included studies for online computer-based eLearning

4: Characteristics of included studies for online eLearning

STUDY ID	Methods			Participants			Interventions		
	STUDY DESIGN	LOCATION	COMPARISON	TOTAL NUMBER	YEAR OF STUDY	HEALTHCARE SPECIALITY	CHARACTERISTICS	TIME AND TECHNOLOGY	TEST/OUTCOMES
Alhazem 2012a	RCT	UK	4 samples: control (total) Parallel	3	First year	Nursing	CG: students in the control group did not have access to Suthwick World but received all the usual supervision/academic teaching staff IG: students had access to Suthwick World, computer software designed to improve medication dose calculation problem-solving skills	4 7 months 4 Computer, Suthwick World software	Knowledge: overall numerical score
Alhazem 2012b	RCT	UK	4 samples: control (total) Parallel	2	First year	Nursing	CG: students in the control group did not have access to Suthwick World but received all usual supervision/academic teaching staff IG: Students had access to Suthwick World, computer software designed to improve medication dose calculation problem-solving skills	4 6 months 4 Computer, Suthwick World software	Knowledge: overall numerical score
Amey 2012	RCT	Spain	4 samples: control (total) Parallel	6	Second year	Physiotherapy	CG: books and case IG: students had access to website with detailed articles, including theory, images and self-assessment feature	4 3 weeks 4 computer, website	Knowledge: NSQ Skills: OSCE Satisfaction: positive Likert-scale overall score
Burns 2006	RCT	USA	4 samples: control (total) Parallel	8	Fourth year	Medicine	CG: students received no CG IG: students used the BMQ (beta) school	4 6 weeks 4 computer, website	Knowledge: standardized written examination Satisfaction: survey
Buchanan 2014	RCT	Switzerland	4 samples: control (total) Parallel	216	Final year	Nursing	CG: students received a lecture IG: an e-learning session on pressure ulcers	4 1 hour 4 computer, website	Knowledge: 3 or more independent assessments Satisfaction: overall value judgement observed on or reassurance etc
Burke 2010	RCT	UK	4 samples: control (total) Parallel	76	First year	Nursing	CG: students received a face-to-face session which reinforced the content and structure of the tutorial IG: students in the intervention group worked through the online tutorial which they accessed via a dedicated area on the university's virtual learning environment	4 1 hour 4 computer, online access	Skills: all search skills were involved a search of the cumulative index to nursing and all of health literature (CNRS) on a given topic area
Buswell 2007	RCT	USA	4 samples: control (total) Parallel	11	Second year to fourth year	Medicine	CG: students received lectures with no access to the web tutorial IG1: students in the computer group had access to the a computer tutorial on the web IG2: students in this group had access to both the lecture and web tutorial	4 4 hrs + 1 hr 4 computer with Macromedia Flash Cold Fusion Studio (Macromedia), RealVideo (realized), online access	Knowledge: cognitive assessment and instrument: All but one Likert-scale assessment
Carman 2011	RCT	Spain	4 samples: control (total) Parallel	6	N/A	Physiotherapy	CG: students received study questions and were allowed to self-refer to all notes online and books IG: students had access to the web-based intervention entitled Analyzing, Assessing, and Treating Smaller Oral Dental Health: Books: Game Studies on Oral Health/Practice of Dental Medicine	4 3 weeks 4 computer, website	Skills: OSCE All but one positive Likert-scale (3 overall positive responses) Satisfaction: positive Likert-scale (3 overall score) 10-dimension

STUDY ID	Methods			Participants			Interventions		
	STUDY DESIGN	LOCATION	COMPARISON	TOTAL NUMBER	YEAR OF STUDY	HEALTHCARE SPECIALITY	CHARACTERISTICS	TIME AND TECHNOLOGY	TEST (OUTCOMES)
	STUDY DESIGN	LOCATION	COMPARISON	TOTAL NUMBER	YEAR OF STUDY	HEALTHCARE SPECIALITY			
Chambers	RCT	Israel	4. web-based 4. control	50	Primary	Medicine	CG students had access to all resources on the Internet that were based on the study protocol. IG students had access to an ultra-brief website.	4. 2. 30 mins 4. computer, website, HTML, active server page (ASP), a database (SQL), a Microsoft	Knowledge: interactive evaluation on about medications
Chen et al	RCT	USA	4. web-based 4. control	67	1998	Healthcare provider/ students	CG students received no training and received only lines on book reading and online case. IG students received a virtual advance organizer. IG II students used the case advance organizer receiving the case, concept and explanation on the concept map in a web format.	4. 1 week 4. computer, a virtual case advance organizer, case advance organizer	Knowledge: concept map The objective included multiple choice and essay questions, post-test 1, quiz and a complex scenario question was administered one week after completion.
Chen et al	RCT	Taiwan	4. web-based 4. control	60	Fourth year	Nurses	CG students received only case material and received no additional case. IG students received on the case material used case computer based learning tool with which students could drill and practice case to help their learning through autonomous self-evaluation.	4. 10 weeks 4. computer, online access to the e-learning system	Knowledge: attitude and final test
Corcoran	RCT	USA	4. web-based 4. control	70	Third year	Medical	CG students received identical package of e-based clinical case material with no other instruction. IG students received a e-based network—CASE—that was taught as a method for identifying underlying disorders of health issues. IG II students had access to web material including slides and received the CASE e-enhanced instruction via the Internet.	4. 4 weeks 4. computer, website, video	Skill: performance simulation All built, used a standard literature (a normally disease to a normal sign)
D'Almeida et al	RCT	USA	4. web-based 4. control	80	N/A	Dentistry	CG students received no additional material beyond what was delivered in their curriculum. IG students received a web-based training program comprised of three interactive intervention components: a 15 min on-orientation and learning objectives. The content material was presented in a web format.	4. 3 weeks 4. computer, website	Knowledge, skill and attitudes were all measured using a 10-item Likert-type questionnaire based on the conceptual framework study.
Enderson et al	RCT	USA	4. web-based 4. control	80	Third year	Pharmacy	CG students received no intervention. IG students received a web-based tutorial.	4. 1 hour 4. computer, website, video	Knowledge: content-related question describing essential process of all not specified medication. Skill: new knowledge and attitude.
Farrington	RCT	South	4. web-based 4. control	70	Second year	Nurses	CG students were taught in an on-boarded clinical skills room and all resources of all the situation additional resources. IG students had access to Moodle® – for searching slides, learning necessary, read notes, looking web resources and linking to relevant website and questions.	4. 10 weeks 4. computer, online access	Knowledge: concept simulation Skill: attitude, practice Literature and open questions
Farrington et al	RCT	USA	4. web-based 4. control	70	First year	Dentistry	CG web-based self-instruction and all key audio case self-instruction. IG while case studied the narrative and using the all key audio case and the real language using the web-based format.	4. one day 4. all desired audio case access, computer and online access for the web-based self-instruction	Knowledge: concept fill in the blank/ oral case Skill: attitude, confidence Survey consisted of a questionnaire with Likert-type responses

STUDY ID	Methods			Participants			Interventions		
	STUDY DESIGN	LOCATION	COMPARISON	TOTAL NUMBER	YEAR OF STUDY	HEALTHCARE SPECIALITY	CHARACTERISTICS	TIME AND TECHNOLOGY	TEST OUTCOMES
Fluorocasts	RCT	USA	standard care multidisciplinary learning	26	Fourth year	Pharmacy	CG students received no intervention on their writing assignments KI students in this group were given a website address to access real-time lab courses which they were required to watch to ensure any their training and standards their course will not fall short in the use of inhalers and ear and eye drops	4 months computer with Powerpoint and Internet capabilities for digital slides and audio, available via web access of dvd	Knowledge to know over the
Health tools	RCT	Germany	standard care traditional learning	124	Fourth year + 1 year of medical training	Medicine	CG students received a paper book based didactic manual covering the intervention, but selected needs with multiple assessments and feedback throughout KI students received an online health skills course about oral cavity and dentures	4 days (1/2) computer website	Knowledge to know (KQ) Skill in 26 standardized tasks and seven questions assessed toward a procedural understanding of the course on Allergic dental caries on Current Medication Satisfaction coefficient in the Use of Computer-based media
Fitness	RCT	USA	standard care 4 learning	74	11/11	Nurse	CG students received a web-based course on cardiometabolic intervention KI: this group worked together on case studies, activities and critical thinking independently Students in the control group also used online case studies that understand the course content	4 weeks computer website	Knowledge to know (KQ) Skill in 10 standardized tasks Satisfaction: attitude toward computer-assisted instruction (a), 10 standardized tasks, each measured on a 5-point scale, and three factors (i.e. control, usability, usability)
Cardiovascular	RCT	Thailand	standard care multidisciplinary learning	26	Fourth year	Nurse	CG students received lecture and booklets on individuality KI students had access to a web-based learning unit around the lecture content and individuality	4 weeks computer capable of accessing interactive assets, a animation and online access	Knowledge to know (KQ) Skill in 10 standardized tasks Satisfaction: attitude toward computer-assisted instruction (a), 10 standardized tasks, each measured on a 5-point scale, and three factors (i.e. control, usability, usability)
Hourglass	RCT	USA	4 learning multidisciplinary learning	20	Third year	Medicine	CG students from the previous year served as historical control and address the second research question that compared students not at the intervention to those who did not KI students had access to the web-based standardized course case KI students worked in groups of three and conducted a total of three SP in course. Students received one of three sites in each encounter (linker, conductive encounter, observer) conducted the checklist on history taking and physical examination on history or observer conducted the checklist on communication	4 hours computer website	Skill in checklist Satisfaction: 64 items evaluation survey with responses on a Likert 5-point scale (1=not at all, 5=very good), and 4 (1=not at all, 5=very good)
Healthcare	RCT	USA	4 learning multidisciplinary learning	20	Second year	Medicine	CG students received a traditional lecture and group work KI students received a computer-assisted instruction manual was developed that covers the essential of all in animation and the manual was used to develop and distribute on network and distribution	4 days computer website	Knowledge to know (KQ) Skill in 10 standardized tasks

STUDY ID	Methods			Participants			Interventions		
	STUDY DESIGN	LOCATION	COMPARISON	TOTAL NUMBER	YEAR OF STUDY	HEALTHCARE SPECIALITY	CHARACTERISTICS	TIME AND TECHNOLOGY	TEST (OUTCOMES)
Johnson	RCT	USA	classroom vs. multifaceted	88	Fourth year	Medicine	CG students had to deal with a normal without the use of the Internet. IG these students had to design a nursing schedule into the website.	4 free N/A 4 computer, website	Knowledge (MO) Satisfaction (research form (increased in the test))
Parsons	RCT	Canada	classroom vs. multifaceted	7	Second year	Medicine	CG students were presented with the real-world case on pediatrics disorder. IG this group received an online course and had modules that covered pediatrics disorder.	4 a mixture on average 4 computer with online access with WebCT	Knowledge (MO) and direct content of the online material Satisfaction (questionnaire)
Markovitch	RCT	USA	classroom vs. classroom	33	Third year	Medicine	CG students received web-based training covering basic concepts: hypothesis and small-d algorithm tasks. IG students received interactive case education covering real-world case work: hypothesis and small-d algorithm.	4 IG: 10 a week IG: 6 weeks 4 computer with email, internet and online access	Knowledge (a self-reported score and self-rated MO)
Markovitch	RCT	USA	classroom vs. classroom	73	Third year	Medicine	CG students received a lesson daily. IG students received daily problem induction, evaluation and educational components whereby patients to case one were submitted online.	4 6 weeks 4 computer with email, internet, online access for "MyCourse" course management system	Knowledge (orthodontic assessment on form for each patient)
Konradi	RCT	USA	classroom vs. multifaceted	6	Second year	Dentistry	CG students received only hard copy of dental records. IG this group used digital records on computers.	4 free N/A 4 computer, online access	Knowledge (orthodontic assessment on form for each patient) Satisfaction (survey done at the end of the course for acceptance of the web-based recordation)
Leung	RCT	China	classroom vs. multifaceted	73	Fourth year	Medicine	CG students did not receive the workshop, no ill case-related material during their own history rotation. IG students received case in a workshop on clinical reason rather than web-based.	4 no mixture in course classes, final case workshop 4 computer, online access	Knowledge (clinical reasoning problems (CRP) score and clinical thinking inventory (CTI) score) Satisfaction (score before, questionnaire, each time, students rated the experience using a Likert scale (1=never did agree, 5=strongly agree))
Leung	RCT	USA	classroom vs. multifaceted	73	N/A	Medicine	CG students had to prepare a written article on unrelated case. IG 1. students conducted case on the computer IG 2. two computer case on feedback, self-regulation and outcomes.	4 free N/A 4 computer, online access	Knowledge (a test based on debatable final case that was discussed throughout the three-year study period, 25 open questions on conceptual, low-back pain, and history score (CG, computer case-related) were included in the exam. 25 Likert scale to complete the case. IG Satisfaction anonymous questionnaires – anonymous on a seven-point scale)
Leung	RCT	Canada	classroom vs. multifaceted	36	Second year	Medicine	CG students received a PowerPoint teaching session and were allowed to use two neuroanatomy textbooks. IG students used an access to a call action tool in electronic dental nerve tool one.	4 final case 4 computer, online access	Knowledge (a test based on debatable final case) Satisfaction (questionnaire and assessment on a seven-point scale)
Liberman	RCT	USA	classroom vs. multifaceted	33	Second year	Medicine	CG students were not assigned a patient and could not participate in the web discussion. IG students had access to an Internet connection and used the application to discuss a series of four cases involving substantial ethical problems.	4 free N/A 4 computer, online access	Knowledge (final written case analysis) Satisfaction (subjective evaluation of the course by both students (using a course-evaluation instrument) and faculty (all non-evaluation instrument developed for this study))

STUDY ID	Methods			Participants			Interventions		
	STUDY DESIGN	LOCATION	COMPARISON	TOTAL NUMBER	YEAR OF STUDY	HEALTHCARE SPECIALITY	CHARACTERISTICS	TIME AND TECHNOLOGY	TEST/OUTCOMES
Luzon	RCT	Taiwan	4-arm (vs. traditional learning)	14	Second year	Nurse	CG: evidence on pre- and classroom lecture and skill demonstration. IG: evidence were able to use a web-based course and were able to view the content on demand with access to a classroom, bulletin board, and email.	<ul style="list-style-type: none"> 4 days (N/A) 4 computer, online access and Intervention software 	<p>Knowledge: Increase of an infection knowledge assessment at day 0 and a quiz one.</p> <p>Skill: A 1-minute situational skill performance rating with possible score range from 0-100.</p>
Massachusetts	RCT	USA	4-arm (vs. traditional learning)	47	N/A	Nurse	CG: evidence independently read and learn from a pre-based traditional module. IG: evidence independently read and learn from a pre-based traditional module with links included. IG II: evidence viewed the pre-module in a mobile cell phone screen in the form of a web page.	<ul style="list-style-type: none"> 4 1 hour 4 computer, online access 	<p>Knowledge: vs. (NCO)</p> <p>All bodies go from awareness taking the respondents to a self-rated level of confidence on a 5-point scale ranging from no confidence at all to complete confidence.</p> <p>Satisfaction: evidence of a reaction survey the cards have were asked to rate satisfaction of the learning module on a scale of 1-5 (1 indicating strongly disagree and 5 indicating strongly agree)</p>
Mainhattan.com	RCT	Germany	4-arm (vs. traditional learning)	88	Fourth year	Medicine	CG: evidence looked at lecture procedure and recording in radiology and radiological four access the 4 learning online. IG: evidence viewed additional procedure and recording in radiology and radiological that case to the 4 learning online 4 case.	<ul style="list-style-type: none"> 4 days (N/A) 4 computer, online access 	<p>Knowledge: cases consisted of 100 cases, with 25 cases randomly chosen from a pool of 1072 cases.</p>
Manitoba.org	RCT	UK	4-arm (vs. traditional learning)	138	N/A	Medicine	CG: evidence were all via access to a learning management system through the course resources with no formal learning content. IG: evidence used an online acute breathless difficulty learning course.	<ul style="list-style-type: none"> 4 6 weeks 4 computer, online access 	<p>Knowledge: post intervention (NCO) assessment.</p> <p>All bodies: email course.</p>
Mathematics	RCT	Sweden	4-arm (vs. traditional learning)	18	Second year	Dentistry	CG: evidence on pre- and access to the case and reference material was available through a web-based case. IG: evidence had access case and reference material were available through interactive software.	<ul style="list-style-type: none"> 4 6 weeks 4 computer containing the intervention software and online access 	<p>Knowledge: within using within comparison between their answer and that of the expert and oral performance.</p> <p>Satisfaction: questionnaire.</p>
Merika.com	RCT	Germany	4-arm (vs. traditional learning)	85	Third year	Dentistry	CG: evidence received didactic lecture and self-paced learning on. IG: evidence had access online module.	<ul style="list-style-type: none"> 4 6 weeks 4 computer with online platform and email client 	<p>Knowledge: (NCO)</p> <p>All bodies: email course with answers chosen between 1 and 5 (1 = totally disagree, 5 = I totally agree), assessment of course.</p> <p>Satisfaction: questionnaire.</p>
Merika.com	RCT	Germany	4-arm (vs. traditional learning)	85	Third year	Dentistry	CG: evidence received a traditional lecture. IG: evidence had access to traditional face-to-face lecture, but also received email content via mobile 4 case 4 email case on the learning content of the lecture.	<ul style="list-style-type: none"> 4 6 30 minute sessions 4 computer with online platform and email client 	<p>Satisfaction: questionnaire.</p>

STUDY ID	Method			Participants			Interventions		
	STUDY DESIGN	LOCATION	COMPARISON	TOTAL NUMBER	YEAR OF STUDY	HEALTHCARE SPECIFICITY	CHARACTERISTICS	TIME AND TECHNOLOGY	TEST/OUTCOMES
	Control group	RCT	USA	4. simulated traditional learning	58	Third year	Medical	CG: students received traditional lecture-based IG: students received a web-based lecture program created to each lecture/discussion including the basic concepts essential to learn. Interactive forums	4 weeks computer with internet, audio and video support
Failure group	RCT	Canada	4. simulated traditional learning	81	Fourth year	Medical	CG: students received standard lecture- based with varying additional learning resources other than those recommended to all students IG1: students received same case studies as control, but in an interactive computer based format and used enriched with detail rich feedback IG2: students received both the standard clinical material usual resource computer based case studies	4 weeks computer with internet, software installed, online access and CD drive	Knowledge (40 MCQ) and patient modified question case- Satisfaction as a questionnaire of their perceptions of the value of their resources
Peer review	RCT	Germany	4. simulated traditional learning	94	Second and third medical semester	Dentary	CG: students received a lecture presented the same content. Included notes, audio- visuals, with the use of PowerPoint. It was available for the students to consult on or discuss during and after the lecture IG: students received a modular and online of course of clinical education, NRE and articles. It was linked with a search in the virtual space online for additional resources, with case presentation only, and further resources	4 sessions they lasted (average 60 minutes) computer with internet	Knowledge (7 MCQ) and three case presentations Satisfaction, awareness about educational and didactics value of the teaching methods were given and the students were asked to express their agreement on a con- sensus Likert scale (5-point agreement, from full agreement)
Problem based	RCT	USA and Israel	4. simulated traditional learning	55	Second and third year	All disciplines, nursing, physiotherapy	CG: students received a writing activities for biomedical advance module offered with face-to-face instruction IG: students used a writing activities conducted in a virtual and interactive virtual tools (ADR, email) and resources provided as tools	4 days (1/2) computer with Web + over the PowerPoint, Internet Process (ASP- SOWE) Internet, library (over social-media) access and email support	Knowledge (over written 6-articles online quiz + Satisfaction Likert scale) with peer-review interaction among discuss to several groups
Research group	RCT	Germany	4. simulated traditional learning	138	Fourth year	Medical	CG: students received traditional classroom teaching in course study on case histories IG: students used web-based collaborative teaching module on the diagnosis of several case of diagnosis	4 weeks web-based collaborative teaching module, 2 learning management systems (LMS) the internet live chat, asynchronous group discussion and the exchange of documents was used to create the online module	Knowledge (40 MCQ) (post-course) problem solving case (final case) Satisfaction questionnaire
Research group	RCT	Germany	4. simulated traditional learning	70	Fourth year	Medical	CG: no description given IG: students received case study on online module consisting in addition to the traditional multiple choice	4 hours case-based over week over 6 weeks computer with online access for the web-based learning management system (LMS)	Knowledge (40 MCQ) Satisfaction survey conducted at beginning and at the end of the 6- week course

STUDY ID	Methods			Participants			Interventions		
	STUDY DESIGN	LOCATION	COMPARISON	TOTAL NUMBER	YEAR OF STUDY	HEALTHCARE SPECIALITY	CHARACTERISTICS	TIME AND TECHNOLOGY	TEST/OUTCOMES
BK120004	RCT	Canada	4 learning vs traditional learning	8	Third and fourth year	Medicine	CG audience received no intervention and received only KI audience completed the ultra-rapid based course and procedure booklet	<ul style="list-style-type: none"> 4 minutes computer, online access with access for digital images, short clip, and instructional text, images, hospital website 	Knowledge post-test multiple choice examination
FR000006	RCT	Ireland	7.4 learning vs standard	8	Third year	Medicine	CG audience received course material offered through conventional method and were able to access in an email all available with an instructor for a novel interactive web-based learning KI audience used MIBCT access to the study materials, discussion forum, review system	<ul style="list-style-type: none"> 4 weeks computer, online access for MIBCT 	Knowledge post-test multiple choice, narrative and short answer questions Satisfaction: Impact of CT course of training and the Learning Experience' course of CT course on a novel Likert scale
50100005	RCT	USA	7.4 learning vs standard	8	Second to fourth year (mainly third year)	Medicine	CG audience received a PowerPoint presentation KI audience received an online self-paced, self-directed learning module provided self-education	<ul style="list-style-type: none"> 4 months computer, PowerPoint presentation and online access 	Knowledge measured with a modified version of the Dermatology Knowledge and Attitude survey
50100004	RCT	Sweden	4 learning vs standard	8	First year	Dentistry	CG audience were able to read the essential web-based slides KI audience had access to the same web-based slides but also to 6 different cases	<ul style="list-style-type: none"> 4 weeks computer, online access 	Knowledge assessed with 6 questions Skill performance was assessed on a scale from 1 to 4 (poor to excellent) for each of 6 different cases of hand washing Attitude questionnaire with 10 questions Overall knowledge and attitude questionnaire-based intervention and learning was filled in after completion of all the phases. 7 of these questions were answered on a Visual Analogue Scale (VAS) 0-100 mm and the remaining 3 were open text questions
50100002	RCT	The Netherlands	4 learning vs traditional learning	18	Second year	Medicine	CG audience received photocopied set of cases of an occupational medicine workbook, practical guidelines manual and advertisement KI audience had access to occupational medicine learning case on individual computers	<ul style="list-style-type: none"> 4 half a day computer, online access 	Knowledge: 10 questions divided in multiple choice, open-ended and multiple choice Attitude: 10 questions on a 5-point Likert scale was used with anchor statements: disagree to agree Satisfaction: 6 questions (1 was a general rating for satisfaction (range 1-10), 5 questions about satisfaction with the course content (1-point Likert scale), minimum score 5 (neutral) and 5 questions about satisfaction with learning (1-point Likert scale, minimum score 5 (neutral))
50100001	RCT	USA	4 learning vs traditional learning	8	Fourth year	Medicine	CG audience received a live lecture and then group discussion work KI audience received an interactive-based PowerPoint slide presentation from the same lecture with the option of audio	<ul style="list-style-type: none"> 4 days (1/2) computer, PowerPoint presentation and online access and audio 	Knowledge: an open book exam that has been used on the course for 1 year Satisfaction: audience used the post-test on all 4 their lectures on a 5-point Likert scale and they provided narrative about their experience with the live lecture and the online lecture

STUDY ID	Methods			Participants			Interventions		
	STUDY DESIGN	LOCATION	COMPARISON	TOTAL NUMBER	YEAR OF STUDY	HEALTHCARE SPECIALITY	CHARACTERISTICS	TIME AND TECHNOLOGY	TEST /OUTCOMES
	Solid state	RCT	USA	4 virtual vs 4 similar traditional learning	8	Third and fourth year	Medicine	G1: audience received an online lecture consisted of an Inimes-based PowerPoint™ slide presentation with no audio narration. K1: audience received an online lecture consisted of an Inimes-based PowerPoint™ slide presentation with audio narration.	• 4 hrs (K) • technical (K)(S)
Solid state	RCT	USA	4 similar vs traditional learning	8	Third year	All of the	G1: audience received lecture on general surgery and surgical assessment. K1: audience received lecture on general surgery and surgical assessment and additional virtual didactic conference.	• 4 hours • technology (K)(S)	Knowledge sub-quest one
Simulation	RCT	USA	4 similar vs traditional learning	21	N/A	Medicine	G1: audience were based on the standard neonatal resuscitation course. K1: audience had access to the standard neonatal educational programme and additional virtual didactic access to the guidelines of AHA/ACC, Baby Check Learning Module.	• 4 hours • technology (K)(S)	Skills: Formative assessment of neonatal resuscitation skills on standardized checklist. Satisfaction: measured using a Likert 5-point questionnaire.
Web form	RCT	Switzerland	4 similar vs traditional learning	16	Third year	Medicine	G1: audience received normal lecture included a video demonstration and access to a self-directed web-based learning module on anatomy created on K1. K1: audience received a self-directed web-based learning module on anatomy created on K1. K2: audience's confidence assessed concerning through role play in small groups, one medical student acted as a teacher and another one acted as the digital tutor. All had no standardized case description. K3: audience supported interaction with real patients, counselling encounters with real patients who smoke.	• 4 hours • computer, online access	Knowledge on MCQ Skills: role play OSCE
Substantiated form	RCT	USA	4 similar vs traditional learning	8	Third year	Medicine	G1: audience received two PowerPoint™ presented one. K1: audience had access web-based learning course.	• 4 hour • computer, online access and software for the web-based SimScore Interactive Medical Software.	Knowledge on-quest on coordination care, long-term medical on-line based on quiz on question case to diagnose the first case.
Simulation	RCT	USA	4 similar vs traditional learning	8	N/A	All of the	G1: audience received traditional methods of teaching and no access the intervention. K1: audience in the course not only underwent the traditional case files, but also were given access to a Virtual Cadaverology Clinic.	• 4 hrs (K) • computer, online access	For knowledge and ability of a patient, multiple-choice, short-answer, knowledge-based one- and two-second student satisfaction questionnaire was administered.
Transmission	RCT	USA	4 similar vs traditional learning	24	Second year	Pharmacy	G1: audience worked in small group worksheet. K1: audience used an Inimes-based tool for which they could develop any concerning three as they wished.	• 4 real time • computer and online access	Skills: overview and their inhibitor for our patients checklist.

STUDY ID	Methods			Participants			Interventions		
	STUDY DESIGN	LOCATION	COMPARISON	TOTAL NUMBER	YEAR OF STUDY	HEALTHCARE SPECIALITY	CHARACTERISTICS	TIME AND TECHNOLOGY	TEST /OUTCOMES
Trinkali 2011	RCT	USA	eLearning vs. traditional learning	94	Fifty year	Medicine	CG: students received a PowerPoint presentation and video IG: students received information through interactive multimedia slides, with external resources and 2 video cases with questions	<ul style="list-style-type: none"> 3 days before lecture until 1 day before OSCE computer (Java enabled) and online access 	Knowledge: 12 item multiple-choice test Skills: OSCE Attitude: a 12-item attitudes questionnaire with another 4-point scale (1 = strongly disagree, 2 = somewhat disagree, 3 = somewhat agree, 4 = strongly agree) was used to assess students' feeling toward patients with substance abuse and their treatment
Wang 2009	RCT	China	eLearning vs. traditional learning	123	Second year	Nursing	CG: students received a slideshow presentation IG: students received an online based resource in which had to self learn the topic which also allowed online discussion	<ul style="list-style-type: none"> time N/A computer and online access 	Knowledge: MCQ Satisfaction: questionnaire
Yeung 2012	RCT	UK	eLearning vs. traditional learning	78	Second year	Medicine	CG: students received a text/image based document IG: students received an online module with different views and an unlimited time allocation	<ul style="list-style-type: none"> time N/A computer and online access 	Knowledge: MCQ Satisfaction: subjective questionnaire using a 5-point Likert scale

CG: Control group

IG: Intervention group

*Publication contained two studies

5: Risk of bias in included studies

In this section we will cover risk of bias for the 52 included parallel RCTs studies. Risk of bias for the eight included cluster RCTs will be presented separately in a consecutive section.

Thirty-one of the studies were considered to be of low quality because of high risk of bias. [1-30] Twenty-nine of the studies [31-46] had one or more categories classified as an unclear risk of bias, especially regarding the allocation of participants to intervention groups. There was only one study [47] with all the categories classified as low risk of bias - see Figure 2 (Risk of bias graph) and Figure 3 (Risk of bias for each individual parallel RCT separately).

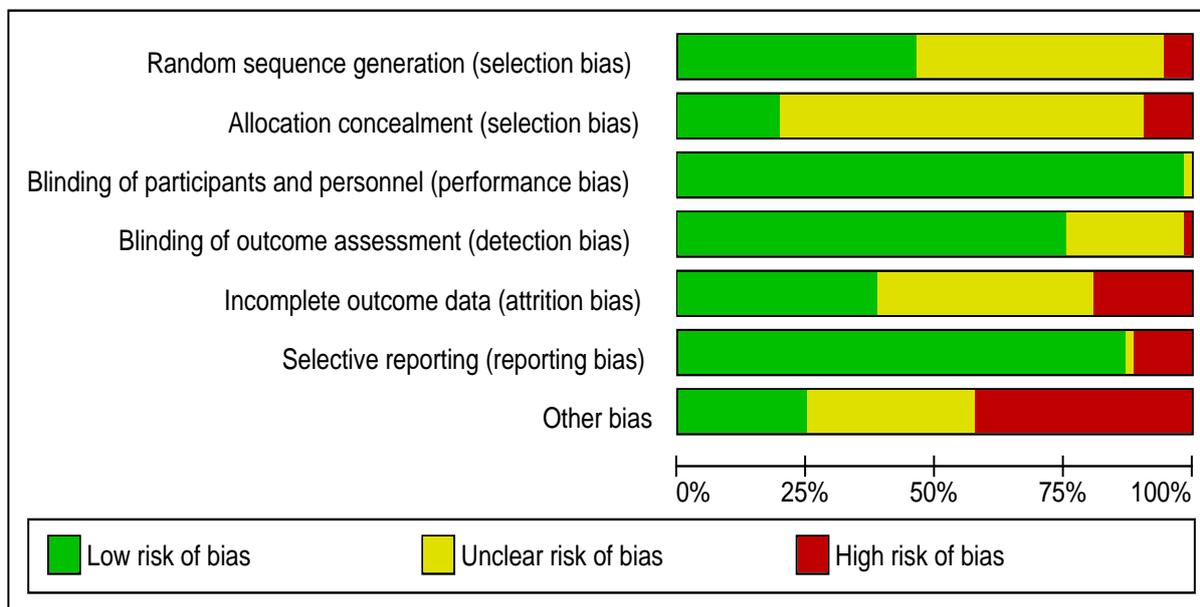


Figure 2. Risk of bias graph

	Random sequence generation (selection bias)	Allocation concealment (selection bias)	Blinding of participants and personnel (performance bias)	Blinding of outcome assessment (detection bias)	Incomplete outcome data (attrition bias)	Selective reporting (reporting bias)	Other bias
Ainsworth 2012a[83]	+	+	+	+	+	+	+
Ainsworth 2012b[83]	+	+	+	+	+	+	?
Arroyo-Morales 2012[57]	+	?	+	+	+	+	+
Beekman 2008[79]	+	?	+	+	+	+	?
Brettle 2013[53]	+	?	+	+	+	+	?
Buzzelli 2002[54]	?	?	+	+	+	+	+
Chao 2003[26]	?	?	+	+	+	+	?
Chen 2007[81]	+	+	+	+	+	+	+
C-Villanueva 2012[55]	+	?	+	+	+	+	+
Erickson 2003[30]	+	?	+	+	+	+	?
Fernandez 2011[76]	?	?	+	+	+	+	+
Fleming 2003[73]	+	?	+	+	+	+	?
Friedl 2006[32]	?	?	+	+	+	+	?
Frith 2003[74]	?	+	+	+	+	+	+
Gerdprasert 2011[33]	?	?	+	+	+	+	?
Hauer 2009[34]	?	?	+	+	+	+	+
Jenkins 2008[78]	+	?	+	+	+	+	?
Juliani 2011[25]	+	+	+	+	+	+	+
Kandasamy 2009[80]	+	+	+	+	+	+	?
Kerfoot 2008[35]	?	?	+	+	+	+	?
Kerfoot 2010[36]	?	?	+	+	+	+	+
Komolpis 2002[37]	?	?	+	+	+	+	+
Lee 2010[38]	+	?	+	+	+	+	+
Leong 2003[39]	+	?	+	+	+	+	+
Lewis 2011[40]	+	+	+	+	+	+	+
Lipman 2001[41]	?	?	+	+	+	+	?
Maag 2004[43]	?	?	+	+	+	+	+
Mahnken 2011[44]	+	+	+	+	+	+	+
Mattheos 2004[46]	+	?	+	+	+	+	?
Nkenke 2012[47]	?	?	?	?	?	?	+
Nkenke 2012a[48]	+	+	+	+	+	+	+
Ochoa 2008[49]	+	+	+	+	+	+	+
Palmer 2008[50]	?	?	+	+	+	+	+
Peroz 2009[51]	?	?	+	+	+	+	+
Phadtare 2009[52]	+	+	+	+	+	+	?
Raupach 2009[59]	?	?	+	+	+	+	+
Raupach 2010[60]	?	?	+	+	+	+	+
Ricks 2008[77]	+	?	+	+	+	+	?
Romanov 2006[61]	?	?	+	+	+	+	+
Salas 2013[62]	?	?	+	+	+	+	+
Schittek 2005[63]	?	?	+	+	+	+	+
Smits 2012[64]	+	?	+	+	+	+	+
Spickard 2002[65]	+	+	+	+	+	+	+
Spickard 2004[66]	?	?	+	+	+	+	+
Stain 2005[67]	?	?	?	?	?	?	?
Stewart 2013[68]	+	+	+	+	+	+	?
Stolz 2012[69]	+	?	+	+	+	+	+
Subramanian 2012[70]	?	?	+	+	+	+	?
Succar 2010[82]	?	?	+	+	+	+	+
Truncali 2011[72]	?	+	?	?	?	?	+
Wang 2009[56]	+	?	+	+	+	+	+
Yeung 2012[75]	+	+	+	+	+	+	+

Figure 3. Risk of bias for each individual parallel RCT separately

Random sequence generation and allocation (selection bias)

Most studies (25 of the 52 studies, 48%) included little or no information about the *random sequence generation* and were therefore classified as having an unclear risk of bias. [1, 3, 8, 11, 12, 14, 18, 19, 22-24, 30, 31, 33, 35, 38, 40, 41, 43, 44, 47-50] Only three of the 52 studies (6%) had a high risk of bias for *random sequence generation*. One [7] of these studies generated the allocation sequence by assigning students to an odd or even number in the order with which they were entering the room. The other two studies violated the randomization plan by letting students choose between three alternative assignments freely [6] or by assigning students to the study groups in a consecutive way, i.e. based on the order in which they undertook a specific internship.[9] The Random sequence generation was classified as judged to result in a low risk of bias for 24 [2, 5, 10, 13-16, 20, 21, 25, 27-30, 32, 36, 37, 39, 42, 45, 46, 51, 52] of the 52 studies (46%).

The method used in the majority of the cases to generate a random number sequence was computer software [5, 13-16, 21, 25, 27-30, 37, 39, 46, 51, 52]. Furthermore, one study used name drawing, [2] two studies used a random number table [20, 45] and one other used “odd” and “even” conditions from a random number series.[39]

There was no information about the allocation concealment method in 37 [1, 3, 4, 6, 8, 11-14, 16-22, 26-28, 31-36, 38-42, 44-46, 50, 53] out of the 52 trials (73%) and therefore these studies were classified as having an unclear risk of allocation bias. Five studies (10%) had high risk of allocation bias. One of these studies [2] facilitated its randomization process by drawing the name inside the class room within the presence of all class members; and another study [23] posted their randomization result on the website four days before the lecture. The other three studies [7, 9, 24] reported having problems in their randomization procedures, which made the allocation concealment impossible. Ten studies (19%) had a low risk of bias for allocation concealment. Four [25, 29, 30, 52] of these studies generated the random numbers on a computer and delivered them in a way that ensured concealment of allocation. Two studies from the same paper used the centralized randomization process.[15] The remaining four studies [10, 15, 36, 37, 42] used opaque envelopes for concealment.

Blinding (performance bias and detection bias)

The risk of bias assessment for blinding of participants and personnel focused only on the knowledge and skills outcomes. The risk of bias was classified as low for all but one study,[47] even though blinding of participants and personnel was not possible in any of these studies because of the nature of the intervention. The only study considered to have a high risk of bias related to blinding of participants and personnel [47] did not report any outcome on knowledge or skill. Our overall assessment for the performance bias was based on the fact that only the 43 studies investigating knowledge [2, 3, 5-12, 15-17, 20-23, 25-30, 32, 33, 35-40, 42, 44-46, 50, 53-58] and the 11 studies [1, 3, 6, 13, 14, 16, 21, 23, 32, 33, 52] measuring skills had an objective outcome assessment. Therefore, the assessment was considered impervious to the student’s opinion about the teaching method. As indicated before, subjective outcomes such as attitudes and student satisfaction were not included in the risk of bias assessment for *blinding of participants and personnel*. These outcomes are more prone to performance bias when participants aren’t blinded due to their subjective nature and also focusing on attitudes and student satisfaction would therefore have resulted in a high risk of bias in all studies.

Thirty-nine of the 52 included parallel RCTs (75%) were considered to be at low risk of bias for the *blinding of outcome assessment*. The risk of bias was considered low risk not only in studies where all outcome assessors were blinded [8, 14, 15, 19, 32, 42, 43, 50, 52] but also in studies with unblinded assessors as long as the method of outcome assessment included no element of interpretation and a classification of a result could be done unambiguously [2, 4, 5, 7, 9, 10, 12, 17, 18, 22, 24-29, 31, 33-36, 38-41, 45, 46, 53], e.g. the only assessment was a multiple choice test. Twelve studies (22%) were rated as having an unclear risk of bias due to the lack of information about blinding of the outcome assessors [1, 3, 6, 11, 13, 16, 20, 21, 23, 36, 37, 44]. Only one study [30] had high risk for detection bias because it reported a mixed knowledge outcome for which a part of the result was considered unblinded.

Incomplete outcome data (attrition bias)

As a consequence of the fact that none of the students were blinded there is a high risk of attrition bias for any outcome that relies on active participation of students for follow-up (e.g. answering a questionnaire on attitudes and satisfaction and taking a knowledge test).

A substantial number (10 out of 42, 19%) of the studies did not report complete outcome data (e.g. only reported the mean test score but did not report the number of students who were analysed) or had differential drop-out rates in the different intervention groups and were classified as high risk of bias. Two of high risk of bias studies (4%) showed a difference in the attrition/exclusion rates between the experimental groups. [1, 29] Five studies (12%) that were classified as having a high risk of bias had missing/unreported data and did not account for or comment on that. [13, 20, 23, 24, 28] The remaining three studies reported inconsistent sample sizes.[8, 22, 26] Twenty (38%) studies were classified as having a low risk of bias for incomplete outcome data. [3, 5, 6, 15-17, 27, 31-36, 40, 43, 46, 47, 50, 51] These studies reported whether attrition and exclusion had occurred. The information provided regarding the reason for not analysing all participants was either similar for the groups being compared and/or showed only a small and statistically insignificant difference between the studies.

Because details of attrition and exclusion were not reported, 22 studies (42%) were classified as having an unclear risk of bias for *incomplete outcome data* [2, 4, 7, 9-12, 14, 18, 19, 21, 25, 28, 38, 39, 41, 42, 44, 45, 52, 53]In these studies it was not clear if there was any level of attrition among the experimental groups at all.

Selective reporting (reporting bias)

The majority of studies (45 out of 52,87%) were rated as having a low risk of selective reporting bias [1, 4-14, 16-23, 25, 26, 28-47, 50-52]. The assessment of selective reporting bias required the authors to report results for all outcomes mentioned in the methods sections of the published articles; protocols were not available to our reviewers. Only one study (54) (5%) was rated as having unclear risk of selective reporting bias because the authors presented more results than the outcomes mentioned in the method section. Six out of the 52 studies (12%) were rated as having a high risk of selective reporting bias. Four of these studies [2, 3, 24, 53] did not report the results in full, making it impossible to get separate results for each group. Two studies presented in the same article extended their study period to have a long-term outcome.[15]

Other potential sources of bias

Volunteer bias is an important and sometimes almost inevitable problem in studies assessing different ways of learning. Therefore, volunteer bias resulted in a high risk of bias classification in 16 of the 52 included studies (31%) [5-7, 10, 12, 14-17, 19, 23-27, 30] It was unclear whether volunteer bias was a problem in 15 of the 52 studies (29%) and therefore they were classified as having an unclear risk of bias. [3, 13, 21, 22, 28, 29, 31-33, 37, 44-46, 51, 52] Among them, nine of the studies did not provide information for the recruitment process [3, 21, 22, 31-33, 44, 45, 51], while six studies [13, 28, 29, 37, 46, 52] approached all the students but not all of them agreed to participate in the trial. Twenty studies (39%) recruited or approached entire class rooms or the entire year and were therefore at low risk of volunteer bias. [1, 2, 4, 8, 9, 11, 18, 20, 34-36, 38-43, 47, 50, 53]

We classified six more studies (12%) as having a high risk of other potential sources of bias. [1, 2, 4, 11, 13, 18, 21] Two studies suffered from imbalanced experimental groups where more material or information was given in one group compared to the other. In one study the web-based intervention group was not exposed to comparable knowledge/skills [21] as was the control group. In another study [18] the experimental groups were not provided with equivalent academic education because the students in the control group were provided only with facts that were taken from a website that is accessible to the general population. Contamination (i.e. the control group was also exposed to the eLearning intervention) was also a concern in one study (6%), which was categorised as having a high risk of bias.[11] However, it is possible that contamination occurred in several of the other included trials as it is likely that students shared material with course mates who were randomised to a different group. Three studies were rated as having a high risk of other bias because one study used a historical control group,[1] one allowed some of the students to hand in their assessment, a schedule, in person rather than electronically,[2] while another study reported that authors had a conflict of interest with spaced education.[4]

We classified *other bias* as high risk of bias if one of the elements assessed was of high risk even when other elements were rated as having an unclear or low risk of bias. For example, if there was a high risk of volunteer bias but an unclear risk for using comparable learning interventions between experimental groups we would classify it as having a high risk of bias. Please refer to Figure 3 for the assessment per study.

Risk of bias in cluster RCTs

Eight studies included in our review were cluster RCTs. [54-61] In these studies one or more risk of bias items were categorised as high risk of bias. Therefore, the methods and analyses employed in these cluster RCTs were generally not judged to be of high quality.

Recruitment bias was not addressed in two [58, 59] of the eight included studies. Two other studies were assessed as high risk for recruitment bias because they applied the randomization process before recruiting the participants. [55, 56] The remaining studies [54, 57, 60, 61] that were judged to be of low risk of recruitment bias had provided sufficient information on the participant flow and randomization process.

Baseline characteristics differed between the intervention and control group in two studies. [60, 61] In three other studies there was a difference in educational level, primary care clerkships or academic grades for the previous semester at baseline. These imbalances were judged to be of high risk of affecting the outcome [55, 58] or confirmed to have modified the effect.[59] Three studies [54, 56, 57] provided no information on baseline characteristics and whether these were different between the groups.

None of the studies reported loss of entire clusters. However, three studies [55, 57, 61] reported loss of individual participants and three additional studies had a high [60] or imbalanced [58] drop-out rate or reported inconsistent numbers,[54] all of which resulted in a high-risk of bias classification. One study reported attrition in both groups but was judged as having an unclear risk of loss of clusters for providing no further information.[59] One study [56] reported attrition but was judged to be of low risk of bias as the attrition was limited and could not have affected the results.

The data analysis of two studies [56, 60] accounted for the cluster unit. The rest of the cluster RCT studies [14, 54, 55, 57, 61, 62] suffered from unit of analysis error (i.e. incorrectly analysed participants as independent individuals rather than the unit they were randomized in). Therefore there is a high risk of false positive conclusions in these studies.

It was unclear whether or not volunteer bias had occurred in two studies. [54, 58] The remaining six studies [55-57, 59] were all categorised as having a low risk of volunteer bias.