



# e LEARNING for undergraduate health professional education

**A systematic review informing a radical  
transformation of health workforce  
development**

Edited by: Najeeb Al-Shorbaji, Rifat Atun,  
Josip Car, Azeem Majeed, Erica Wheeler

Imperial College  
London





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WHO Library Cataloguing-in-Publication Data

eLearning for undergraduate health professional education: a systematic review informing a radical transformation of health workforce development / edited by Najeeb Al-Shorbaji ... [et al.].

1.Health Personnel - education. 2. Education, Medical, Undergraduate. 3.Computer-Assisted Instruction - methods. 4.Education, Distance - methods. 5.Review. I.Al-Shorbaji, Najeeb. II.Atun, Rifat. III.Car, Josip. IV.Majeed, Azeem. V.Wheeler, Erica.

ISBN 978 92 4 150826 1

(NLM classification: W 18)

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Design and layout: L'IV Com Sàrl, Villars-sous-Yens, Switzerland.

Printed in Switzerland.

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# Foreword

A defining feature of health systems in the 21<sup>st</sup> century will be the capacity to respond to populations' needs, while at the same time anticipating future scenarios and effectively planning for evolving requirements. Nowhere is this more apparent than in the health workforce domain: a fundamental mismatch exists between supply and demand in both the global and national health labour markets, and this is likely to increase due to prevalent demographic, epidemiologic and macroeconomic trends.

Unchecked loss of health workers due to attrition and migration, maldistribution within countries, absolute deficits in some low- and middle-income countries, uneven quality and performance of the health workforce, outdated training models and an over-reliance on cadres focusing on curative services in secondary and tertiary care settings are some of the most common health workforce challenges hindering efforts to attain global and national health objectives. At the same time, we have better evidence than ever before on effective solutions. For instance, it is widely recognized that what, how and where students are taught and who educates and trains the health workforce are major factors in determining the readiness and resilience of a health system, including the capacity to produce the adequate types and number of health workers, to equip them with the required competencies, and to deploy and retain them where they are most needed.

The scope and magnitude of the health workforce challenges we face require both greater investment and more effective and strategic use of available resources: in this context, it becomes necessary to fully exploit the potential of innovative approaches and new technologies to health workforce education, deployment and management.

We live in an era where technology is enabling us to gain knowledge at a speed formerly inaccessible. Information

and communication technology (ICT) in particular, is an effective enabler to improve the health of populations, both directly and through improved health workforce capacity and accessibility.

The Department of Health Workforce in collaboration with the Department of Knowledge, Ethics and Research commissioned this report to provide countries with evidence to inform and guide the adoption of innovative, technology-enabled models into health professional education, so as to augment capacities to scale up production, enhance quality and relevance of training, and adopt equity-focused policies.

The analysis identifies the different forms of ICT that are used to deliver undergraduate health professional education and evaluates the effects of both networked and non-networked computer-based eLearning on students' knowledge, skills, attitudes and satisfaction. It provides insight into advantages and disadvantages of eLearning and an overview of how the quality of eLearning can be measured. Importantly, it identifies and discusses the critical success factors for the implementation and adaptation of eLearning interventions, as well as strategies to equitably and effectively introduce, institutionalize and sustain eLearning.

Furthermore, the report demonstrates the need to strengthen mechanisms at the country level between health workforce institutions of higher learning and ministries of health and education, in order to support quality education across an increasing number of health professionals.

eLearning has an under-exploited potential to support health workforce capacity building in different contexts, and can empower health workers to take charge directly of their own competency development, to enable them to play a full role as change agents in addressing the challenges we will face in the 21<sup>st</sup> century.

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# Acknowledgements

The development and compilation of this report has been a challenge that could not be met without the help of large number of people who have graciously and without reservation offered their skills and expertise.

In addition to the efforts of the contributors listed, this work would have been impossible without the support of partners at the World Health Organization; the authors had the opportunity to present thier initial findings and receive comments and input from Dr Najeeb Al Shrobaji, Dr Erica Wheeler and Ms Diana Zandi. Additional discussions were also help with Dr Meena Cherian. The authors are grateful

for their feedback which has proved invaluable to the continuing research.

The authors are thankful to Imperial College London's librarian Timothy Reeves for helping them develop the search strategy and to library assistant Natasha Suri for her invaluable help with finding all the necessary studies.

Finally, the authors express their appreciation for the funding from the Health Workforce Department of the World Health Organization that made the production of this report possible.

# Abbreviations

**ACPE:** Accreditation Council for Pharmacy Education

**CAI:** Computer-assisted instruction

**CAL:** Computer-aided learning

**CBI:** Computer-based instruction

**CBL:** Computer-based eLearning

**CBT:** Computer-based training

**CD-ROM:** Compact disc read-only memory

**CI:** Confidence intervals

**CIPP:** Context, Input, Process, Product approach

**CMC:** Computer-mediated instruction

**CPX:** Clinical performance evaluation

**cRCT:** Cluster randomized control trial

**CSF:** Critical success factor

**DVD:** Digital versatile disc

**ECGs:** Electrocardiographs

**eMM:** eLearning maturity model

**GeHU:** Global eHealth Unit

**ICT:** Information and communications technology

**IP:** Internet protocol

**IT:** Information technology

**LAN:** Local area network

**LCMS:** Learning content management systems

**LMS:** Learning management systems

**MCQ:** Multiple-choice questionnaire MD: Mean difference

**MDGs:** Millennium development goals

**MOOC:** Massive open online course

**OSCE:** Objective structured clinical examination

**OSS:** Open source eLearning software

**PC:** Personal computer

**PDA:** Personal digital assistant

**PDF:** Portable document format

**PES:** Proprietary eLearning software

**RCT:** Randomized control trial

**RR:** Risk ratio

**SCORM:** Shared content object reference model

**SD:** Standard deviation

**SMD:** Standardized mean difference

**TCP:** Transmission control protocol

**UNESCO:** United Nations Educational, Scientific and Cultural Organization

**UNICEF:** United Nations Children's Fund

**UNIQUE:** European University Quality in eLearning

**UNU-IIGH:** United Nations University-International Institute for Global Health

**USB:** Universal serial bus

**VLE:** Virtual learning environment

**VoIP:** Voice-over Internet protocol

**WHO:** World Health Organization

**2D:** 2-dimensional space

**3D:** 3-dimensional space

# Glossary

**Asynchronous delivery:** delivery of eLearning activities where participants are not required to be online and taking part at the same time.

**Basic vocational training:** see undergraduate education.

**Blended approach:** see blended learning.

**Blended learning:** mixed mode of delivery combining traditional classroom learning with eLearning techniques.

**Complete eLearning approach:** see eLearning, full or complete approach.

**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.

**Distance learning:** the delivery of education where student and tutor are not co-located and may be in different time zones. eLearning technology is used to deliver predefined structured curricula fully, using eLearning technology or in a combination of eLearning and face-to-face learning.

**eLearning:** an approach to teaching and learning, representing all or part of the educational model applied, that is based on the use of electronic media and devices as tools for improving access to training, communication and interaction, and that facilitates the adoption of new ways of understanding and developing learning.

**eLearning, full or complete approach:** learning with no face-to-face component, that relies entirely of the use of eLearning technology and techniques for the delivery of learning.

**Flexible learning:** facilitates a range of options for the learner relating to several aspects of their learning experience, including time, content, instructional approach and delivery. A key difference between distance and flexible learning is that it is the learner who can define the dimensions of learning.

**Full eLearning approach:** see eLearning, full or complete approach.

**Internet and local area network-based eLearning interventions:** interventions that make use of the transmission control protocol (TCP) and the Internet protocol (IP) as a standard. TCP/IP connection is essential in providing the full functionalities of web-based educational interventions. The absence of a network connection would result in the loss of both functionality and usability to such an extent that the original intended purpose is not provided.

**mLearning:** any activity that allows individuals to be more productive when consuming, interacting with or creating information, mediated through a compact digital portable device that the individual carries on a regular basis, has reliable connectivity, and fits in a pocket or purse.

**Non-networked computer-based eLearning interventions:** standalone software applications, where Internet/intranet connections are not required for the learning activities, are assigned to the computer-based category. The main tasks of the eLearning software are performed on a personal computer (PC) or laptop. The delivery channel of the computer-based intervention is typically via CD-ROM or USB memory stick. If the delivery mode of the software is based on a networked connection, but the learning activities do not rely on this connection (i.e. a replacement delivery channel could easily be identified with low efforts/costs, without any restrictions on original intended usage), then this is also a computer-based intervention.

**Outcome-based education:** a performance-based educational approach where the focus is on the outcomes expected of educational interventions. Outcome-based education clearly defines the knowledge, skills, attitudes and behaviours expected and can be used to inform curriculum design and evaluation.

**Psychomotor skills trainer:** technology that will develop fine motor coordination skills and techniques in education,

such as in the precise use of instruments or tools (e.g. a laparoscope used in surgery).

**Serious games:** educational games and simulations.

**Synchronous delivery:** delivery of eLearning activities where participants are required to be online and taking part in real time.

**Traditional campus-based education:** this occurs where students are within a higher education institution and follow predefined curricula to complete an academic programme of study. Education may be delivered using traditional face-to-face learning, but some courses or modules may be delivered either wholly or in part via eLearning. eLearning technology can also be used to “flip the classroom” where students use eLearning technology to view lectures and read course material outside the classroom and classroom time is dedicated to interactive problem-solving exercises.

**Virtual reality environments:** computer-generated representation of a real or artificial environment. This can be interacted with by external involvement, allowing for a first-person active learning experience.

**Undergraduate education:** any type of initial study leading to a qualification that: (i) is recognized by the relevant governmental or professional bodies of the country where the study was conducted, and (ii) enables its holder primary entry into the health-care workforce.

# Executive summary

## Introduction and aims

### About this report

The World Health Organization (WHO) Department of Health Workforce in collaboration with the Department of Knowledge, Ethics and Research commissioned the Global eHealth Unit (GeHU) at Imperial College London to conduct a systematic review of the scientific literature to evaluate the effectiveness of eLearning for undergraduate health professional education.

### Aims and scope

This report aims to:

- identify the different forms of technology that have been used in the past decade to deliver undergraduate health professional education;
- evaluate the effects of non-networked computer-based eLearning and networked web-based eLearning on students' knowledge, skills, attitudes and satisfaction;
- provide insight into generally perceived advantages and disadvantages of eLearning;
- provide a general overview of how the quality of eLearning can be measured;
- identify and discuss critical success factors (CSFs) for the implementation and adaptation of eLearning interventions;
- discuss strategies to introduce, institutionalize and sustain eLearning equitably and effectively
- provide practice and policy recommendations, and directions for future research.

## Background and terminology

- Many health systems worldwide experience a crippling shortage in the health-care workforce.
- In 2006, WHO estimated the shortage in the global health-care workforce to be approximately 4.3 million.
- The shortage of adequately trained health-care workers is aggravated by an outward migration of the health-care workforce.
- Traditional modes of education are limited by an even greater shortage of teachers and lecturers for different aspects of health professional education, from bedside teaching to foundations of health sciences.
- Health professional educational institutions worldwide are thus seeking to innovate in order to respond better to this need to improve, make more efficient and standardize teaching and learning.
- Information and communication technology (ICT) offers promising new modes for the delivery of education – called eLearning when used on its own, or blended learning when used in combination with traditional educational methods.
- eLearning and blended learning allow for the combination of hands-on, skills-based training as well as self-directed, knowledge-based learning. Both may:
  - help reduce the costs associated with delivering educational content;
  - facilitate the development and scalability of educational interventions;
  - break down the geographical and temporal barriers that limit the access to, and availability of, education;
  - improve access to relevant experts and novel curricula;
  - allow for personalization of eLearning based on learner behaviour;

- facilitate “immersive learning” through augmented reality and 3D learning environments, and ubiquitous learning through mobile learning and cloud learning environments.
- eLearning should be conceptualized as the medium by which learning is delivered. However, the successful delivery of educational outcomes using this medium relies on its successful integration with pedagogy and knowledge of content.

## Methods

- The authors conducted a systematic review following the methods recommended by the Cochrane Collaboration.
- Inclusion criteria following the PICO classification, namely:
  - participants: students of undergraduate health-related university degrees; or of basic health-related vocational training programmes;
  - intervention: eLearning or blended learning methods used to deliver the learning content of the courses/programmes under evaluation;
  - comparison: eLearning or blended learning methods compared to traditional learning, an alternative eLearning or blended learning method, or no intervention;
  - outcomes: students’ knowledge, skills, attitudes and satisfaction.

The study also took into account the health economic properties of the interventions and any reported advantages and disadvantages.

- A preliminary search of Medline identified a wide variety of technologies that had been used to deliver health science education. For this reason, it was decided to follow a two-staged approach to the systematic review:
  - systematic mapping of the literature identified;
  - further refinement of the review question.
- Due to significant changes in technology over the past decade, it was decided to limit electronic searches to studies published on or after 2000.
- The output of this phase was a systematic review protocol that will inform a series of Cochrane systematic reviews on the effectiveness of different forms of eLearning for the delivery of undergraduate and post-registration health professional education.
- A search strategy was developed consisting of a combination of subject headings and keywords that captured the participant and the intervention elements of the inclusion criteria. Where possible, validated methodological filters were added for identifying randomized controlled trials (RCTs).
- The search strategy was adapted and used to conduct a comprehensive search of the major medical, psychological and educational bibliographic databases i.e. Medline, EMBASE, PsycINFO, Cochrane Central Register of Controlled Trials (CENTRAL), Web of Science, and Educational Resources Information Center (ERIC). In addition, the list of references of relevant studies or systematic reviews was searched for additional references.
- Working in pairs, the researchers reviewed authors and independently screened the titles and abstracts of the citations identified by the searches. They then screened the full text reports of potential included studies and assessed them against the inclusion criteria for the review. Review authors met to compare their results and reach consensus. Any disagreements were resolved through discussion or by involving an additional author who acted as an arbiter.
- The researchers identified more included studies than originally anticipated. Careful consideration of team capacity prompted them to revise the scope of the systematic review. Consequently, it was decided to appraise systematically the evidence for non-networked computer-based eLearning interventions and for Internet and local area network-based eLearning interventions
- Data were extracted from the included studies using a standardized data extraction form that was developed and piloted at the GeHU. As part of the data extraction phase, the risk of bias of the included studies was assessed using tools recommended by the Cochrane Collaboration.
- Heterogeneity was qualitatively assessed across the included studies to assess the possibility of performing our meta-analysis. Owing to considerable clinical and methodological heterogeneity, the results were presented using a thematic summary approach.

## Subject matter

- Overall, 209 studies were identified that met the inclusion criteria for the systematic review.

- The initial mapping exercise led to the identification of five broad categories of eLearning interventions based on the underlying technology:
  - non-networked computer-based;
  - Internet and local area network-based eLearning;
  - psychomotor skills trainer;
  - virtual reality environments;
  - digital game-based learning.
- It was decided to focus on non-networked computer-based and Internet and local area network-based eLearning only, as these are the two forms of technology that are most likely to be available in a multiplicity of settings.

### Non-networked computer-based eLearning

- Overall, 47 records published between 2001 and 2013 were compatible with the definition of computer-based eLearning. Since two of the included records reported the results of two separate cluster randomized controlled trials (cRCT), 49 studies were included, amounting to 4955 participants.
- Thirty-five studies (71%) evaluated the effect of eLearning on undergraduate medical education. The remaining studies recruited students of medical allied professions: nursing, psychology, dentistry and physical therapy.
- The majority of the included studies (48 out of 49) evaluated programs running on personal computers (PCs) or laptops. The delivery modes used to deliver the educational materials included: CD-ROM, learning management systems (e.g. WebCT, Vista, and Blackboard), DVD, email and web browsers.

Only one of the included studies evaluated the use of a Personal Digital Assistant (PDA) to deliver the educational materials.

- Forty-two studies (89%) were conducted in high-income countries: Australia, Canada, Croatia, France, Germany, Japan, Norway, Republic of Korea, Switzerland, United Kingdom and United States of America (USA). Only five studies were conducted in low- and middle-income countries: Brazil, China, Thailand.
- Overall, 40 studies measured knowledge, 16 assessed skills, 14 assessed students' attitudes, and 13 assessed student satisfaction.

- Forty studies (82%) compared eLearning to traditional learning methods, and nine studies compared one mode of eLearning to an alternative mode of eLearning.

### ELEARNING VERSUS TRADITIONAL LEARNING

- Knowledge was assessed in 33 of the 40 studies comparing eLearning to traditional learning. Of these, 11 studies (33%) demonstrated statistically significant knowledge gains for those students allocated to the CBL methods compared to those allocated to traditional learning methods. Differences in post- intervention knowledge were not statistically significant in 19 studies (58%). Two studies showed mixed results, either favouring the eLearning intervention, the traditional learning method, or neither method depending on the knowledge indicator used.

One study did not test for statistically significant differences in knowledge gains.

- Skill was assessed in 13 of the 40 studies comparing eLearning to traditional learning. Of these, eight studies found a statistically significant difference in skill acquisition favouring the participants allocated to the CBL group compared to those allocated to traditional learning methods. Two studies found mixed results depending on the time point of outcome assessment or the indicator of skill acquisition used. Differences in skill acquisition were statistically nonsignificant in three studies (23%).
- Attitudes were measured in 12 of the 40 studies comparing eLearning to traditional learning. Five studies (42%) found more favourable attitudes among students allocated to CBL than among those allocated to traditional learning. Six studies (50%) found no statistically significant differences in attitudes between the eLearning and the traditional learning groups. One study comparing traditional learning methods to two different forms of eLearning (CBL with no interaction, and CBL with interaction) found that more students would recommend the eLearning intervention with no interaction when compared to traditional learning methods; the difference between the eLearning intervention with interaction and traditional learning methods was statistically nonsignificant.
- Satisfaction was measured in nine of the 40 studies comparing eLearning to traditional learning. Five studies (56%) found a significantly higher proportion of students exposed to the CBL intervention that expressed satisfaction with the intervention compared to those



exposed to traditional learning methods. Two studies found higher levels of satisfaction among students allocated to traditional learning methods compared to those allocated to CBL methods. One study did not find any statistically significant difference, and another study did not test for statistically significant differences.

### **ELEARNING VERSUS ELEARNING**

- Knowledge was measured in seven of the nine studies comparing different eLearning modalities. Three studies found statistically significant knowledge gains that favoured students using 3D-enhanced visual aids (compared to students using standard 2D visual aids) and those using an interactive computer-based module (compared to students using a plain text computer-based modules). Differences in knowledge gains were statistically nonsignificant in three studies. One study found mixed results depending on the knowledge indicator used.
- Skills acquisition was measured in three of the nine studies comparing different eLearning modalities. One study found higher skill acquisition among students using the mouse to trigger animated demonstrations of abdominal examination compared to students using more passive versions of the same modules (i.e. watch-only demonstrations) or those using drag-and-drop features to simulate abdominal manoeuvres. Differences in skill acquisition were not statistically significant in the remaining two studies.
- Attitude was measured in only two of the nine studies comparing different eLearning modalities. Students in one of these studies rated a 3D learning aid more favourably than a standard 2D learning aid in relation to intelligibility for glaucoma surgery. This study found no statistically significant differences between the two groups for intelligibility for cataract surgery. In the other study, participants rated a targeted eLearning module for leukaemia more favourably than existing online resources.
- Satisfaction was measured in four of the nine studies comparing different eLearning modalities. These studies found that students showed higher levels of satisfaction with a targeted eLearning module on leukaemia (compared to existing standard online modules), a 3D learning aid for ophthalmic procedures (compared to a 2D learning aid), 3D computer models (compared to 2D computer models), and a computer tutorial following a linear format (compared to a computer tutorial following a branched format).

### **Internet, networked, online or local area network-based eLearning**

- Overall, 59 records published between 2000 and 2013 were found to be compatible with the definition of web-based eLearning. Since one of the included records reported the results of two consecutive but separate RCTs, a total of 60 studies amounting to 6750 participants were reviewed.
- Fifty-five per cent of the included studies evaluated the effect of eLearning on undergraduate medical education. The remaining studies recruited students of medical allied professions: nursing, pharmacy and physical therapy.
- The majority of the included studies (55 out of 60) utilized a website to present the educational materials to the participants. In three studies the learning materials were delivered via email, one study used videoconference lectures to present the learning material, and one study used a visual concept map.
- Eighty-five per cent of the included studies were conducted in high-income countries: Australia, Belgium, Canada, Finland, Germany, Netherlands, Spain, Sweden, Switzerland, United Kingdom and USA. Only seven studies were conducted in low- and middle-income countries: Brazil, China, Taipei (China) and Thailand. One study was conducted simultaneously in Brazil and the USA.
- Overall, 53 of the included studies measured knowledge, 16 assessed skills, 14 studies students' attitudes and 33 assessed student satisfaction.
- Fifty studies (83%) compared eLearning to traditional learning methods, and 10 studies compared one mode of eLearning to an alternative mode of eLearning.

### **ELEARNING VERSUS TRADITIONAL LEARNING**

- Knowledge was assessed in 43 of the 50 studies comparing eLearning to traditional learning. Of these, 12 studies (27%) demonstrated statistically significant knowledge gains for those students allocated to the web-based eLearning methods compared to those allocated to traditional learning methods. Differences in post-intervention knowledge were not statistically significant in 24 studies (48%). Three studies using multiple measures of knowledge showed mixed results, either favouring the eLearning intervention, the traditional learning method, or neither method depending on the

knowledge indicator used. One study did not test for statistically significant differences in knowledge gains. Three studies found significantly higher knowledge gains in those students exposed to traditional learning methods.

- Skill was assessed in 15 of the 50 studies comparing eLearning to traditional learning. Of these, six studies (40%) found a statistically significant difference in skill acquisition favouring the participants allocated to the web-based eLearning group compared to those allocated to traditional learning methods. One study found mixed results depending on the indicator of skill acquisition used. Differences in skill acquisition were statistically not significant in three studies (21%). Four studies (26%) did not test for statistical significant differences, and one study found significantly higher skill gains in students exposed to traditional learning methods.
- Attitudes were measured in 12 of the 50 studies comparing eLearning to traditional learning. Of these, eight studies (67%) did not find a statistically significant difference between the two learning methods, or found mixed results depending on the test under evaluation. Three studies did not test for statistical significant differences, and one study reported more positive attitudes that favoured the web-based intervention.
- Satisfaction was measured in 29 of the 50 studies comparing eLearning to traditional learning. Of these, four studies (14%) found a significantly higher proportion of students exposed to the web-based eLearning intervention that expressed satisfaction with the intervention compared to those exposed to traditional learning methods. Twenty studies (74%) did not find any statistically significant difference between the two learning methods. Four studies did not test for statistically significant differences, and one study reported higher satisfaction levels among those exposed to traditional learning methods.

## ELEARNING VERSUS ELEARNING

- Knowledge was measured in all of the 10 studies comparing different eLearning modalities. Five studies found statistically significant differences between the two eLearning modalities: three of them favouring an active form of web-based eLearning and two favouring a passive form of web-based eLearning. Four studies found no significant statistical differences, and one study did not test for these differences.

- Skills acquisition was measured in one of the 10 studies comparing different eLearning modalities. This study found no statistically significant differences in skill acquisition between a passive and an active eLearning modality.
- Attitude was measured in two of the 10 studies comparing different eLearning modalities. One study found no significant differences and one study did not test for these differences.
- Satisfaction was measured in four of the 10 studies comparing different eLearning modalities. Two studies found no differences between the studies comparing different eLearning modalities, and two studies found higher satisfaction levels among students using a collaborative online module enhanced with social features (compared to those using the same module but working independently) and a narrated Microsoft® PowerPoint® presentation (compared to a Microsoft® PowerPoint® presentation without audio).

## General discussion

- There was a high degree of heterogeneity among the included studies in terms of the types of degrees, seniority of students, delivery mode used by the interventions, duration and frequency of exposure to the interventions, and measures of outcomes. Additionally, the majority of studies had important methodological flaws that may have biased the findings. For this reason, it was impossible to conduct a meta-analysis to determine an effect size of eLearning on learning outcomes.
- The findings of the included studies suggest that both computer-based and web-based eLearning is no better and no worse than traditional learning with regards to knowledge and skill acquisition. Policy-makers and educators should take this into account when planning educational programmes.
- The picture concerning students' attitudes and satisfaction is unclear. Policy-makers and educators should consider that an intervention's acceptability is likely to influence its effectiveness. Therefore, they should strive to understand those specific aspects of an eLearning intervention that are influencing students' and teachers' perceptions, attitudes and beliefs. Where possible, they should aim to address these factors.
- Learners usually reported the following advantages in relation to eLearning interventions: ease of access and

flexibility, portability, improved student-teacher contact and discussions, and increased discussions with peers.

- Among the most common disadvantages reported by learners were: more time-consuming; lack of student-teacher interaction and tutor support, feelings of isolation, being unable to clarify doubts with a tutor, and lack of in-depth group discussion.
- From the perspective of an educational provider, the most common advantages include: monetary savings, scalability of educational materials, freeing up of lecturers' time to allow more complex subjects to be covered in tutor-led workshops, ease of development and updating of educational materials, coverage of the population, portability, and enabling students to practise skills prior to experience with real patients.
- The implementation and adoption of eLearning interventions is influenced by the following key elements:
  - the problem being addressed by the eLearning intervention;
  - the characteristics of the intervention;
  - the adopting system;
  - the characteristics of the health system;
  - broad contextual factors.

The holistic consideration of these factors will enable education providers to better plan educational interventions in order to improve their outcomes, efficiency and equity.

- A number of CSFs operate within each of the elements mentioned above, including:
  - organizational setting;
  - technological infrastructure;
  - instructional systems design;
  - curriculum development;
  - delivery.
- After identifying the gaps in knowledge, the authors recommend that future studies should be carried out in order to:
  - assess the outcomes of eLearning in health-care education and training in low- and middle-income countries;
  - assess the impact of eLearning in the education and training of health-allied professionals;
  - provide more insight into the design of learning materials, and how different design decisions can impact on the efficacy and effectiveness of eLearning interventions;
  - ensure the methodological quality of the evaluation studies and avoid caveats such as contamination, high attrition rates and volunteer bias;
  - acknowledge the role of the educational environment and culture in which eLearning interventions are embedded;
  - evaluate the impact of eLearning on the long-term retention of knowledge and skills;
  - assess the economic properties of eLearning interventions.



# Part One

## Introduction, aims and methods

eLearning is used increasingly in health care to support the delivery of learning in outcome-based education. Broadly speaking, eLearning is considered to be the application and integration of educational technology to the learning process.



# About this report

The World Health Organization (WHO) Department of eHealth, Knowledge Management and Sharing commissioned the Global eHealth Unit (GeHU) at Imperial College London to conduct a systematic review of the scientific literature to evaluate the effectiveness of eLearning for the delivery of undergraduate health professional education. This report summarizes the findings of the systematic review, discusses them and puts them in a broader context, and culminates in policy recommendations.

## Aims and scope

The aims of this report are to:

- identify the different forms of technology that have been used in the past decade to deliver undergraduate health professional education;
- evaluate the effects of non-networked computer-based eLearning (CBL) and networked web-based eLearning on students' knowledge, skills, attitudes and satisfaction;
- provide insight into generally perceived advantages and disadvantages of eLearning;
- provide a general overview on how quality of eLearning can be measured;
- identify and discuss critical success factors for the implementation and adaptation of eLearning interventions;
- discuss strategies to introduce, institutionalize and sustain eLearning equitably and effectively (including cost-effectively);
- provide practice and policy recommendations, and directions for future research.

For the purpose of this review undergraduate education or basic vocational training was defined as any type of initial

study leading to a qualification that: (i) is recognized by the relevant governmental or professional bodies of the country where the study was conducted; and (ii) enables its holder to have primary entry into the health-care workforce. It therefore includes graduate medical education courses from the USA.

A definition and general description of eLearning is provided below.

## Background and terminology

Health workers are fundamental to ensuring equitable access to health services and achieving universal health coverage. Many countries continue to experience a severe health workforce shortage resulting from lack of adequate training and migration (brain drain). As identified by the *World health report, 2006*, 57 countries face critical health workforce shortages (1). WHO estimates that 2.4 million physicians, nurses and midwives and 1.9 million health aid workers, pharmacists, technicians and auxiliary personnel are needed to meet the Millennium Development Goals (MGDs) set for 2015. eLearning could help tackle the estimated 4.3 million global shortage in health workers, whose ranks must be sufficiently increased if the those goals are to be achieved (2).

eLearning is used increasingly in health care to support the delivery of learning in outcome-based education. Broadly speaking, eLearning is considered to be the application and integration of educational technology to the learning process.

For the purposes of this report we have adopted the following definition of eLearning: an approach to teaching and learning, representing all or part of the educational model applied, that is based on the use of electronic media and devices as tools for improving access to training, communication and interaction and that facilitates the adoption of new ways of understanding and developing learning (3).

This definition considers the concept of eLearning as a continuum that includes a mixed mode of delivery combining traditional classroom learning with eLearning techniques, defined as blended learning (4).

Traditional learning is any learning activity undertaken in the traditional classroom environment; it is co-located, face-to-face instruction and practical work.

In contrast, a full or complete eLearning approach is defined as learning with no face-to-face component that relies entirely on the use of eLearning technology and techniques for its delivery. Full eLearning can be distributed geographically and/or temporally, and communication between student and teacher is handled electronically.

A blended approach is a mix of the traditional and fully online methodologies, where some of the learning is undertaken in the traditional classroom environment but the use of eLearning technologies and techniques are also applied.

The distinction between technology-enhanced traditional classroom learning and a truly blended learning delivery model lies in the fact that the blended model is a fully integrated approach, utilizing aspects of face-to-face and online delivery. Course content is specifically designed for blended delivery, in contrast to the more simplistic application of supporting in the technology-enhanced classroom (5).

While the majority of blended learning definitions focus on this combination of eLearning technology and methods with traditional face-to-face instructor-led teaching (6–8), some definitions move away from the application of technology in education and focus more on pedagogical (9) and/or design principles (10,11).

The suitability of blended learning for health-care training has been highlighted by several authors (12–16) due to the need to combine hands-on skills-based training at practical level as well as self-directed learning. For a complete overview of the conceptualization of blended learning and its potential implications in the context of developing countries, see Annex 1.

## Applications of eLearning in higher education

The scope and applications of eLearning are closely linked to the capabilities afforded by information and communication technologies (ICTs), allowing new possibilities for facilitating and supporting learning in higher education (17).

Traditional classroom learning has been transformed by the changes brought about by the digital revolution and the dawn of the information and knowledge age. Since the early days of computer-based training (CBT), the widespread adoption of the Internet, broadband, wireless and mobile technologies (16) have been exploited, resulting in rapid development of learning technology, improving the accessibility of education and changing learner expectations with regard to their learning journey (18,19).

The majority of universities have implemented eLearning in some context (20) to support traditional campus-based education or to enable access to distance or flexible learning.

Traditional campus-based education occurs where students are within a higher education institution and follow predefined curricula to complete an academic programme of study. Education may be delivered using traditional face-to-face learning, but some courses or modules may be delivered either wholly or in part via eLearning. eLearning technology can also be used to “flip the classroom” where students use eLearning technology to view lectures and read course material outside the classroom and classroom time is dedicated to interactive problem-solving exercises (21).

Distance learning refers to the delivery of education where student and tutor are not co-located and may live in different time zones. eLearning technology is used to deliver predefined structured curricula, fully using eLearning technology alone or in a combination with face-to-face learning.

Flexible learning facilitates for learners a range of options relating to several aspects of their learning experience, including time, content, instructional approach and delivery. A key difference between distance and flexible learning is that in the latter case it is the learner who can define the dimensions of learning (22).

The use of eLearning within higher education presents many opportunities for universities, including the reduction of the costs associated with delivery of educational outcomes (20), improving scalability of educational developments (19), increasing access and availability to education by breaking down geographical and temporal barriers and allowing access to relevant experts and novel curricula (23). It is possible that, in time, the use of eLearning technology will be so integrated into teaching and learning practice in higher education that the consideration of eLearning as something alternative to traditional learning techniques will be an impossible comparison (24).



## Aspects of eLearning

eLearning technology is the medium by which learning is delivered (25) and is the key focus of this report. However, eLearning is a complex process integrating the use of educational technology into the process of teaching and learning (26). This relationship between technology, pedagogy and content knowledge (27) is key to the successful delivery of educational outcomes using technology.

### THE TECHNOLOGY

Many of the essential elements of what we now call eLearning have been evident in higher education since the early 1980s when the first computers became a financially viable option for universities (28). The first CBT courseware was proprietary and was often developed by information technology (IT) or subject area enthusiasts (17) This courseware was loaded to dedicated personal computers (PCs), often in classrooms and laboratories (29).

As the processing power of computers increased, commercial and increasingly user-friendly software was developed. During this time PCs with CD-ROMs became widely adopted enabling the use of the CD-ROM as an effective delivery channel for educational material.

In the 1990s, coinciding with the increasing availability of web technology, the first learning management systems (LMS) and online training courses were implemented. Early web technology was typically "read only" (30). eLearning technology became able to support asynchronous (not in real time) communication using email and basic discussion functionality, and enabled the uploading and online dissemination of prerecorded lectures, multimedia and text content.

In the early 2000s, broadband technology became widely adopted and Internet protocols developed, enabling the next generation of web technology. Web 2.0, or the dynamic web, could handle two-way read/write communication. Software became more sophisticated, allowing synchronous (real-time) communication, and supported group working environments (18,30).

Learning technology during this time developed to integrate videoconferencing, screencasting, blogs, wikis, voice-over Internet protocol (VoIP) technology, learning content management systems (LCMS) and podcasts.

### THE PEDAGOGY

Pedagogy can be defined generically as the "science and art of teaching". By adopting and using existing well-defined pedagogical theories, eLearning can effectively engage learners to acquire knowledge, skills, attitudes and behaviours (31,32) in a rich, complex learning process (33).

As with traditional learning, pedagogy is an important consideration in the process of eLearning. Key pedagogical theories associated with eLearning include behaviourism, cognitivism, constructivism and social constructivism.

Behaviourist approaches focus on learning occurring as a result of information transfer from teacher to student. The teacher is central to this approach and learning occurs through reinforcement as students listen, observe, memorize and respond to knowledge presented to them (34,35).

Cognitivism considers learning not solely as a response to stimuli but also as the application of knowledge and active participation. Bloom identified the following six cognitive domains from simple recall to the more complex evaluation: knowledge, comprehension, application, analysis, synthesis and evaluation (36).

Constructivism focuses on the process of constructing new knowledge based on previously acquired knowledge. The student is actively engaged and undertakes activities to construct this new knowledge. Activities based on constructivist approaches include problem-based learning such as virtual patients and case-based learning (25).

Social constructivism builds on the theory of constructivism by adding a social dimension and engaging participants in chat and discussion as a method of constructing new knowledge. By sharing ideas and experiences, the group is able to assimilate a new level of knowledge (37,38). Learning technology based on Web 2.0 effectively supports the social constructivism pedagogical model by enabling collaborative group working environments.

### THE CONTENT

Content knowledge is the knowledge of the subject area (27) relating to the educational outcome of the intervention. Content knowledge informs the development of learning material with a view to the curriculum position, expected outcomes and learner background (33).

This knowledge, combined with the application of educational technology and appropriate pedagogical principles, is the basis

for the development and delivery of eLearning content to meet the outcomes of the intervention (39).

Standards have been developed to guide the development of eLearning content. The Shared Content Object Reference Model (SCORM) was developed to provide standards for the use, exchange, management and tracking of learning content (40,41). The model ensures the five SCORM "ilities" (interoperability, reusability, accessibility, manageability and durability) thereby protecting any investment that is made in the creation of any aspect of eLearning from tools to content.

Developed content may then be delivered synchronously (real-time) or asynchronously with varying degrees and types of interactivity (42). These topics are given more consideration in Annex 1. In both developing and developed countries, network connectivity and bandwidth availability are key obstacles to the effective delivery of eLearning content (25,43). Delivery of online content requires the "shrinking" of content to fit the available bandwidth (44,43). An alternative to this approach is the delivery of eLearning partially or completely offline. This issue is central to this report and each of these approaches to eLearning delivery is considered and analysed for effectiveness as a medium for the delivery of educational interventions.

## eLearning in developing countries

In developing countries, technology plays an increasingly vital role in education (43). International organizations such as the United Nations and WHO have acknowledged eLearning as a useful tool in addressing education needs in health care, especially in developing countries (45,46).

However, despite the rapid growth in learning technology in recent years, instructors in rural and/or developing areas may have access to only the most basic or earlier generations of technology (41). This lack of access to technology has been identified as a major challenge to the implementation of technology-enhanced teaching in developing countries (47). In order to access online learning materials, individuals need access to a PC or a smart device (tablet or telephone), as well as access to the Internet.

According to the International Telecommunication Union (48), 2.7 billion people are using the Internet, corresponding to 39% of the world's population. In developing countries only 31% of the population is online, compared to 77%

in developed countries. Ninety per cent of the 1.1 billion households not connected to the Internet are in developing countries.

Technologies used in eLearning can vary from a simple audio tape or a DVD to sophisticated multipoint videoconferencing facilities supported by simulation and online applications (49).

Many eLearning platforms (both LMS and LCMS) currently available are based on either proprietary eLearning software (PES) or open source eLearning software (OSS). OSS usage in implementing eLearning systems is emphasized more in developing countries because of challenges faced when implementing the PES. Bygbjerg (50) describes two characteristics of PES that make it ill-suited for use in developing countries. First, the rapidly escalating cost of proprietary software leaves too little of an institution's ICT budget available for creative exploration once the software has been installed and minimally supported (51). Second, reduced flexibility to adapt to institutional culture, teaching practices and disciplinary uniqueness occurs when software development is driven by mass market economics (52).

Several initiatives, led by key Internet players such as Facebook, Google, Wikipedia and others, are currently taking place. These initiatives could eventually have a significant impact in the way online health education is delivered. Facebook has recently announced the project Internet.org in partnership with some of the biggest social media and mobile delivery players to cut the cost of delivering basic Internet services on mobiles telephones, especially in developing countries (53).

Similarly, Wikipedia Zero has been setup by the Wikimedia Foundation to enable free mobile access to Wikipedia content in developing countries (54). WikiProject Medicine (55) is another Wikipedia initiative aimed at quality control of health-related content on Wikipedia.

Massive Open Online Courses (MOOCs) have been recognized as a potentially powerful tool in developing countries (56). Some of the main MOOC providers in the USA, such as Coursera, EdX, Udacity, and FutureLearn in the United Kingdom, are already playing a key role in the development and support of world health education.

Further considerations of eLearning in developing countries can be found in Annex 1.

## Structure of the report

The findings are presented in chapters 3 and 4 of Part 2 which deals with subject matter. Chapter 3 addresses

the findings of the systematic review on non-networked computer-based eLearning and Internet while Chapter 4 deals with local area network-based eLearning. In Part 4, Chapter 5 provides a broader perspective of the findings and offers insight into potential advantages and disadvantages of eLearning. Chapter 6 identifies and discusses critical success factors for implementation and adaptation of eLearning interventions, while Chapter 7 outlines strategies to introduce eLearning equitably and effectively. The institutionalizing and sustaining of eLearning are examined in Chapter 8. Chapter 9 considers the quality of eLearning.

In Part 4 of this report, Chapter 10 summarizes the key findings, Chapter 11 addresses the strengths and limitations of the systematic review, and Chapter 12 puts the findings in the context of wider literature on the topic. Chapter 13 offers practice and policy advice, while Chapter 14 makes recommendations for future research.

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# Methods

The systematic review followed the recommendations of the Cochrane Handbook for Systematic Reviews of Interventions (1).

A brief description of the methods is described below, with a more detailed description in Annex 2.

## Search strategy

A search strategy was developed for use in MEDLINE (OvidSP) with a combination of keywords and MeSH terms that captured the types of intervention and the types of participants under evaluation in this systematic review (see Annex 3). The search strategy was adapted for use in EMBASE (OvidSP), PsycINFO (Ovid SP), Cochrane Central Register of Controlled Trials (CENTRAL), Web of Science, and Educational Resources Information Center (ERIC) (ProQuest). Where available, validated methodological filters were used to limit the searches to randomized controlled trials (RCTs) and cluster RCTs (cRCTs). The searches were made between 16 and 20 August 2013 and were limited to studies published on or after 2000. The number of hits before and after de-duplication is summarized in Annex 4.

## Inclusion criteria

The study used the PICO elements to inform the inclusion criteria. RCTs in any language were included if they met all of the following criteria:

- participants: students of (i) undergraduate, health-related university degrees, or (ii) basic, health-related vocational training programmes;
- intervention: eLearning or blended learning methods used to deliver the learning content of the courses/programmes under evaluation;
- comparison: eLearning or blended learning methods to (i) traditional learning, (ii) an alternative eLearning or blended learning method, or (iii) no intervention;
- outcomes: students' (i) knowledge, (ii) skills, (iii) attitudes and (iv) satisfaction. Additionally, the health economic properties of the interventions were considered, along with any reported advantages or disadvantages.

## Study selection and data collection

The study selection process is summarized in the PRISMA flow diagrams included in Annex 5. In brief, the titles and abstracts of the citations identified by the electronic searches were screened to identify potentially relevant studies. The full-text report of potentially relevant studies was assessed to ensure compliance with the inclusion criteria of the systematic review. Data were extracted from the included studies using a standardized data extraction sheet developed for this purpose (see Annex 6). During the data extraction process, the risk of bias of included studies was assessed using the tools recommended by the Cochrane Collaboration.<sup>1</sup>

## Summarizing the data

First, a systematic mapping of the types of technologies used by the included studies to deliver the learning materials was conducted. Through this, the main types of delivery technologies for evaluation were identified as (i) non-networked CBL and (ii) Internet, networked, online or local area network-based learning.

The characteristics of the participants and of the interventions were qualitatively compared between the included studies to determine the feasibility of conducting a meta-analysis. As there was substantial clinical and methodological heterogeneity, a meta-analysis was not

conducted. Instead, a narrative synthesis approach was adopted to summarize the evidence, as recommended by Rodgers and colleagues (2). Future developments of this project should include a careful assessment of the characteristics of studies to determine those that can be combined in a meta-analysis.

A combination of the studies included in this review and grey literature reports was used to evaluate the advantages and disadvantages of eLearning, the critical success factors for the implementation and adoption of eLearning methods, the strategies to introduce eLearning equitably and effectively, strategies to institutionalize and sustain eLearning, and the quality of eLearning. A conceptual framework developed at Imperial College London was adapted to conceptualize the integration of eLearning methods into educational systems (3).

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## References

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2. Rodgers M, Sowden A, Petticrew M, Arai L, Roberts H, Britten N et al. Testing methodological guidance on the conduct of narrative synthesis in systematic reviews. *Evaluation*. 2009;15(1):47-71.
3. Atun R, Jongh T De, Secci F, Ohiri K, Adeyi O. Integration of targeted health interventions into health systems: a conceptual framework for analysis. *Health Policy Plan*. 2010;25:104-11.

# Part Two

## Subject matter

Five broad categories of eLearning interventions were identified on the basis of the technologies employed.





# Subject matter

The initial search yielded 12 208 records. Out of these, 3117 duplicate records were removed using EndNote X5.1. Therefore, the titles and abstracts of 9091 records were screened. After this initial screening, 8780 records were excluded. The full-text reports were retrieved for the remaining 311 records and assessed for eligibility. Of these, 102 papers that did not meet the eligibility criteria for this systematic review were excluded. Thus, 209 studies were included in the review (see Annex 5).

To identify the scope of the different eLearning interventions covered by the included studies, a scoping exercise was performed. Five broad categories of eLearning interventions were identified on the basis of the technologies employed. These categories were defined as follows:

- **Non-networked 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 so long as the learning activities do not rely on this connection.
- **Internet 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 or 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 improving their engagement, attitudes, motivation and knowledge.

Each included study was allocated to one of these categories. If multiple categories could be applicable, the one that fitted best was chosen. It was decided to focus on non-networked computer-based and Internet and local area network-based eLearning interventions only in this review because these are the two forms of technology which are most likely to be available in a multiplicity of settings, including in low- and middle-income countries.

# Non-networked computer-based eLearning

Of the 209 included studies in this systematic review, 47 articles (1–47) complied with the term “non-networked computer-based” and are discussed in this section. Hu et al. (17) and Fritz et al. (48) reported results from the same study. Hu et al. was the primary publication, whereas the publication by Fritz et al. was a secondary analysis. Therefore, the report by Fritz et al. was used to supplement the report by Hu et al., but only the report by Hu et al. was included in the 47 articles (17,48). Two (28,44) of the 47 articles reported results of two separate cluster RCTs that were analysed separately and therefore the total number of evaluated trials was 49.

The selection process is depicted in Figure A.5.1 of Annex 5. A description of each of the included trials and its findings is included in Annex 7. The findings are summarized, discussed and interpreted below.

## Findings

### Included studies

The studies included in this chapter were published in peer-reviewed journals between 2001 and 2013 and were all parallel RCTs or cluster RCTs. There were no clear trends in terms of increase in publication of non-networked computer-based studies in the time period investigated. Out of all 49 included studies, 35 studies (1–3,6,8,11,12,14,15,18,20,21,23–27,29,30,32–44,46,47) investigated eLearning in the field of medicine. Eight of the articles classified as medical-allied professions (5,9,10,13,19,22,28) dealt exclusively with nursing. Additionally, one article (45) dealt with both medicine and psychology, whereas another study (17) dealt with medicine, dentistry and physical therapy. Four studies (4,7,16,31) investigated eLearning for dentistry students.

### PARTICIPANT CHARACTERISTICS

The total number of participants included across all trials was 4955. The smallest study included eight participants in the control group and eight participants in the intervention

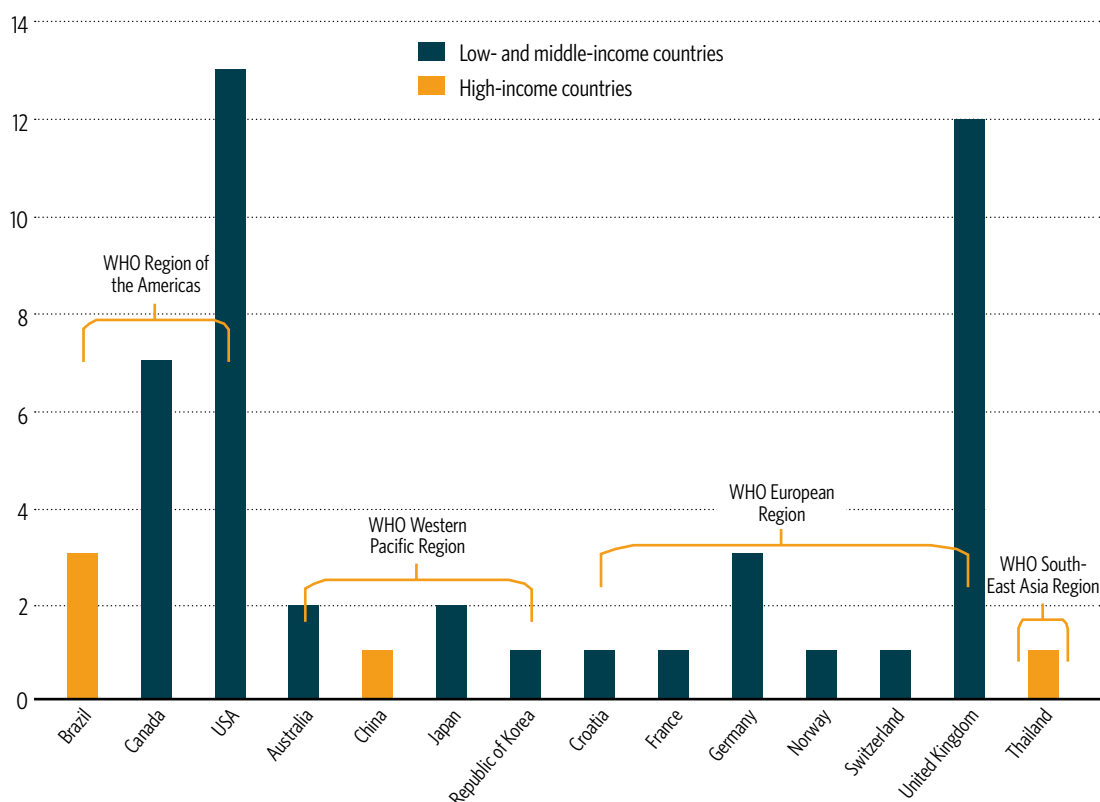
group (33). The study with the largest control group had 177 participants (32), while the largest intervention group had 113 participants (5). Most studies were conducted among undergraduate university students, apart from two studies (5,10) that investigated the effect of non-networked CBL for vocational training. Of the 11 studies that specified the age of the students, the lowest mean age of participants in a control group was 22.4 years (4) and the oldest was 30 years (9). The lowest mean age in an intervention group was 21.8 years (4) and the highest was 30 years (9). Indeed, there were no important differences in age between the compared groups in these studies.

### INTERVENTION CHARACTERISTICS

Forty studies (1–16,19,22–29,31,32,34,37–41,43–47) compared eLearning to traditional learning, and nine studies (17,18,20,21,30,33,35,36,42) compared one mode of eLearning to another mode of eLearning. The shortest duration of exposure was 20 minutes (21) and the longest was one year (32). Most of the studies (42 out of 49, or 86%) were conducted in high-income countries, and 13 of these (2,7,10,11,14,16,19,21,31,38,40–42) were in the USA. The remaining five studies were conducted in low- and middle-income countries: one (43) in Thailand, one (23) in China, and three (25,34,39) in Brazil. Figure 3.1 shows the distribution of the country origins of the included studies.

The majority of the studies used programs that run on PCs or laptops (1–12,14–47). One study (13) investigated the use of a personal digital assistant (PDA), which is a small portable electronic device that can be regarded as the predecessor to a computer tablet and smartphone, with PDFs from Elsevier. Sixteen studies delivered the eLearning intervention to the students on a CD-ROM (1,2,6–10,16,19,22,23,34,41,44,45). The eLearning software and material used in the remaining studies was distributed via a variety of sources, where specified: learning management systems such as WebCT Blackboard (4,17), DVDs (4,31,35), the Internet (3,21,25), stored on a computer (27,32,43) or for one study (13) on a PDA, and via email (30). Several interventions used standard vendor software such as Adobe® (25,28), Macromedia Authorware (40) and Microsoft® PowerPoint® (3,10).

**Figure 31. Country origin of included examined studies for low- and middle-income countries and high-income countries separately**



## PRIMARY OUTCOMES

### Students' knowledge

The knowledge gained from the exposure to the intervention was assessed in a number of different ways in the included studies. Overall, 40 (1–5,7–11,13–19,21–30,32,34–37,39–43,45,46) of the 49 studies looked at a knowledge-based outcome. Nineteen of these studies (3–5,8,10,11,14,15,17,19,21,24,25,27,35,37,39,45,46) used only a multiple-choice questionnaire (MCQ) to test students' knowledge and understanding, with another nine (1,9,18,26,29,30,32,34,40) studies using a MCQ in conjunction with additional testing method (e.g. short answer questions or X-ray image interpretation). A further 11 studies (2,13,16,22,23,28,36,41–43) measured students' knowledge gain via other testing means, including case analysis, X-ray image interpretation and written examinations. The study by Bogacki et al. (7) specified no clear examination method in the assessment of the participants' knowledge.

### Students' skills

Skills were assessed in 16 studies (5,6,12,19–24,31,33,37,38,44,47), which used various methods to assess the outcome. Ten studies (5,12,19,21,22,24,37,38,44) used a rating scale and/or checklists (e.g. an objective structured clinical examination, or OSCE) to assess clinical skills. Three studies (20,33,47) used the Imperial College surgical assessment device and a checklist for the assessment. Another study (31) used a grading rubric to assess ability to carve teeth in wax. In one study (23) no method of skill assessment was described. Finally, one study assessing the ability to conduct orotracheal fiberoptic intubation (6) evaluated successful intubation in real time.

### Students' attitudes

Feedback from students assessed with regard to their attitude towards the eLearning intervention was reported as an outcome in a total of 14 studies (4,8,12,19,22,26,28–31,35,44). This was measured using a single questionnaire, where

participants were asked to provide ratings via Likert scales in 11 of the included studies (8,22,26,28–31,35,44). One study (12) used a questionnaire and did not mention the use of Likert scales. In the remaining two (4,19) studies, Likert scales were combined with another method – i.e. focus groups in Bains et al. (4) and an additional questionnaire in Jeffries et al. (19).

### **Student satisfaction**

Student satisfaction was considered as an outcome in 13 studies (14,17,19,22,23,26–28,35,36,40,45). Eight of these studies (14,17,23,27,28,35,36) specified that student satisfaction was evaluated with Likert scale questionnaires. The five remaining studies comparing student satisfaction among the students (19,22,26,40,45) used different types of questionnaires without mentioning the use of Likert scales.

## **SECONDARY OUTCOMES**

### **Health economic properties of the elearning intervention**

Health economic properties of the eLearning intervention were rarely mentioned in the included computer-based studies. However, some of the studies addressed certain financial and resource-related elements of eLearning. Davis et al. (9) mentioned that costs for producing the eLearning package were minimal, and well within normal departmental budgets for teaching undergraduates. Ackermann et al. (1) wrote that effective learning can be performed with the use of few resources and provides a very economical mode for educating medical students. Bradley et al. (8) stated that the in-house development of the traditional learning course material took 40 hours for preparation, 10 hours to administer each semester and the Internet site used for the eLearning group took 100 hours to develop. The eLearning course material also included a CD-ROM produced externally at an estimated cost of £30 per CD (8). McDonough et al. (27) reported that it took local IT staff four hours to install the program on 20 PCs and that no maintenance was required after that point. Vivekananda-Schmidt et al. (44) stated that the costs of designing the eLearning course were £11 740 (US\$ 22 045). Tunuguntla et al. (42) wrote in reference to comparing two different types of eLearning, “The cost ratio (measured in hours) for the module was about 2:3: about 72 h for creation of the static graphics vs. 106 h for the animations.”

### **Adverse or unintended effects of elearning**

Adverse or unintended events of the eLearning intervention were not reported in any of the studies.

### **Excluded studies**

Initially, 70 studies were categorized as non-networked CBL studies. Seven of these studies (49–55) were reclassified as network-based because the functionality of the eLearning intervention would be lost without an Internet connection, and were excluded for that reason. Also excluded were six studies (56–61) that were reclassified as simulation-based studies which focused on, for instance, practising ultrasound with an expert able to access the ultrasound screen (61). One study (62) was reclassified as mLearning because lectures were viewed on an iPod (62) and this study was also excluded.

Eleven studies (63–73) were excluded during the data extraction phase because they met one or more of the exclusion criteria. Four studies (63,65,67,72) out of the 11 were excluded as they were published before 2000. Five studies (68–71,73) were excluded because the study design was not a parallel or cluster RCT (e.g. a crossover design) (70). One study was excluded because the participants were not undergraduate students (64), and an additional study (66) was a secondary publication of another included study (17).

### **RISK OF BIAS IN INCLUDED STUDIES**

Risk of bias for the 41 parallel RCTs will be covered in this chapter and risk of bias for the eight cluster RCTs will be presented in the next chapter.

Overall, the majority of the included parallel RCTs were considered to be of low quality because of high risk of bias (2,5–8,10,12–18,21,24–26,30,31,36,37,40–43,45). Only a few studies (1,11,20,22,23,27,29,32–35,39,40,46,47) were of high quality with none of the assessed categories rated as high risk of bias (Figure 3.2). The majority of studies had one or more categories classified as unclear risk of bias, especially with regard to the allocation of participants to intervention groups. See Figure 3.2 (risk of bias) and Figure 3.3 (Risk of bias for each parallel RCT separately).

**Random sequence generation and allocation (selection bias)**

Most studies (27 of the 41 studies, or 66%) included little or no information about the random sequence generation and were therefore classified as having an unclear risk of bias (1,2,6,10–15,18,20,22–25,29,30,32–34,37,39–43,47). Of the remaining studies, only two (21,26) had a high risk of bias for random sequence generation. One (21) of these studies generated the allocation sequence by assigning students to an intervention in the order in which they were entering the room. The other study (26) classified as high risk used radioactive decay numbers to generate the random sequence. Although this is considered a good method, the study did not randomize all participants, as 20 students were allocated to the control group for practical reasons. The random sequence generation was judged to result in a low risk of bias for 12 (5,7–9,16,17,27,31,35,36,45,46) of the 41 studies (29%).

The method used in the majority of the cases to generate a random number sequence was computer software (5,7,9,16,17,31,36,45,46). Furthermore, two studies used a random number table (8,35) and one (27) used “odd” and “even” conditions from a series of random numbers.

There was no information about the allocation concealment method in 36 (1,2,6,7,10,11,13–18,20–27,29–35,37,39–43,45–47) of the 41 trials (88%) and therefore these studies were classified as having an unclear risk of allocation bias. Five studies (12%) (5,8,9,12,36) had a low risk of allocation bias. Two (5,36) of the five studies classified as low risk of bias generated the random numbers on a computer and the numbers were delivered in a way that ensured concealment of allocation, whereas the remaining three studies (8,9,12) all used opaque envelopes for concealment.

**Figure 3.2. Risk of bias**

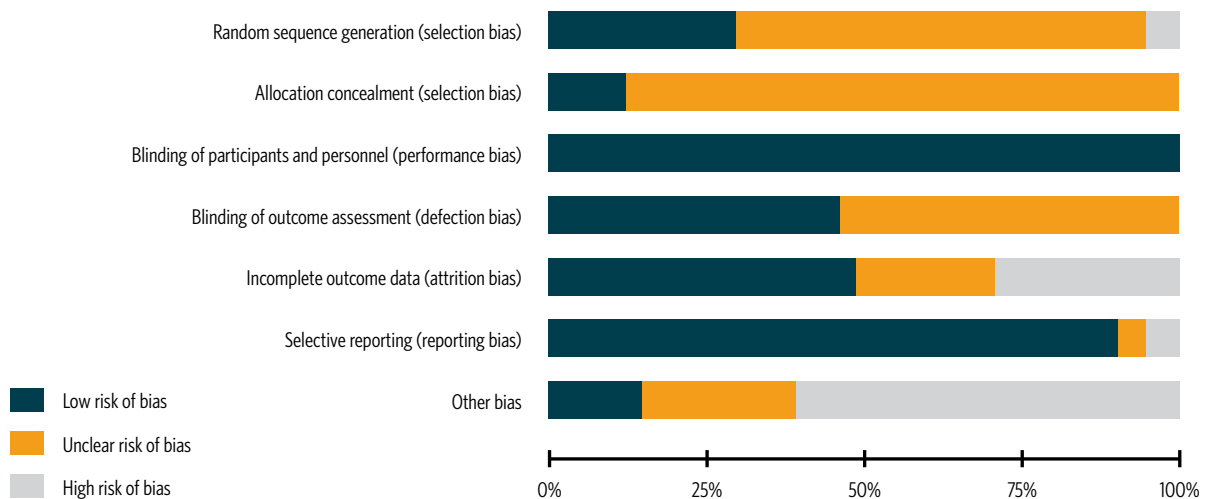


Figure 3.3. Risk of bias for each parallel RCT separately

	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
Ackermann 2012	?	?	+	+	+	+	?
Amesse 2008	?	?	+	+	?	+	-
Bloomfield 2012	+	+	+	+	?	+	-
Boet 2012	?	?	+	+	+	+	-
Bogacki 2004	+	?	+	+	+	?	-
Bradley 2005	+	+	+	+	-	+	-
Davis 2008	+	+	+	+	-	+	+
Feeg 2005	?	?	+	?	-	-	-
Gelb 2001	?	?	+	?	?	+	+
Glicksman 2009	?	+	+	+	+	+	-
Goldsworthy 2006	?	?	+	?	-	?	-
Green 2011	?	?	+	?	?	+	-
Holt 2001	?	?	+	?	-	+	-
Howedon 2002	+	?	+	+	+	+	-
Hu 2010	+	?	+	?	+	+	-
Hudson 2004	?	?	+	+	-	-	-
Jowett 2007	?	?	+	?	?	+	?
Kalet 2012	-	?	+	?	+	+	-
Kim 2003	?	?	+	+	?	+	?
Kong 2009	?	?	+	?	+	+	?
Kurlhara 2004	?	?	+	+	?	+	-
Lira 2013	?	?	+	?	+	+	-
Maleck 2001	-	?	+	?	-	+	-
McDonough 2002	+	?	+	?	+	+	?
Miedzybrodzka 2001	?	?	+	?	+	+	+
Morgulis 2012	?	?	+	?	+	+	-
Nance 2009	+	?	+	+	+	+	-
Nola 2005	?	?	+	?	+	+	+
Nousiainen 2000	?	?	+	+	?	+	?
Perfeito 2008	?	?	+	?	+	+	?
Prinz 2005	+	?	+	?	+	+	?
Pusic 2007	+	+	+	+	-	+	-
Qayumi 2004	?	?	+	+	+	+	-
Seabra 2004	?	?	+	+	+	+	?
Shomaker 2002	?	?	+	?	-	+	?
Solomon 2004	?	?	+	?	-	+	-
Tunuguntia 2001	?	?	+	?	-	+	-
Vichitvepaisal 2001	?	?	+	?	-	+	-
Weih 2008	+	?	+	?	+	+	-
Williams 2001	+	?	+	+	+	+	+
Xeroulis 2007	?	?	+	+	?	+	?

### 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 studies, although blinding of participants and personnel was not possible in any of these studies because of the nature of the interventions. The assessment was based on the fact that the 35 studies (1,2,5,7–11,13–18,21–27,29,30,32,34–37,39–43,45,46) investigating knowledge and the six studies (6,12,20,31,33,47) where only skills were measured 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. Subjective outcomes are more prone to performance bias when participants are not blinded since participants’ responses are easily affected by, for instance, concerns about the consequences of responding negatively to a programme developed by the lecturer. Attitudes and student satisfaction would therefore have resulted in a high risk of bias for performance bias in all of the included studies.

Nineteen (1,2,5–9,12,16,18,22,24,31,33,36,37,39,46,47) of the 41 RCTs (46%) 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 but also in studies with unblinded assessors if the method of outcome assessment included no element of interpretation and a classification of a result could be done unambiguously (e.g. the only assessment was a multiple-choice test). The remaining 22 studies (10,11,13–15,17,20,21,23,25–27,29,30,32,34,35,40–43,45) (or 54%) were rated as having an unclear risk of bias due to lack of information about the blinding of the outcome assessors.

### 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 (12 out of 41, 29%) of the studies (8–10,13,15,18,26,36,40–42,45) did not report complete outcome data (e.g. they reported only the mean test score but did not report the number of students analysed) or had differential drop-out rates in the different intervention groups and were consequently classified as at high risk of bias. Seven of the studies classified as being at high risk of bias (9,10,15,36,40–42) showed a difference in the

attrition/exclusion rates between the intervention groups. Five studies (8,13,18,26,45) that were classified as having a high risk of bias had missing/unreported data and did not account for or comment on this.

Twenty (49%) studies (1,6,7,12,16,17,21,23,25,27,29–32,34,35,37,39,43,46) were classified as having low risk of bias for incomplete outcome data. These studies reported if 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, nine studies (22%) (2,5,11,14,20,22,24,33,47) were classified as having unclear risk of bias for incomplete outcome data. In these studies it was not clear if there was excessive drop-out in one group compared to the other(s) or if it had occurred at all.

### **Selective reporting (reporting bias)**

The majority of studies (37 out of 41, or 90%) (1,2,5,6,8,9,11,12,14–17,20–27,29–37,39–43,45–47) were rated at low risk of selective reporting bias. This was mainly due to the categorization criteria for low risk of bias that required the authors only to report results for all outcomes reported in the methods sections of the published articles; protocols were not available to our reviewers. Only two studies (7,13) were rated as having an unclear risk of bias (5%). This was a result of the authors not presenting sufficient details on planned tests to allow reviewers to assess the risk of selective reporting bias. Similarly, only two (10,18) of the 41 studies (5%) were categorized as having a high risk of selective reporting bias. One of these studies (18) described one or more outcome measures that had been investigated and then did not report these in the results. The other study (10) omitted two questions out of 20 in the analysis of the results without giving any explanation for the exclusion or results for them, and reported only the comparison between the controls and a subgroup of the intervention group rather than the entire intervention group.

### **Other potential sources of bias**

Volunteer bias is an important and sometimes almost inevitable problem in studies assessing different ways of learning. Volunteer bias therefore resulted in a high risk of bias classification in 18 (44%) of the 41 included studies (2,5,7,8,12,15–18,21,30,31,36,37,41–43,45). It was unclear whether volunteer bias was a problem in 14 (34%) of the 41 studies

(1,6,10,13,14,20,22,24,25,27,33,35,39,47). Only nine studies (22%) randomized entire classrooms or the entire year and were therefore at low risk of volunteer bias (9,11,23,26,29,32,34,40,46).

Nine studies (22%) (6,10,13,14,18,25,26,37,45) were classified as having a high risk of bias other than volunteer bias and types earlier described. Five of these studies (6,10,13,14,25) suffered from imbalanced comparison groups, where more material or information was given in one group compared to others. This was only the case for the intervention group and thus biased the results away from the null. Contamination (i.e. the control group was also exposed to the eLearning intervention) was also a concern in one study (45) that was categorized as being at high risk of bias. However, it is possible that contamination occurred in several of the other included trials as it is likely that students shared material with others on the same course who were randomized to a different group. A study investigating different computer-based formats (18) had differential attendance among the different eLearning interventions, and was therefore also considered to be at high risk of bias. Another study (26) categorized as having a high risk of bias was the study that breached the RCT design because 20 students were added to the control group without having been randomized as such; the analysis of results did not take this into account following a per protocol analysis rather than intention to treat. Finally, one study of academic performance of medical students (24) presented only some of the results stratified by the different intervention groups, whereas the rest were presented stratified by performance groups; thus not all analyses are reported according to the group to which they were randomized.

Seven studies (17%) (6,8,16,17,20,22,40) were classified as having an unclear risk of other bias. Three of these studies (8,22,40) had (either) one or two students attending interventions they were not allocated to, or the reviewer was unable to assess whether contamination could have taken place. One study (17) had small baseline differences that were likely to have occurred by chance. Another study (6) failed to report any information on who the students recruited were (i.e. course, year etc.). A study of teaching methods for intraoral radiography (16) did not clearly state what the control group was exposed to. Finally, a study investigating teaching methods for surgical skills (20) did not compare two different intervention methods, but instead exposed one group to the intervention for a longer time.

As several types of bias were assessed under “other potential sources of bias”, other bias was classified as high risk of bias if one of the elements assessed was of high risk, even though other elements were unclear or low-risk.

For example, if there was a high risk of volunteer bias but an unclear risk of contamination, a study was classified as having a high risk of bias. See Figure 3.3 for the assessment per study.

### **Risk of bias in cluster RCTs**

Eight studies reported in six articles included in the review were cluster RCTs (3,4,19,28,38,44). The methods and analyses employed in these cluster RCTs were generally not judged to be of high quality as one or more risk-of-bias items being categorized as high risk of bias.

The recruitment process and recruitment bias were not addressed in six (3,4,19,28,38) of the eight included studies. The remaining two studies (44) that were judged to be of low risk of recruitment bias had provided enough information on the participant flow and randomization process for this assessment to be made.

Baseline characteristics differed between the intervention and control group in six studies (4,28,38,44). In two studies (28) the authors chose not to combine the results of two separate cluster RCTs because of these differences. In the other four studies (4,38,44) there was a difference in previous experience with the field being taught, or experience in using a computer, between the intervention and control groups. These studies were therefore all judged to have a high risk of bias affecting the outcome. Two studies (3,19) provided no information on baseline characteristics and whether these were different between the groups.

None of the studies reported loss of entire clusters. However, all but one study (3) reported drop-out of individual participants. Six (4,28,38,44) of the studies had a high drop-out rate that resulted in a high risk of bias classification. One study investigating eLearning as a method of teaching skills for performing electrocardiographs (ECGs) (19) reported attrition, but this study was judged to have a low risk of bias because the attrition was limited and was very unlikely to have affected the results.

Two studies examining methods of teaching musculoskeletal examination skills (44) accounted for the cluster unit in the analysis of the results. The rest of the cluster RCT studies (3,4,19,28,38) suffered from unit-of-analysis error (i.e. incorrectly analysis of participants as independent individuals rather than the unit they were randomized to) (74). Therefore, in these studies there is a high risk of false-positive conclusions. Two studies of teaching methods for drug calculation skills (28) addressed the issue of a reduced effective sample size due to the nature of the cluster RCT design but did not account for it in the data analysis.

Volunteer bias was a problem in only one of the cluster RCTs (38). In another study (3) it was unclear whether or not there was a risk of volunteer bias. The remaining six studies (4,19,28,44) were all categorized as having a low risk of volunteer bias.

In the study by Roppolo et al. (38) there was a high risk of selective outcome reporting because the authors state that cognitive testing took place but they did not report the results.

### **EFFECTS OF NON-NETWORKED COMPUTER-BASED ELEARNING INTERVENTIONS**

The 49 randomized trials included in the review assessed the effectiveness of non-networked CBL interventions in terms of knowledge, skills, attitudes and satisfaction. The findings were based on comparisons between CBL and traditional learning, or between various modes of CBL. A study may have compared more than one outcome between groups, and each outcome may have been assessed in multiple ways. For instance, a study which compared students' acquisition of skills may have assessed skills in terms of the students' performance on a global rating scale, ability to perform a specific procedure, as well as the ability to comply with requirements in a checklist. As a result, the number of comparisons made across studies for a particular outcome may exceed the number of studies that report that outcome.

The studies were divided into two research themes evaluating the impact of eLearning interventions for undergraduate health-care education: traditional learning versus eLearning, and eLearning versus eLearning.

#### **Traditional learning versus eLearning**

Forty of the included studies (82%) compared non-networked CBL with traditional learning (1–16,19,22–29,31,32,34,37–41,43–47). See Table 3.1 for a summary of findings of the individual studies, and to appendix 7 for a further description of the nature of the interventions.

#### **► Knowledge**

Among the 40 studies which compared non-networked computer-based eLearning with traditional learning, knowledge was assessed in 33 studies (83%) (1–5,7–11,13–16,19,22–29,32,34,37,39–41,43,46), five of which were cluster RCTs (3,4,19,28). Eleven studies (33%) (1,2,10,13,14,23,24,28,37) assessing knowledge gain demonstrated significantly higher knowledge gains for students assigned to CBL compared to those exposed to traditional learning. Outcome measures



for these studies were based on correct responses to questions which included true-false, multiple-choice or fill-in-the-blanks types of assessments. The sample size for these studies ranged from 19 to 225 with all but four studies (10,13,28) conducted on medical students. Seven of these studies used full eLearning as the main intervention (1,2,13,14,28,37,73) whereas four used blended learning (10,16,23,32).

None of the included studies found greater gain in knowledge for the traditional learning group.

Post-intervention knowledge was not significantly different between eLearning and traditional learning in 19 (58%) of the included studies (3–5,7–9,11,15,16,19,22,27,29,34,39–41,45,46).

Two studies (6%) (25,43) showed mixed results – i.e. favouring the intervention, control, or neither group depending on the specific indicator of knowledge being assessed. A study by Lira et al. (25) initially found no difference between the traditional and eLearning group, but found that the eLearning group had statistically significantly better post-test scores after one month. A study by Vichitvejpaisal et al. (43) showed that students taught blood gas interpretation using a textbook had greater improvement from pre-test to post-test compared to those in the eLearning group, but after three weeks the final test scores of both groups failed to show a significant difference between the two groups.

In one study (3%) (26) knowledge was assessed but was not tested for statistically significant differences between the intervention groups. The study showed knowledge improvement in the two eLearning groups as well as in the traditional learning group, whereas the control group that received no intervention showed hardly any improvement.

#### ► Skills

Overall, 13 studies – nine RCTs (5,6,12,22–24,31,37,47) and four cluster RCTs (19,38,44) – measured skills as an outcome.

Of the studies that evaluated differences in skill acquisition, eight (62%) (12,23,24,37,38,44,47) found significantly greater skill acquisition among students assigned to eLearning compared to those assigned to traditional learning. The range of skills assessed by these studies included performance in specific tasks such as cardiopulmonary resuscitation, fiberoptic intubation and knot-tying skills, performance in OSCE, as well as self-efficacy assessments. The number of participants included in these studies ranged from 19 to 354. All eight studies were conducted using medical students (12,23,24,37,38,44,47).

Three studies (23%) (19,22,31) did not detect a significant difference in skill acquisition between groups. None of the 13 studies demonstrated more favourable results for traditional learning compared to eLearning.

Results were mixed for two studies (15%) (5,6). In one of these (5), testing hand-washing skills of nursing students assigned to computer-assisted versus conventional learning, skills were similar in both groups at two-week follow-up but were in favour of the intervention group at eight-week follow-up. In the other study (6), which focused on intubation skills, successful intubation was more common in the eLearning group compared to the traditional group, whereas there was no statistically significant difference in the checklist and global rating scale assessment of intubation skills.

#### ► Attitude

Twelve studies – six RCTs (8,12,22,26,29,31) and six cluster RCTs (4,19,28,44) – assessed attitudes as an outcome towards the intervention, primarily through Likert scale surveys.

Five studies (42%) (4,12,28,31,44) found more favourable results for students assigned to CBL compared to traditional learning.

Six studies (50%) (8,19,22,28,29,44) did not detect a statistically significant difference in attitudes between groups. None of the studies found more favourable attitudes towards traditional learning.

One study (8%) (26) that assessed the difference between traditional learning and two different types of eLearning showed mixed results. The comparison between the traditional learning group and the eLearning group with no interaction (i.e. computer-based cases with no tests) showed that statistically, significantly more students would recommend the eLearning group with no interaction. However, the comparison between the control and the eLearning group with interaction (i.e. cases with multiple choice and free-text questions) did not show a statistically significant difference (26).

#### ► Student satisfaction

Student satisfaction was assessed in seven RCT studies (14,22,23,26,27,40,45) and two cluster RCT studies (19,28).

Out of nine studies looking at the level of student satisfaction, five studies (56%) (14,22,23,28,45) found a significantly greater proportion of students who were satisfied among those

exposed to CBL as compared to those exposed to traditional learning. Student satisfaction was based on questionnaires, surveys and global perceptions of satisfaction.

Two of the studies (22%) (26,27) showed higher satisfaction levels for students assigned to traditional learning group.

One study (11%) (19) did not detect any significant difference while another study (11%) (40) did not test for significant differences and there were no clear trends in terms of one intervention group being superior to another.

### **Comparison of different types of eLearning against each other**

Nine (18%) of the 49 included studies (17,18,20,21,30,33,35,36,42) compared the effectiveness of various modes of non-networked CBL against each other.

#### ► Knowledge

Of the nine studies investigating different modes of eLearning, seven studies (78%) (17,18,21,30,35,36,42) compared various forms of CBL and their effects on knowledge. One study (17), comparing the effectiveness of 3D versus 2D images of the larynx projected on a computer screen, demonstrated higher test scores for students assigned to view 2D images. Another study (35), assessing the effectiveness of an actual video of ophthalmic procedures versus actual video supplemented with 3D video, demonstrated higher scores on theoretical knowledge for the group assigned to 3D video.

One study (30), comparing two types of eLearning for teaching a module on leukaemia, found that the more interactive eLearning intervention that included questions resulted in statistically significantly higher mean percentage scores on the post-test on leukaemia, compared to the more passive intervention group who saw only text and had no questions to answer.

No differences were found in three studies (18,21,42) comparing different eLearning modalities with each other. Two of the studies (18,21) compared groups of eLearning with different levels of student interaction with each other, whereas one group received no intervention. The third study (42) compared the effects of two versions of a program, one with animations and one with static graphics.

One study (36) showed mixed findings, with one eLearning mode exhibiting superior results with respect to a particular knowledge test and another eLearning mode exhibiting better results with respect to a different knowledge test..

#### ► Skills

Skill acquisition was assessed in three (33%) (20,21,33) of the nine studies that compared different eLearning modalities. Of the three studies that assessed skill, one study (21) demonstrated better skill acquisition with the use of a particular mode of eLearning over other modes. That study investigated the effects of three different methods of manipulating contents for learning abdominal examination: click, watch and drag. The results showed that students who were able to use the mouse to trigger animated demonstrations ("click") performed better in auscultation than those who were in a more passive learning group where students had control only over the pace of the presentation ("watch"). The "click" group also outperformed students who were in a more active learning group where they were able to drag tools in motions simulating actual performance of the task ("drag") in terms of abdominal palpation and additional manoeuvres. In addition, more students in the "drag" and "click" groups correctly diagnosed a simulated patient as having appendicitis than students in the "watch" group.

Two studies (20,33) failed to demonstrate any difference in skill acquisition between eLearning modes.

#### ► Attitude

Prinz et al. (35) and Morgulis et al. (30) were the only studies that assessed attitude among the nine studies comparing different eLearning modalities. The study by Prinz et al. showed that the students in the 3D group rated the learning aid in the 3D group as more useful compared to the control group students' rating of the learning aid available in the control group, and the difference was statistically significant. Intelligibility for glaucoma surgery and improvement of spatial ability both received statistically significantly more positive responses in the 3D group compared to the control group. However, no difference was found for intelligibility for cataract surgery (35). Similarly, the study by Morgulis et al. (30), which compared the use of existing online resources with a purpose-built, targeted eLearning module on leukaemia for medical students, demonstrated an overwhelmingly positive response from students assigned to the targeted module.

#### ► Student satisfaction

Four studies (33%) (17,35,36) compared the effects of different eLearning modes on student satisfaction. The study by Prinz et al. (35), earlier cited for favourable results of 3D over 2D learning of ophthalmic procedures on knowledge gained, reported greater student satisfaction with the 3D video. Although the study by Hu et al. (17) found

**Table 3.1. Summary of findings for the 40 studies comparing non-networked computer-based eLearning (CBL) with traditional learning**

Study	Discipline	Findings*			
		Knowledge	Skills	Attitude	Satisfaction
Ackermann 2010 <sup>1</sup>	Medicine	E	-	-	-
Amesse 2008 <sup>2</sup>	Medicine	E	-	-	-
Armstrong 2009 <sup>3</sup>	Medicine	NS	-	-	-
Bains 2011 <sup>4</sup>	Dentistry	NS	-	E	-
Bloomfield 2010 <sup>5</sup>	Nursing	NS	M	-	-
Boet 2010 <sup>6</sup>	Medicine	-	M	-	-
Bogacki 2004 <sup>7</sup>	Dentistry	NS	-	-	-
Bradley 2005 <sup>8</sup>	Medicine	NS	-	NS	-
Davis 2008 <sup>9</sup>	Nursing	NS	-	-	-
Feeg 2005 <sup>10</sup>	Nursing	E	-	-	-
Gelb 2001 <sup>11</sup>	Medicine	NS	-	-	-
Glicksman 2009 <sup>12</sup>	Medicine	-	E	E	-
Goldsworthy 2006 <sup>13</sup>	Nursing	E	-	-	-
Green 2011 <sup>14</sup>	Medicine	E	-	-	E
Holt 2001 <sup>15</sup>	Medicine	NS	-	-	-
Howerton 2002 <sup>16</sup>	Dentistry	NS	-	-	-
Jeffries 2003 <sup>19</sup>	Nursing	NS	NS	NS	NS
Kim 2003 <sup>22</sup>	Nursing	NS	NS	NS	E
Kong 2009 <sup>23</sup>	Medicine	E	E	-	E
Kurihara 2004 <sup>24</sup>	Medicine	E	E	-	-
Lira 2013 <sup>25</sup>	Medicine	M	-	-	-
Maleck 2001 <sup>26</sup>	Medicine	DNTa	-	M	T
McDonough 2002 <sup>27</sup>	Medicine	NS	-	-	T
McMullan 2011a <sup>28</sup>	Nursing	E	-	NS	Eb
McMullan 2011b <sup>28</sup>	Nursing	E	-	E	-
Miedzybrodzka 2001 <sup>29</sup>	Medicine	NS	-	NS	-
Nance 2009 <sup>31</sup>	Dentistry	-	NS	E	-
Nola 2005 <sup>32</sup>	Medicine	E	-	-	-
Perfeito 2008 <sup>34</sup>	Medicine	NS	-	-	-
Qayumi 2004 <sup>37</sup>	Medicine	E	E	-	-
Roppolo 2011 <sup>38</sup>	Medicine	-	E	-	-
Seabra 2004 <sup>39</sup>	Medicine	NS	-	-	-
Shomaker 2002 <sup>40</sup>	Medicine	NS	-	-	DNTc
Solomon 2004 <sup>41</sup>	Medicine	NS	-	-	-
Vichitvejpaisal 2001 <sup>43</sup>	Medicine	M	-	-	-
Vivekananda-Schmidt 2005a <sup>44</sup>	Medicine	-	E	NS	-
Vivekananda-Schmidt 2005b <sup>44</sup>	Medicine	-	E	E	-
Weih 2008 <sup>45</sup>	Medicine, Psychology	NS	-	-	E
Williams 2001 <sup>46</sup>	Medicine	NS	-	-	-
Xeroulis 2007 <sup>47</sup>	Medicine	-	E	-	-

\*Note:

E = results favoured CBL over traditional learning

NS = no significant difference between CBL and traditional learning

M = mixed results

T = results favoured traditional learning over CBL

DNT = difference not tested

a: knowledge improvement in the two eLearning groups as well as the traditional learning group, whereas the control group that received no intervention showed hardly any improvement.

b: in the cluster RCT by McMullan 2011 (28) the results for satisfaction were pooled for the two cohorts (McMullan 2011a and McMullan 2011b) and the result presented for McMullan 2011a therefore also includes students from the McMullan 2011b cohort.

c: no clear trends in terms of one intervention group being superior to another.

that knowledge gained was higher for the 2D versus the 3D learning group, enjoyment was higher in students assigned to 3D computer models. A study (36) that compared the effectiveness of a linear versus branched format for computer tutorials demonstrated that, while the layout did not make a difference to their gain in ability, students in the linear group were slightly less likely to rate the tutorial as “valuable”.

## Discussion

### Summary of main results

The review compared non-networked computer-based eLearning interventions with traditional learning and compared different types of non-networked CBL. The outcomes assessed were gain in knowledge, gain in skills, attitude towards the intervention, and student satisfaction.

### COMPUTER-BASED ELEARNING VERSUS TRADITIONAL LEARNING

The systematic review of studies comparing CBL with traditional learning showed that 11 (33%) of the 33 studies (1,2,10,13,14,23,24,28,32,37) found a benefit in using eLearning as opposed to traditional learning in terms of gain in knowledge. There was a greater gain in skills in eLearning groups in eight studies (62%) (12,23,24,37,38,44,47) out of the 13 studies assessing skills. Of the 16 studies showing a greater gain in knowledge and skills, 12 studies (75%) (2,10,12–14,24,28,37,38,44) had at least one risk-of-bias item rated as high risk.

The majority of studies (21 out of 33, or 63%) (3–5,7–9,11,15,16,19,22,25,27,29,34,39–41,43,45,46) either did not find a statistically significant difference in knowledge gain between the two types of learning methods or showed mixed results for eLearning versus traditional learning, depending on the test of knowledge that was used. The difference between skills acquisition in the two intervention groups was not statistically significant or the study showed mixed results for eLearning versus traditional learning in five studies (38%) (5,6,19,22,31) out of the 13 studies testing skills. Among the studies that found either no difference or mixed results for knowledge and skills, 15 (56%) (3–9,15,16,19,25,40,41,43,45) of the 27 studies had at least one risk-of-bias item rated as high risk.

None of the studies showed that the gain in knowledge and skills was greater in the traditional learning group than in the eLearning group. One study (26) assessed knowledge but did not evaluate whether the difference in test results between the traditional learning and the eLearning group was statistically significant.

Attitudes towards the intervention were more positive in the eLearning groups in five (42%) (4,12,28,31,44) of the 12 studies assessing attitude. However, seven studies (58%) (8,19,22,26,28) either did not find a statistically significant difference between the two types of learning methods or showed mixed results for eLearning versus traditional learning depending on the test evaluated.

Five (56%) (14,22,23,28,45) of the nine studies comparing students' level of satisfaction were more positive towards the eLearning intervention. There was no statistically significant difference between the two types of learning methods in one of the studies (19) assessing satisfaction. Two studies (22%) (26,27) reported greater satisfaction with traditional learning when compared to eLearning in a quantitative way. One study (40) assessed student satisfaction but did not test for a statistically significant difference between groups.

Although most of the included studies comparing eLearning with traditional learning reported seemingly similar CBL programs, there were some differences in the extent of interaction available (e.g. answering a quiz on a computer as opposed to using a PDA as a learning aid when learning how to do drug calculations). Furthermore, the duration of exposure to the eLearning interventions varied considerably between the included studies.

### COMPARING DIFFERENT TYPES OF ELEARNING

Studies comparing different eLearning modalities were also reviewed. Typically these studies compare a “passive” eLearning mode, such as reading a slide show on a computer, to a more “active” eLearning mode, such as reading a slide show and answering an MCQ. The comparison of studies assessing the difference between eLearning modalities did not show any clear trends for knowledge and skills gained in terms of more passive eLearning modalities being outperformed by eLearning programmes that required more active participation by the student. However, the different eLearning modalities being compared between studies were very heterogeneous.

Similarly, there were no clear trends for attitude, but only two studies (30,35) compared students' attitudes towards the different eLearning modalities. However, comparison of student satisfaction in three studies showed that the more passive eLearning modalities were outperformed in terms of greater student satisfaction by eLearning programs that required more active participation by the student.

Surprisingly, none of the studies included addressed the cost-effectiveness of eLearning versus traditional learning

and therefore it is not possible to answer this important question. Only six articles (1,8,9,27,42,44) mentioned economic elements such as hours spent developing the program.

Also, none of the studies reported any adverse effects of eLearning. This may be because no adverse effects were identified or may simply be a result of the studies not investigating adverse effects.

## OVERALL COMPLETENESS AND APPLICABILITY OF EVIDENCE

Most of the included studies were conducted at universities and involved students studying medicine, dentistry or medical-allied studies. The mean age among participants in those studies that reported the age of participants ranged from 21.8 to 30 years of age. Thus, the included participants represented the target population of undergraduate health-care students well. However, an important difference between the participants in the systematic review and the general population of university students is that the review sample relied mainly on students who volunteered to participate or gave their consent. Volunteers are likely to be more enthusiastic and eager to use the eLearning intervention compared to the general population. Therefore, they may not be completely representative of undergraduate university students in general. However, whether or not the results also apply to postgraduate students or to the workforce remains to be determined.

The results and conclusions of this systematic review apply to students in the field of medicine, dentistry or medical-allied studies. Furthermore, it is also likely that the results also apply to students following other similar university degree courses that were not included in this review.

The majority of the included studies compared CBL to traditional learning in terms of knowledge and/or skills gained. Some studies also compared attitudes towards the learning methods and student satisfaction. Thus, they provide important evidence to answer the research questions. Furthermore, the nine studies comparing different modes of eLearning provide additional knowledge about the complexity and nature of eLearning in undergraduate health-care education. These provide a valuable source for further comprehending the effects of the different eLearning modalities on knowledge and skills gained.

The studies included in the review differed in terms of duration of exposure to the intervention, which ranged between 12 minutes (20) and one year (32). Consequently, this diversity results in a substantial amount of heterogeneity between the different studies. The eLearning modalities

were also different in terms of complexity, ranging from a simple PDF file to software with videos, quizzes and other interactive features. However, nearly all studies used computers – apart from one study that used a PDA (13) – with software that could function without the Internet. Therefore, these eLearning modalities have the potential to be used in most parts of the world.

Of the 49 included studies, five (23,25,34,39,43) were conducted in low- and middle-income countries and 44 in high-income countries. This does not limit the general applicability of the interventions to developed countries because the interventions evaluated were solely computer-based and did not require web access to function. Therefore, even remote areas without Internet access could potentially use CBL. However, since only five studies (23,25,34,39,43) were conducted in low-income countries, generalization to low-income countries should be done with caution since factors that were not addressed in the included studies may be of importance in low-income countries. For example, computer literacy is likely to be a lot less prevalent in low-income countries. Studies from the African and Eastern Mediterranean and regions were not found, and are therefore not included in this review.

Even though it is likely that there are many similarities within the included regions, there may also be several important differences that could result in potentially different effects of non-networked CBL (for instance, lower computer literacy could make the implementation of a eLearning course more difficult).

## QUALITY OF EVIDENCE

The total number of participants included was 4955. However, included in this number are the participants from eight cluster RCTs reported in six articles (3,4,19,28,38,44). The number of participants has not been adjusted for possible dependence among participants within a cluster.

The quality and reporting of the 49 studies included was very variable. Hardly any of the included studies adhered to the CONSORT guidelines for reporting of RCTs (75) and therefore many studies were classified as having an unclear risk of bias in one or more categories.

Of the 16 studies showing greater gain in knowledge and/or skills in the eLearning groups, three studies (10,13,14) had an important problem in the study design. The students in these studies received additional material in the eLearning intervention group compared to the control group, which could have overestimated the effects of eLearning. One of these three studies (10) also had a high risk of both selection

and attrition bias as well as an insufficient description of the methods employed, which meant that the allocation of participants and blinding of outcome assessment could not be assessed for quality. Among the studies finding a benefit, four studies (2,12,37,38) had a high risk and six (1,10,13,14,24,47) had an unclear risk of volunteer bias. Volunteer bias could have resulted from a sample of students who are regular computer users and therefore eLearning would be the better teaching method when compared to traditional learning, which might not be the case in the general population (76,77).

One of the studies (45) that did not find a significant effect of eLearning in terms of knowledge and/or skills gained had a high risk of contamination - i.e. it was very likely that the students in the control group were also exposed to the intervention. Three other studies (8,22,40) that did not find a significant effect of eLearning were considered to have an unclear risk of contamination due to their methodological limitations and one to two documented cases of contamination. If contamination does occur, it has the potential to bias the results towards the null (74). Two (3,41) of the 27 studies that did not find a significant difference had a small sample size and therefore could have been underpowered.

Due to the nature of the intervention, blinding of the participants was not possible in any of the included studies. Subjective outcomes such as students' attitudes and level of satisfaction will always have a high risk of bias if there is no blinding (74). For instance, the students may feel obliged to respond positively to an intervention planned by their professor. Furthermore, it is also likely that those who are followed up for the full time of the study represent a group of students who are more enthusiastic about eLearning than the background population, resulting in attrition bias. Similarly, volunteer bias may result in a sample of students whose opinions are more positive towards the intervention from the very beginning of the study and thus return more favourable results. Therefore, these subjective outcomes should be interpreted with caution.

Volunteer bias was an important problem in nearly 50% of the included trials (2,5,7,8,12,15-18,21,30,31,36,37,41-43,45,62). This can result in a skewed sample of students who are more interested in eLearning and perhaps more capable of learning with this intervention due to their higher level of familiarity with computers. As a result, they may not be exactly representative of the general population. The volunteers are also likely to have a higher level of participation compared to the general population and, consequently, the results presented here could be showing the best case scenario (76,77).

Eight studies were cluster RCTs (3,4,19,28,38,44) and were generally not considered to be of high quality. The authors for two (28) of the eight studies stated that the main reason for choosing the cluster RCT design was to avoid contamination (i.e. exposing controls to the intervention). However, the other studies (3,4,19,38,44) specified no reason for their choice of a cluster randomized design and it may have been selected for convenience rather than to avoid contamination.

Overall, the evidence included in this systematic review is considered to be of variable quality, and a robust conclusion that would apply to the general population on whether there is a difference between CBL and traditional learning cannot be drawn. However, this systematic review can give an indication of whether there is a difference in the gain of knowledge and skills between CBL and traditional learning.

#### POTENTIAL BIASES IN THE REVIEW PROCESS

One or more aspects of the methodology used were unclear in the majority of the included trials, and in some cases it was also unclear whether attrition had occurred. Although authors were contacted to obtain the missing information, some authors did not reply to requests and others did not know the answers. Due to time constraints, not all authors were contacted.

To make the review feasible in the time available, 10 reviewers were involved in the data extraction process, which resulted in some differences in the interpretation of some of the assessed categories. Therefore, three reviewers went over the entire data extraction again to ensure that it was done in a uniform way and made amendments where necessary after consensus.

The field of eLearning has yet to establish a widespread standard terminology for the different specific types of eLearning and thus comparison with other studies was slightly complex. However, the review used a simple and clear definition of CBL. Thus, if other studies described their eLearning methods in detail, it was easily possible to categorize a method as a computer-based, web-based or simulation-based eLearning method.

#### Conclusion

The aim of the review was to determine if there is a difference between non-networked CBL and traditional learning for undergraduate health-care students. Because the studies included in this systematic review had a number of limitations, a robust conclusion allowing for

generalization to all undergraduate students around the world cannot be drawn. Nevertheless, the included evidence from the highest quality studies, as well as from those of lower quality, indicate that non-networked CBL can be equivalent to, and perhaps even superior to, traditional learning in terms of knowledge and skills gained. Thus, CBL is likely to be a convenient and possibly also more cost-effective alternative to traditional learning that could help increase the health-care workforce globally.

The results indicate that students were more favourable towards the eLearning intervention. However, due to a high risk of bias these results should be interpreted with caution.

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# Internet and local area network-based eLearning

Of the 209 studies that met the inclusion criteria in this systematic review, 59 articles (1–59) complied with the term “Internet and local area network-based” and are discussed in this section. One study (33) involved students in two consecutive RCTs that were analysed separately so the total number of evaluated trials was therefore 60. These 60 trials included seven studies (24,53–57,59) that were reclassified as network-based eLearning from non-networked eLearning because the functionality of the eLearning intervention would be lost without an Internet connection.

The selection process is depicted in Figure A.5.2 of Annex 5. A description of each of the included trials and its findings is included in Annex 7. Here the findings are summarized, discussed and interpreted.

## Findings

### Included studies

All studies were published in peer-reviewed journals between 2000 and 2013 except for one dissertation (58). All included studies were parallel or cluster RCTs. On the basis of the included number of RCTs and cluster RCTs, there seems to be an increasing publication trend after 2007. Eighteen of the included studies (30%) were published between 2000 and 2007 (i.e. during eight years). The remaining 42 studies (70%) were published in the shorter period between 2008 and mid-2013 (i.e. during 5.5 years).

Out of all 60 studies included in the review, 33 investigated eLearning in the field of medicine (2,4,8,10–12,14–17,20,21,25,26,30,35–39,41–47,49,52,54,55,57,59). Thirteen of the articles (1,3,9,18,19,29,32,33,51,53,56) were exclusively from nursing, three (31,34,58) dealt with physical therapy whereas three others dealt with pharmacy (6,7,48). Nine studies (5,13,22–24,27,40,50) investigated eLearning for dentistry students. Additionally, one article (28) dealt with medicine, nursing and physical therapy while the remaining study recruited university students but did not define their discipline (58).

### PARTICIPANT CHARACTERISTICS

The total number of participants included across all trials was 6750. The study with the smallest control group had 10 participants (54), whereas the largest control group had 249 participants (5). The study with the smallest intervention group had 10 participants (30), while the largest intervention group had 349 participants (5).

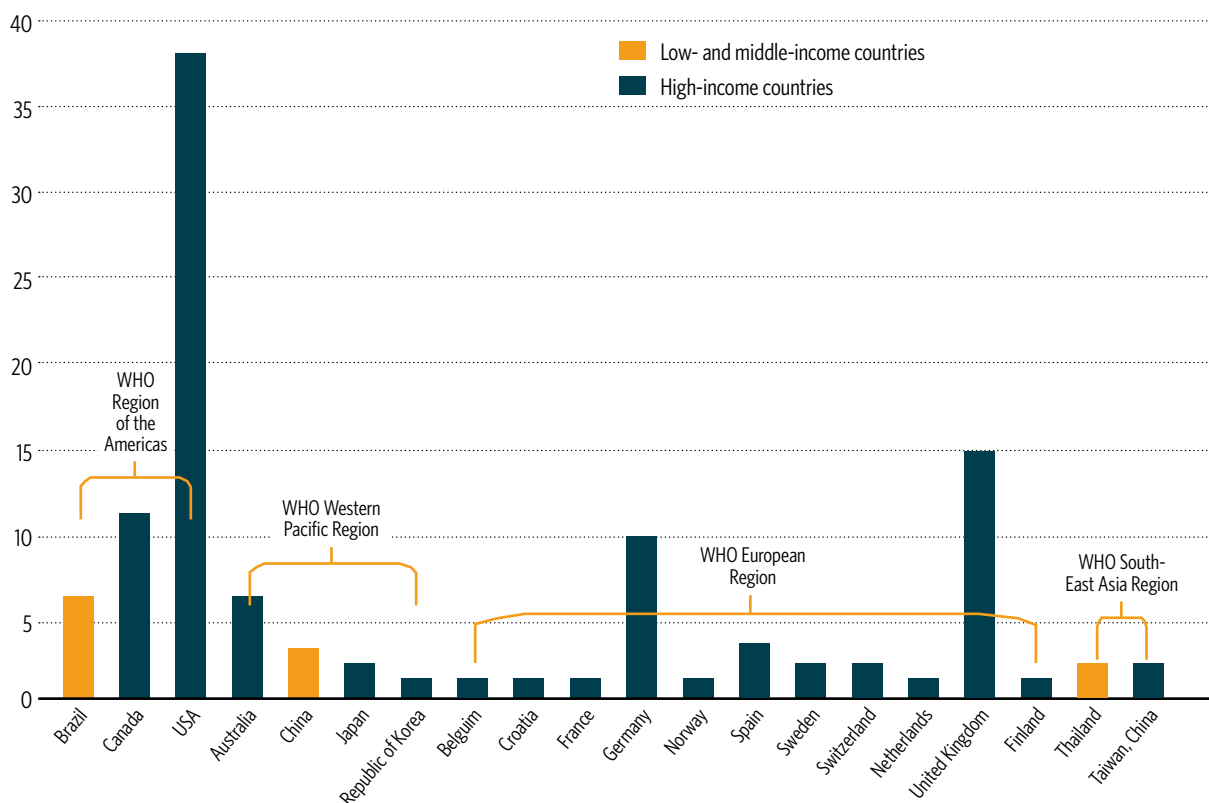
Most studies were conducted among undergraduate university students apart from nine studies (3,5–7,9,18,29,30,56) that investigated the effect of networked-based eLearning for vocational training. Out of the 20 studies (33%) (6,8,9,16,21,23–25,28,29,31,33,34,41,42,48,50,52,53) that specified the age of the students, the lowest mean age of participants in a control group was 20 years (31) and the oldest was 30 years (53). The lowest mean age in an intervention group was 19.9 years (52) and the highest was 30 years (53).

### INTERVENTION CHARACTERISTICS

Fifty studies compared eLearning to traditional learning, and 10 studies (2,11,12,21,22,38–40,43,51) compared one mode of eLearning to another mode of eLearning. The shortest duration of exposure was 9.05 minutes (57) and the longest was nine months (33). Most of the studies (51 out of 60, or 85%) were conducted exclusively in high-income countries. Seven studies were conducted solely in low-to-middle-income countries: two in Brazil (1,2), two in China (14,32), one in Thailand (9) and two in Taiwan, China (3,18). One study (28) was conducted simultaneously in Brazil and the USA. Figure 4.1 shows the distribution of country origin of the included studies.

The majority of the studies used a website to present the learning material to the participants as part of their intervention (1–10,13–22,24–43,45–57,59). Three studies (11,12,23) used a spaced educational intervention – i.e. an intervention in which the educational exposures are spaced and repeated over time (60). In these studies the learning material was presented regularly by email (11,12,23). One study used

**Figure 4.1. Country origin of included examined studies for low- and middle-income countries and high-income countries separately**



videoconference lectures as an intervention (44) and one used a visual concept map (58).

## PRIMARY OUTCOMES

### ► Students' knowledge

The knowledge gained from the exposure to the intervention was assessed in a number of different ways in the included studies. Overall, 53 (1–3,5–9,11–22,24–28,30,32–44,46,47,49–59) of the 60 studies looked at a knowledge-based outcome. Nineteen of these studies (1,8,11,16,19,21,24–26,32,34,37,46,49,51,52,54,57,59) used only an MCQ to test students' knowledge and understanding. Six studies used an MCQ as a knowledge assessment tool, together with an adaptive spaced test (12), gap text questions (27), matching and short answer questions (38), open-ended and true-or-false questions (41), short essay questions (58) and a key features test (36).

Seven studies reported using test questions or items (7,15,16,20,44,47,55) to assess knowledge of study participants.

Six other studies used open-ended (6,9,40,43) or Likert-style questionnaires (5), or even "fill in the blank" questions (50). The rest of the studies measured students' knowledge gain via other testing means, including general numeracy tests (33), written examinations (17,22,35,42), independent observers' assessment (56), cognitive assessment instruments (30), surgical knowledge test scores (53), a diagnostic thinking inventory and individual students' performance in solving clinical reasoning problems (14), a modified version of the Dartmouth Sleep Knowledge and Attitudes Survey (39), an interactive evaluation about melanoma (2), an orthodontic examination form for each patient (13), or some form of a knowledge assessment scale or checklist (18,28,45).

### ► Students' skills

Skills were evaluated in 16 studies (4–6,8–10,15,18,29,31,34,40,45,46,48,49), using various methods to assess the outcome. Nine studies (9,10,18,31,40,45,46,48,49) used a rating scale and/or checklists (e.g. an OSCE) to assess clinical skills. One study (29) used a search skills test, another one (5) a Likert-style questionnaire, while three studies

evaluated students skills through written assessments such as data collection sheets (6), written case analysis (17) and open questions on standardized tasks (8). Finally, one study (4) measured the degree of new skills acquisition by using a self-assessment report while another (15) measured the time that students took to complete the assigned exercise.

#### ► Students' attitudes

Feedback from students assessed as their attitude towards the eLearning intervention was reported as an outcome in a total of 14 studies (4,5,8,9,19,21,24,25,30–32,40,41,49). In all of these, students' attitudes were measured by questionnaires.

#### ► Student satisfaction

Student satisfaction was considered as an outcome in 33 studies (1,8–10,13–17,19,22–24,26–28,31,34–38,41–43,45,46,50–53,57,59). Seventeen of these studies (9,10,14,16,27,28,31,34,36,38,41–43,45,50,52,53) mentioned that student satisfaction was evaluated with Likert scale questionnaires. The remaining 16 studies comparing student satisfaction among the students (1,8,13,15,17,19,22–24,26,35,37,46,51,57,59) used different types of questionnaires or surveys without mentioning the use of Likert scales.

## SECONDARY OUTCOMES

#### ► Health economic properties of the elearning intervention

Cost-related properties of the eLearning intervention were rarely mentioned in the included Internet and local area network-based studies. However, some of the studies mentioned several financial and resource-related elements of eLearning.

Buzzell et al. (30) expect that in the future there will be a number of experts assisting with the creation of electronic course material for a particular field, and that the development of web-based courses as well as their delivery will therefore not need the involvement of every faculty member at all stages. Hence, "In this way, institutions of higher education will be able to benefit from the cost efficiency associated with the sharing of course materials over the Internet." Stain et al. (44) noted that the costs of setting up videoconferencing were comparable to the costs of live lectures after an initial hardware investment of less than US\$ 10 000. Stewart et al. (45) cited a paper stating that reduction of instructor training time, labour costs and institutional infrastructure could result in significant cost-efficiency. Toumas et al. (48) mentioned in the discussion

that using the Internet leads to "reduced costs in terms of tutor-led workshops and is more efficient, enabling more complex topics to be covered in workshops". Hauer et al. (10) deduced that the video cases were cheaper than the mini clinical performance evaluation (CPX) examination they used. An in-person examination of a class of 150 students cost approximately US\$ 5400, which did not include clinical skills centre maintenance costs, costs of case development and payment of centre staff. In contrast, plain technologies such as video cases were produced at a total cost of US\$ 2200. In addition, the video cases could be reused freely, whereas the in-person mini-CPX requires annual purchase of a licence.

In contrast, Fleming et al. (50) noted that the development of web-based or computer-assisted instruction (CAI) is expensive in terms of time and energy. Phadtare et al. (28) made a general comment on the potential lack of necessary infrastructure and "new" costs associated with online courses.

#### ► Adverse and/or unintended effects of elearning

Adverse or unintended events of the eLearning intervention were not reported in any of the studies.

## EXCLUDED STUDIES

Initially, 65 studies were categorized as Internet and local area network-based eLearning studies. Two studies (61,62) were reclassified as non-networked computer-based studies because their eLearning interventions could be fully functional even without the support of network technologies. Three studies (63–65) were excluded because of insufficient data, while another (11) was excluded as a duplicate paper. Seven studies (66–72) were excluded during the data extraction process, just before the analysis, because they met one or more of the exclusion criteria. Four of these seven studies (68,69,71,72) were excluded because their study design was not a parallel or cluster RCT (e.g. a crossover design) (71). Two studies (67,70) were excluded because they did not include comparison groups for the eLearning intervention (e.g. two different blended teaching methods using a common eLearning intervention in exactly the same way (70). Finally, one study (66) used an eLearning intervention which was considered ineligible for the review ( i.e. electronic voting during the lecture) (66).

## RISK OF BIAS IN THE INCLUDED PARALLEL RCTS

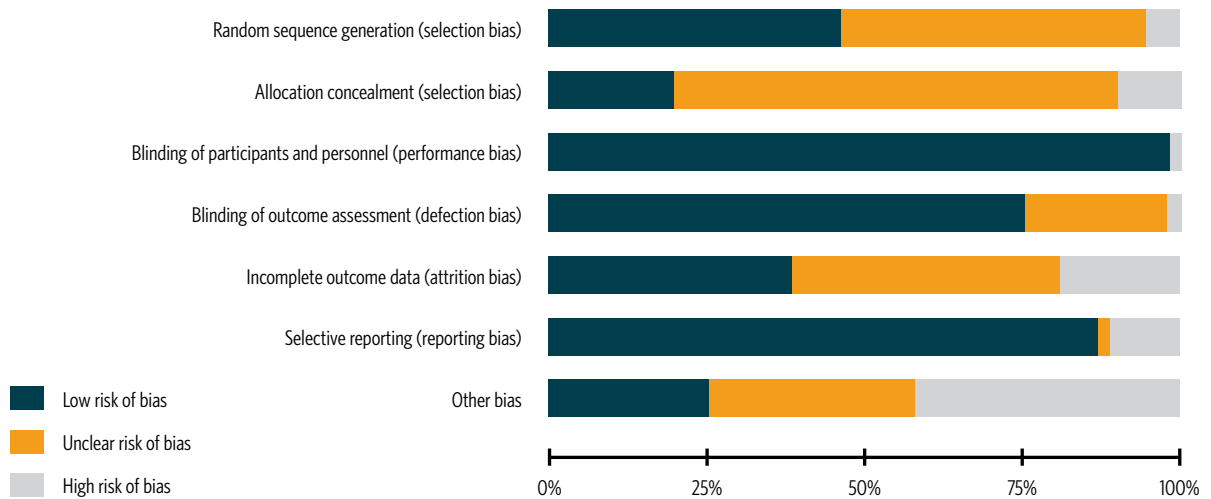
This section covers the risk of bias for the 52 included parallel RCTs. Risk of bias for the eight included cluster RCTs is presented separately later.

Thirty-one of the studies were considered to be of low quality because of high risk of bias (1,9,10,12,14–17,20,25–27,29,31,33,34,37,39–41,46,47,49,51–54,56–59). Twenty-nine of the studies (2,6,8,11,13,19,24,28,30,32,36,38,42–45,50,55) 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 (23) with all the categories classified as having low risk of bias (see Figure 4.2 and Figure 4.3).

## Random sequence generation and allocation (selection bias)

Most studies (25 of the 52 studies, or 48%) included little or no information about the random sequence generation and were therefore classified as having an unclear risk of bias (2,3,8–13,17,19,23,26,27,30,31,36,38–40,43,44,47,49,51,59). Only three of the 52 studies (6%) had a high risk of bias for random sequence generation. One (16) of these studies generated the allocation sequence by assigning students to an intervention in the order with which they entered the room. The other two studies violated the randomization plan by letting students choose between three assignments freely (15) or by assigning students to the study groups in a consecutive way – i.e. based on the order in which they

Figure 4.2. Risk of bias



**Figure 4.3. Risk of bias for each individual parallel RCT separately**

	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	+	+	+	+	+	-	-
Ainsworth 2012b	+	+	+	+	+	-	?
Arroyo-Morales 2012	+	?	+	?	+	+	-
Beekman 2008	+	?	+	+	-	+	?
Brettle 2013	+	?	+	?	-	+	?
Buzzell 2002	?	?	+	+	+	+	+
Cantarero-Villanueva 2012	+	?	+	+	?	+	-
Chao 2003	?	?	+	+	+	+	?
Chen 2007	+	+	+	-	?	+	-
Erickson 2003	+	?	+	+	+	+	?
Fernandez 2011	?	?	+	+	-	+	-
Fleming 2003	+	?	+	+	?	+	?
Friedl 2006	?	?	+	+	+	+	?
Frith 2003	?	-	+	+	-	-	-
Gerdprasert 2011	?	?	+	?	+	-	?
Hauer 2009	?	?	+	?	-	+	-
Jenkins 2008	+	?	+	+	+	+	?
Juliani 2011	+	-	+	+	?	-	-
Kandasamy 2009	+	+	+	+	-	+	?
Kerfoot 2008	?	?	+	+	+	+	?
Kerfoot 2010	?	?	+	+	+	+	-
Komolpis 2002	?	?	+	+	?	+	+
Lee 2010	+	?	+	+	+	+	-
Leong 2003	-	?	+	?	+	+	-
Lewis 2011	-	-	+	+	?	+	-
Lipman 2011	?	?	+	+	-	+	
Maag 2004	?	?	+	+	+	+	+
Mahnken 2011	-	-	+	+	?	+	+
Matheos 2004	+	?	+	+	+	+	?
Nkenke 2012	?	?	?	?	+	+	+
Nkenke 2012a	+	+	+	+	+	+	+
Ochoa 2008	+	+	+	+	?	+	-
Palmer 2008	?	?	+	?	?	+	-
Peroz 2009	?	?	+	+	?	+	-
Phadtare 2009	+	+	+	?	?	+	?
Raupach 2009	?	?	+	+	+	+	+
Raupach 2010	?	?	+	+	+	+	-
Ricks 2008	+	?	+	+	+	?	-
Romanov 2006	?	?	+	+	?	+	+
Salas 2013	?	?	+	+	?	+	-
Schittek 2005	?	?	+	+	?	+	-
Smits 2012	+	?	+	?	-	+	+
Spickard 2002	+	+	+	+	?	+	+
Spickard 2004	?	?	+	+	+	+	+
Stain 2005	?	?	+	?	?	+	?
Stewart 2013	+	+	+	+	?	+	?
Stolz 2012	+	?	+	?	?	+	-
Subramanian 2012	?	?	+	+	-	+	?
Succar 2010	?	?	+	+	?	-	+
Truncali 2011	?	-	+	?	-	+	-
Wang 2009	+	?	+	+	?	+	+
Yeung 2012	+	+	+	+	?	+	-

undertook a specific internship (20). The random sequence generation was classified as likely to result in a low risk of bias for 24 (46%) (1,6,14,22,24,25,28,29,31–34,41,42,45,46,50,52,54–58) of the 52 studies.

The method used to generate a random number sequence in the majority of the cases was computer software (14,22,28,29,31–34,45,46,52,54–58). Furthermore, one study used name drawing (1), two studies used a random number table (41,50) and one other used “odd” and “even” conditions from a random number series (32).

There was no information about the allocation concealment method in 37 (73%) (2,6,8–15,17,19,22,24,26,27,29–32,34,36–41,43,44,46,47,50,53–56,59) of the 52 trials, 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 (1) facilitated its randomization process by drawing the name inside the classroom in the presence of all class members, and another study (49) posted its randomization result on the website four days before the lecture. The other three studies (16,20,51) 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 (45,52,57,58) 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 (33). The remaining four studies (24,25,28,42) 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 (23), 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 (23) did not report any outcome on knowledge or skill. The overall assessment for the performance bias was based on the fact that only the 43 studies investigating knowledge (1,3,5–9,13–20,24–28,30,32–37,41,42,44,46,47,49,50,52–59) and the 11 studies (6,8–10,15,29,31,34,45,46,49) 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

are not blinded, as a result of their subjective nature, and 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 (6,13,17,31,33,40,42,43,45) but also in studies with unblinded assessors so long as the method of outcome assessment included no element of interpretation and a classification of a result could be done unambiguously (1,2,8,11,12,14,16,19,20,24,25,27,30,32,36–39,47,50–57,59) – e.g. the only assessment was a MCQ. Twelve studies (22%) were rated as having an unclear risk of bias due to the lack of information about blinding of the outcome assessors (9,10,15,24,26,28,29,34,41,44,46,49). Only one study (58) had a 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)**

Since 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, or 19%) of the studies did not report complete outcome data (e.g. they reported only the mean test score but did not report the number of students analysed) or had differential drop-out rates in the different intervention groups and were classified as having high risk of bias. Two of the studies at high risk of bias (4%) showed a difference in the attrition/exclusion rates between the experimental groups (10,57). 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 (29,41,49,51,56). The remaining three studies reported inconsistent sample sizes (17,47,53).

Twenty (38%) studies were classified as having a low risk of bias for incomplete outcome data (2,6,8,9,11,13–15,19,22–24,33,34,36,37,43,54,55). 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 (1,12,16,20,25–

28,30–32,38–40,42,44–46,50,52,58,59). In these studies it was not clear whether there was any level of attrition among the experimental groups at all.

#### **Selective reporting (reporting bias)**

Most studies (45 out of 52, or 87%) were rated as having a low risk of selective reporting bias (2,6,8,10–17,19,20,22–32,34,36–47,49,50,52,53,55–58). 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 the reviewers). Only one study (5%) (54) was rated as having unclear risk of selective reporting bias because the authors presented more results than the outcomes mentioned in the methods section. Six out of the 52 studies (12%) were rated as having a high risk of selective reporting bias. Four of these studies (1,9,51,59) did not report the results in full, making it impossible to obtain separate results for each group. Two studies presented in the same article extended their study period to obtain a long-term outcome (33).

#### **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%) (14–16,25,27,31,33,34,37,40,49,51–54,58). It was unclear whether volunteer bias was a problem in 15 (29%) of the 52 studies

and therefore they were classified as having an unclear risk of bias (2,6,8,9,22,28,29,44–47,50,55–57). Among them, nine of the studies did not provide information for the recruitment process (2,6,8,9,22,44,46,47,50), while six studies (28,29,45,55–57) approached all the students but not all of them agreed to participate in the trial. Twenty studies (39%) recruited or approached entire classrooms or the entire year and were therefore at low risk of volunteer bias (1,10–13,17,19,20,23,24,26,30,32,36,38,39,41–43,59).

Six further studies (12%) were classified as having a high risk of other potential sources of bias (1,10,12,26,39,46). 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 (46) as was the control group. In another study (39) 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 also being exposed to the eLearning intervention) was

also a concern in one study (6%), which was categorized as having a high risk of bias (26). However, it is possible that contamination occurred in several of the other included trials as it is likely that students shared material with others who were randomized to a different group. Three studies were rated as having a high risk of other bias because one study used a historical control group (10), one allowed some of the students to hand in their assessment, a schedule, in person rather than electronically (1), while another study reported that the authors had a conflict of interest with spaced education (12).

Other bias was classified as a 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 instance, if there was a high risk of volunteer bias but an unclear risk of using comparable learning interventions between experimental groups, the study was classified as having a high risk of bias. See Figure 4.3 for the assessment per study.

### **Risk of bias in cluster RCTs**

Eight studies included in the review were cluster RCTs (3–5,7,18,21,35,48). In these studies one or more risk-of-bias items were categorized as having a 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 (4,18) of the eight included studies. Two other studies were assessed as being of high risk for recruitment bias because they applied the randomization process before recruiting the participants (3,5). The remaining studies (7,21,35,48) 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 groups in two studies (21,48). In three studies there was a difference in educational level, primary care clerkships or academic grades for the previous semester. These imbalances were judged to represent a high risk of affecting the outcome (3,18) or were confirmed to have modified the effect (4). Three studies (5,7,35) provided no information on baseline characteristics and whether these differed between the groups.

None of the studies reported the loss of entire clusters. However, three studies (3,7,48) reported loss of individual participants and three additional studies had a high (21) or imbalanced (18) drop-out rate or reported inconsistent numbers (35), all of which resulted in a classification of high

risk of bias. One study reported attrition in both groups but was judged to have an unclear risk of loss of clusters as it provided no further information (4). One study (5) 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 (5,21) accounted for the cluster unit. The rest of the cluster RCT studies (3,7,31,35,48,73) suffered from unit-of-analysis error (i.e. it incorrectly analysed participants as independent individuals rather than the unit they were randomized to). 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 (18,35). The remaining six studies (3–5,7) were all categorized as having a low risk of volunteer bias.

## **EFFECTS OF INTERNET AND LOCAL AREA NETWORK-BASED ELEARNING INTERVENTIONS**

The 60 randomized trials included in the review assessed the effectiveness of Internet and local area network-based eLearning interventions in terms of knowledge, skills, attitudes and satisfaction. The findings were based on comparisons between network-based eLearning and traditional learning or between various modes of networked-based eLearning. A study may have compared more than one outcome between groups, and each outcome may have been assessed in multiple ways. For instance, a study which compared students' acquisition of skills may have assessed skills in terms of the students' performance on a global rating scale, the ability to perform a specific procedure, as well as the ability to comply with requirements in a checklist. As a result, the number of comparisons made across studies for a particular outcome may exceed the number of studies that reported on that outcome.

Only two studies (8,9) measured all specified outcomes of knowledge, skills, attitudes and satisfaction.

The studies were divided into two research themes that evaluated the impact of eLearning interventions for undergraduate health-care education: traditional learning versus eLearning, and eLearning versus eLearning.

### **Traditional learning versus eLearning**

Fifty of the 60 included studies (83%) compared network-based eLearning with traditional learning (1,3–10,13–20,23–37,41,42,44–50,52–59). See Table 4.1 for a summary of findings of the individual studies, and see Annex 7 for a further description of the nature of the interventions.



**Table 4.1. Summary of findings from the 50 studies which compared Internet and local area network-based eLearning with traditional learning**

Study	Discipline	Findings*			
		Knowledge	Skills	Attitude	Satisfaction
Ainsworth 2011A33	Nursing	NS	-	-	-
Ainsworth 2011B33	Nursing	E	-	-	-
Arroyo-Morales 201234	Physiotherapy	NS	E	NS	
Baumlin 200035	Medicine	NS	-	-	NS
Beeckman 200756	Nursing	E			
Brettle 201329	Nursing	-	NS	-	-
Buzzell 200230	Medicine	NS		NS	
Cantarero 201231	Physiotherapy	-	NS	DNT	DNT
Chen 200758	Undefined	NS	-	-	-
Chen 20123	Nursing	M	-	-	-
Cox 20084	Medicine	-	DNT	DNT	-
DeBate 20135	Dentistry	T	DNT	NS	-
Erickson 20036	Pharmacy	M	M	-	-
Fernandez 201153	Nursing	NS	-	-	NS
Fleming 200350	Dentistry	NS	-	-	NS
Flowers 20107	Pharmacy	E	-	-	-
Friedl 20068	Medicine	NS	DNT	NS	NS
Gerdprasert 20109	Nursing	NS	E	NS	NS
Hauer 201310	Medicine	-	E	-	E
Jenkins 200855	Medicine	NS	-	-	-
Juliani 20111	Nursing	NS	-	-	DNT
Kandasamy 200957	Medicine	T	-	-	NS
Komolpis 200213	Dentistry	NS	-	-	NS
Lee 201014	Medicine	NS	-	-	NS
Leong 200315	Medicine	M	NS	-	NS
Lewis 201116	Medicine	T	-	-	NS
Lipman 200117	Medicine	E	-	-	NS
Lu 200918	Nursing	NS	E	-	-
Maag 200419	Nursing	NS	-	NS	NS
Mahnekn 201020	Medicine	NS	-	-	-
Nkenke 201224	Dentistry	NS	-	NS	NS
Nkenke 201223	Dentistry	-	-	-	NS
Ochoa 200825	Medicine	E		NS	
Palmer 200826	Medicine	NS	-	-	DNT
Peroz 200927	Dentistry	E			NS
Phadtare 2009 <sup>28</sup>	Medicine, nursing, physiotherapy	E	-	-	E
Raupach 2009 <sup>36</sup>	Medicine	NS	-	-	DNT
Raupach 2010 <sup>37</sup>	Medicine	E	-	-	E
Ricks 2008 <sup>54</sup>	Medicine	E			
Smits 2012 <sup>41</sup>	Medicine	NS	-	T	NS
Spikard 2002 <sup>42</sup>	Medicine	NS	-	-	E

\*Note:

E = results favoured network- based eLearning over traditional learning.

NS = no significant difference between eLearning and traditional learning.

M = mixed results.

T = results favoured traditional learning over network-based eLearning.

DNT = difference not tested.

Study	Discipline	Findings*			
		Knowledge	Skills	Attitude	Satisfaction
Stain 2005 <sup>44</sup>	Medicine	NS	-	-	-
Stewart 2013 <sup>45</sup>	Medicine		DNT		NS
Stolz 2012 <sup>46</sup>	Medicine	NS	T		T
Subramanian 2012 <sup>47</sup>	Medicine	E			
Succar 2010 <sup>59</sup>	Medicine	DNT			NS
Toumas 2009 <sup>48</sup>	Pharmacy		E		
Truncali 2011 <sup>49</sup>	Medicine	E	E	DNT	
Wang 2009 <sup>32</sup>	Nursing	E		NS	
Yeung 2013 <sup>52</sup>	Medicine	NS			NS

### ► Knowledge

Among the 50 studies that compared network-based eLearning with traditional learning, knowledge was assessed in 43 RCT studies (86%) (1,3,5–9,13–20,24–28,30,32–37,41,42,44,46,47,49,50,52–59) and seven cluster RCT studies (3–5,7,18,35,48).

Twelve studies (27%) assessing knowledge gain demonstrated significantly higher knowledge gains for students assigned to network-based eLearning compared to those exposed to traditional learning (7,17,25,27,28,32,33,37,47,49,54,56). Outcome measures for these studies were based on test items or questions (7,47), written case analyses (17), MCQs (25,27,32,37,49,54), the six-subgroup quality scale (SSQS) (28), a general numeracy test (33) and independent assessments by evaluators (56). The sample size of these studies ranged from 39 to 1475. Six of these 12 studies were conducted on medical students (17,25,37,47,49,54), three among nursing students (32,33,56), one among dentistry students (27) and one among pharmacy students (7), while one study (28) was conducted among medicine, nursing and physical therapy students. Five of these studies used full eLearning as the main intervention (25,28,47,54,56) whereas seven used blended learning (7,17,27,32,33,37,49).

Post-intervention knowledge did not differ significantly between eLearning and traditional learning in 24 (48%) of the included studies (1,8,9,13,14,18–20,24,26,30,33–36,41,42,44,46,50,52,53,55,58). Three studies (3,6,15) showed mixed results – i.e. favouring the intervention, the control or neither, depending on the specific indicator of knowledge being assessed. In one study (2%) (59) knowledge was assessed but was not tested for statistically significant differences between the intervention groups.

Finally, there were three studies (5,16,57) that demonstrated significantly higher knowledge gains for students assigned to traditional eLearning compared to those exposed to networked-based learning. Two of these studies (5,57) used full eLearning as the main intervention while the other (16) used blended learning.

### ► Skills

Overall 15 studies – 11 RCTs (6,8–10,15,29,31,34,45,46,49) and four cluster RCTs (4,5,18,48) – measured skills as outcome.

Of the studies that evaluated differences in skill acquisition, six (40%) found significantly greater skill acquisition among students assigned to eLearning (9,10,18,34,48,49). The number of participants included in these studies ranged from 44 to 303. Two of these studies were conducted in medical students (10,49), two in nursing students (9,18), one in physiotherapy students (34) and one in pharmacy students (48). Four of these studies used traditional learning as their main intervention (10,18,34,48) while two used blended learning as the main intervention (9,49).

Three studies (21%) did not detect a significant difference in skill acquisition between groups (15,29,31). One study (6) showed mixed results – i.e. favouring the eLearning or the traditional learning group depending on the specific indicator of skills being assessed. This study had three groups, comparing pharmacy students' knowledge and ability to assess metered-dose inhaler (MDI) after a lecture-based tutorial, a web-based tutorial and being provided no teaching on the topic at all. The MDI technique evaluation scores for the web-based and lecture-based groups were not statistically significantly different from each other ( $p = 0.50$ ) but both significantly differed from scores of the control group ( $p < 0.001$ ). In four studies (26%), skills were

assessed but differences between the intervention groups were not tested for statistical significance (4,5,8,45).

Finally, there was one study (46) that demonstrated significantly higher skill gains for students assigned to traditional eLearning compared to those exposed to web-based learning. This study used full eLearning as the main intervention.

#### ► Attitudes

Twelve studies (24%) - 10 RCTs (8,9,19,24,25,30-32,41,49) and two cluster RCTs (4,5) - assessed attitudes as an outcome of the intervention through questionnaires.

Eight (67%) of these studies (5,8,9,19,24,25,30,32) did not find a statistically significant difference between the two types of learning methods, or the study showed mixed results for eLearning versus traditional learning depending on the test evaluated. Three studies (4,31,49) assessed attitude but did not test for statistically significant differences between the intervention groups. None of the studies reported a significant result on student attitudes favouring networked-based eLearning interventions.

The remaining study (41) reported more positive attitudes towards the intervention in the traditional learning groups. This study used full eLearning as the main intervention.

#### ► Satisfaction

Student satisfaction was assessed in 28 RCTs (1,8-10,13-17,19,23,24,26-28,31,34,36,37,41,42,45,46,50,52,53,57,59) and one cluster RCT study (35).

Out of 29 studies looking at the level of student satisfaction, four (14%) (10,28,37,42) found that a significantly greater proportion of students exposed to network-based eLearning were satisfied compared with those exposed to traditional learning. One of these four studies (37) compared blended learning with traditional learning, while the other three (10,28,42) used full eLearning interventions compared with traditional learning ones. Twenty studies (74%) did not detect any significant difference (8,9,13-17,19,23,24,27,34,35,41,45,50,52,53,57,59), while in four studies satisfaction was assessed (1,26,31,36) but was not tested for statistically significant differences between the intervention groups.

One study (46) using full eLearning as the main intervention reported statistically significant higher student satisfaction in the traditional learning group.

### Comparison of different types of eLearning against each other

Ten (18%) of the included studies (2,11,12,21,22,38-40,43,51) compared the effectiveness of various modes of network-based eLearning against each other. Eight of these studies (2,12,21,22,38-40,51) compared eLearning groups with different levels of student interaction. In two of them "interactivity" was also facilitated by collaborative tools - i.e. online web chats (51), discussion forums and online message systems (38).

#### ► Knowledge

All of the 10 studies comparing various forms of network-based eLearning (2,11,12,21,22,38-40,43,51) measured and reported their effects on knowledge.

Five studies observed a difference in results between different modalities of eLearning. In a study comparing an adaptive form of spaced education against a linear, repetitive one (12), the adaptive eLearning intervention showed better results than its "passive" form. Another study showing significant knowledge acquisition for an "active" eLearning intervention was Chao et al. (2) in which a linear educational environment (website) supported by complementary information (skin anatomy images) which users could access at will was compared to a non-modified website. Similarly, in one study (40) an eLearning intervention allowing students to play a video at will showed better knowledge gains in comparison to an eLearning intervention in which the procedure was linear. In a study on a "passive" type of eLearning (38), offering course material through conventional web technology and allowing students to engage with the instructor only by email, resulted in higher knowledge gains in comparison to an interactive eLearning intervention in which students could make use of all the learning tools of WebCT's virtual learning environment (VLE). A "passive" eLearning intervention also showed favourable results for Salas et al. (39). In this study, participants in the "passive" eLearning group were provided solely with a list of random sleep facts and trivia presented in a PowerPoint® format. The "active" eLearning intervention consisted of an online, self-paced, sleep medicine learning module.

Non-significant statistical differences were found in four studies (11,21,43,51) comparing different eLearning modalities. One study failed to demonstrate any difference in knowledge acquisition between eLearning modes (22).

### ► Skills

Skill acquisition was assessed in one study (40). This study showed no significant differences in skills acquisition between the two different (active vs. passive) eLearning modalities.

### ► Attitude

Manikam et al. (21) and Schitteck Janda et al. (40) were the only studies that assessed attitude among the 10 studies comparing different eLearning modalities. The study by Manikam et al. failed to demonstrate any difference in students' attitudes between the two eLearning modes. In this study a dummy learning package was compared to the ABD learning package - i.e. symptom-based decision-making pathways software. Schitteck Janda et al. reported no significant differences in skills acquisition between the two different (active vs. passive) eLearning modalities.

### ► Satisfaction

Four studies (40%) (22,38,43,51) compared the effects of different eLearning modes on student satisfaction. Two studies (22,38) failed to demonstrate any difference in student satisfaction for the two eLearning modes. Frith et al. (51) reported that students in the group that used collaboratively a six-week web-based course on cardiac rhythm interpretation supported by online chat software were more satisfied than students in the other group who worked on the same course independently. In the study by Spickard et al. (43), students in the groups with the online lecture of PowerPoint® presentation with audio narration were more satisfied than the ones in the group with the online lecture of PowerPoint® presentation without audio narration.

## Discussion

### Summary of main results

The systematic review compared network-based eLearning with traditional learning. The outcomes assessed were gain in knowledge, gain in skills, attitude towards the intervention and student satisfaction.

The systematic review of studies comparing network-based eLearning with traditional learning showed that 12 studies (29%) (7,17,25,27,28,32,33,37,47,49,54,56) of the 43 studies comparing knowledge gain between network-based eLearning and traditional learning found a benefit of using eLearning as opposed to traditional learning in terms of gain in knowledge. There was a slightly greater gain in skills in

eLearning groups in six studies (40%) (9,10,18,34,48,49) out of the 15 studies assessing skills. Of the 17 different studies showing a greater gain in knowledge and skills, 15 studies (88%) (7,9,10,17,25,27,33,34,37,47-49,54,56) had at least one risk-of-bias item rated as high risk.

The majority of studies (27 out of 42, or 64%) (1,3,6,8,9,13-15,18-20,24,26,30,33-36,41,42,44,46,50,52,53,55,58) did not find a statistically significant difference in knowledge gain between the two types of learning methods, or the study showed mixed results for eLearning versus traditional learning depending on the test of knowledge that was being used. The difference between skill acquisition in the two intervention groups was not statistically significant, or the study showed mixed results for eLearning versus traditional learning in five studies (27%) (6,15,29,31) of the 15 studies testing skills. Among the 28 different studies finding no difference or mixed results for knowledge and skills, 17 studies (61%) had at least one risk-of-bias item rated as high risk (1,3,9,14,15,20,26,29,31,33-35,41,46,52,53,58).

Four studies (5,16,46,57) were found with a greater gain in knowledge and skills in the traditional learning group compared to the eLearning group. All of them had at least one risk-of-bias item rated as high risk. Furthermore, five studies (4,5,8,45,47) assessed knowledge and skills but did not evaluate whether test results for each outcome were statistically significantly different for the experimental groups.

None of the 12 studies assessing students' attitude reported more positive attitudes towards the intervention in the eLearning groups than in the traditional learning groups. However, eight studies (67%) did not find a statistically significant difference between the two types of learning methods, or the study showed mixed results for eLearning versus traditional learning depending on the item evaluated (5,8,9,19,24,25,30,32). Three studies (4,31,49) assessed attitude but did not test for statistically significant differences between the experimental groups. The remaining study (41) reported more positive attitudes towards the intervention in the traditional learning groups.

We found that four (14%) of the 29 studies comparing students' level of satisfaction were more positive towards the eLearning intervention (10,28,37,42). There was no statistically significant difference between the two types of learning methods, or the study showed mixed results depending on the test evaluated, in 20 (69%) of the studies assessing satisfaction (8,9,13-17,19,23,24,27,34,35,41,45,50,52,53,57,59). One study (4%) (46) reported greater satisfaction towards traditional learning when compared to eLearning in a quantitative way. Four studies (1,26,31,36) assessed student

satisfaction but did not test for a statistically significant difference between groups.

There were some differences between the network-based interventions used in the included studies. Most of the included studies used a website as part of their intervention. However, some used another intervention method, namely spaced education, video lectures or visual concept maps. Furthermore, there were great variations in length of exposure to the eLearning intervention.

Studies comparing different eLearning modalities were also reviewed. Typically the studies would compare a “passive” eLearning mode (e.g. a dummy learning package) to a more “active” eLearning mode (e.g. an adaptive form of spaced education). The comparison of studies assessing the difference between eLearning modalities did not show any clear trends for knowledge gained in terms of more passive eLearning modalities being outperformed by eLearning programmes that required more active participation by the student.

Only six studies (21,22,38,40,43,51) reported the difference between eLearning modalities on skills acquisition, student attitudes and satisfaction. Most of the results were insignificant or not reported at all. On that basis it was not possible to assess how the different modalities of eLearning affected skills acquisition, student attitudes and satisfaction.

Only eight of the studies reported financial and resource-related elements of eLearning (10,28,30,36,44,45,48,50). Nevertheless, none of the studies included a robust cost-effectiveness analysis of eLearning versus traditional learning and therefore it is not possible to provide an assessment of this important aspect of the integration of eLearning into tertiary health-care education.

Furthermore, no adverse events were reported and there was no mention of investigations conducted to assess if adverse effects exist.

## OVERALL COMPLETENESS AND APPLICABILITY OF EVIDENCE

The participants in the included studies were all studying medicine, dentistry, pharmacy or medical-allied studies. Most of the studies (51 out of 60, 85%) were conducted at universities (1,2,4,8,10–17,19–28,31–35,37–55,57–59,74). Nine of the studies (15%) were conducted at vocational training centres or colleges (3,5–7,9,18,29,30,56). Consequently, the results of this systematic review apply to students studying the same areas of knowledge, but they could also apply to

other similar university or vocational degrees that were not included in this review.

This systematic review compares different university and vocational systems across the world and participants with various backgrounds. In our study, therefore, students in their final year of study (56) may be compared with first-year students (2). Some studies have used mixed-year students, like one study (30) that recruited second- and fourth-year medical students. Nevertheless, the participants are comparable in the sense that their studies will result in permission to practise in their field. The majority of the studies were conducted in high-income countries. Therefore, the results are generalizable to developed countries. However, eight studies (1,2,9,14,18,28,32,75) were conducted in low- and middle-income countries, thus affecting the external validity of these countries. Some other related factors to these countries, e.g. lower computer and Internet availability, as well as lower literacy in computer skills, may also affect also the external validity of the results of this systematic review. Therefore, the generalization of the results to these countries should be done with caution.

By keeping these considerations in mind, the conclusions of this systematic review can be generalized to the general population of university and vocational health-care students in developed countries. Generalization to other types of degrees and to low- and middle-income countries should be done with caution.

## QUALITY OF EVIDENCE

The total number of participants included in the reviewed studies was 6750, including participants from eight cluster RCTs (3–5,7,18,21,35,48). As a result of the inclusion of cluster RCTs, this number may be an overestimate due to possible dependence on participants within a cluster.

The quality and reporting of the 60 included studies was variable. Most of the studies did not adhere to the CONSORT guidelines for reporting of RCTs (76) and therefore they were classified as unclear in one or more of the risk-of-bias items.

Out of the 17 studies showing greater gain in knowledge and/or skills in the eLearning groups, 15 studies (7,9,10,17,25,27,33,34,37,47–49,54,56) had at least one risk-of-bias item classified as high risk of bias. Among the studies finding a benefit, six studies (25,27,33,34,37,49,54) had a high risk and five (9,18,28,47,56) had an unclear risk of volunteer bias. Volunteer bias could have resulted from a sample of students with higher computer literacy and who are regular computer users and therefore eLearning would be the better teaching method for them when compared

to traditional learning, which might not be the case in the general population (77,78).

Furthermore, five studies (10,17,47,49,56) that found eLearning to be superior to traditional learning had a high risk of attrition bias. This could mean that the subset of participants that were analysed were a selected group with better computer skills than the study population, and thus the results are too optimistic.

Only one study (26) of the 29 studies that did not find a significant effect of eLearning compared to traditional learning were considered to be at high risk of contamination. If contamination has occurred, it has the potential to bias the results towards the null (79). Two studies (30,44) that did not find a statistically significant difference had a small sample size and therefore could have been underpowered.

All of the four studies (5,16,46,57) that found traditional learning to be superior to eLearning had at least one risk-of-bias item rated at high risk of bias. One study (46) showing beneficial results for traditional learning compared a group receiving network-based teaching with a group receiving a lecture, a group exposed to case-based teaching using students as actors, and a group receiving case-based teaching with real patients. These four formats were not comparable in terms of the material and information that was provided to each of the intervention groups and therefore the result should be interpreted with caution. Another study (16) had a problem with the random sequence generation, the allocation concealment and volunteer bias and thus had several important problems that should be taken into account when interpreting the results. One study (57) had a high risk of attrition bias that could have resulted in a group of participants who were not comparable to the general population. Finally, one of the studies (5) was classified as having high risk of bias due to recruitment bias and baseline imbalances, and therefore the results should be considered with these problems in mind.

The subjective outcomes, attitudes and student satisfaction, should be interpreted with caution as the students were not blinded. Thus, the students could feel obliged to rate a new eLearning method developed by their teacher higher than the traditional one. Due to high attrition for the subjective outcomes, the participants analysed may also represent a group for whom eLearning is considered the best learning method, whereas those who prefer traditional learning methods dropped out.

Eight studies were cluster RCTs (3–5,7,18,21,35,48) and were generally not considered to be of high quality. All of them

suffered either from design flaws or lack of reporting all the trial design elements.

The overall quality of evidence included in this systematic review is not uniform. The review contains a large number of low-quality studies with only one high-quality study (24). Due to the low quality of most of the included studies, a strong conclusion cannot be drawn on whether there is a clear difference between network-based eLearning and traditional learning effectiveness that applies to the general population. Nevertheless, this systematic review could provide an indication of whether there is some level of difference in the gain of knowledge and skills between network-based eLearning and traditional learning.

### POTENTIAL BIASES IN THE REVIEW PROCESS

For most of the studies there was difficulty in clarifying all the necessary methodological information. Although the reviewers contacted several authors, due to time constraints it was not possible to contact and obtain responses from all of them. Some were also unable to reply to the queries. Therefore many risk-of-bias items were classified as having an unclear risk of bias.

Because of the very large number of studies assessed (9091 titles and abstracts screened, 109 articles fully reviewed), the data extraction team consisted of 10 reviewers. This resulted in a variety of interpretations in several of the assessed categories. As a result, three reviewers went over the entire data extraction a second time to ensure that data extraction was done in a uniform way. Following consensus, they made amendments where necessary.

The lack of a uniform, standardized terminology for eLearning studies was also a complicating factor for the review. For that reason it was decided to use a very simple and clear definition of network-based eLearning. As a result, whenever a study described its eLearning method in detail it was possible to categorize the method easily as a computer-based, a web-based or a simulation-based eLearning method. Although each study was assigned to only one category, it is important to highlight that these are not necessarily mutually exclusive and that there may be some degree of overlap between categories as one form of technology may be built on another. For example, some digital games will require an Internet connection and access to the Internet, and virtual reality environments usually require a computer.

## Conclusion

The aim was to determine whether there is a difference between web-based learning and traditional learning in undergraduate health professional students. There were many limitations in the included studies in this systematic review.

Consequently, a robust conclusion allowing for generalization to all undergraduate students around the world cannot be drawn. The included evidence from the highest quality studies, as well as from those of lower quality, indicates that network-based eLearning is equivalent to, and perhaps even more effective than, traditional learning in terms of knowledge and skills gained. Furthermore, the ubiquity of network-based eLearning provides a convenient and possibly more cost-effective alternative to traditional learning. It is a learning tool that has great potential in supporting capacity-building and competency-development in the health-care workforce globally.

Several studies were identified in which students were more favourable to the eLearning intervention. However, owing to a high risk of bias, these results should be assessed with caution.

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# Part Three

A broader  
perspective

eLEARNING

The perceived need for innovative methods of learning within the health sciences shapes the receptivity of the interventions within the adopting educational institutions and wider health system.



# Potential advantages and disadvantages of eLearning

Advantages of eLearning were discussed in 88 studies (81%), and disadvantages were discussed in 42 studies (38%). Despite relying on secondary rather than primary sources of information, summarizing their discussion points will provide good insight in the generally perceived advantages and disadvantages of eLearning.

## Advantages and disadvantages perceived by learners

Ease of access and flexibility were shown as being particular advantages of eLearning, specifically in the context of students being able to undertake their work at a time and place of their own choosing (1–5). eLearning has particular advantages for learners in remote geographical locations (5) because they can save on their travel and accommodation costs (6–8), potentially enabling previously disadvantaged students by increasing availability of access. eLearning may also enhance access to education in rural settings, developing nations or other remote areas (7,9). However, because Internet access in developing countries is not always reliable, these advantages mainly apply to off-line (computer-based) eLearning.

E-textbooks improve the portability of educational materials, allowing students to dispense with heavy textbooks so long as they have the appropriate computer tablet (10).

In order to undertake eLearning, students require access to the necessary hardware and software and, for web-based packages, a reliable Internet connection. Students and teachers alike must be familiar with the technology (11,12) and the necessary infrastructure to support the process has to be in place (4). Some Internet packages require Internet access of sufficient speed for interactive visual and animated material (13). Despite these concerns, technical difficulties were mentioned in only two studies (11,12).

Digital storage, with access via an eLearning portal, allows additional opportunities for course materials to be revisited as often as needed during the course (14,15) and provides a good source of information for revision purposes (16).

Furthermore, eLearning allows learners to address their own learning needs; self-paced learning provides flexibility to complete learning at a student's own speed and intensity (14,17–22).

eLearning may also result in improved student–teacher contact and student–student discussions (5,23–25). Via Internet-based eLearning, students were able to contact the academic staff online outside the scheduled contact hours (23). eLearning enhanced “the students’ sense of being connected to the college, reducing their sense of isolation and anxiety” (26). For example, online forums allow students to discuss with each other or with staff, which contributed to increased student satisfaction in at least one study (27).

Despite positive findings in some studies regarding interaction and communication, the most common disadvantages discussed were:

- lack of student–teacher interaction and tutor support (4,14–16,28–30);
- feelings of isolation (4,14);
- being unable to clarify with a tutor in person when concepts are not understood (5,16);
- lack of in-depth group discussion (30).

Students indicated a preference for real-life discussions rather than virtual discussions (31).

eLearning was found to be more time-consuming for students than traditional lectures in some studies (20,32), although eLearning can also reduce the time taken for students to complete modules (33–35). Student compliance with self-guided eLearning was found to be lower in one study; many students were prepared to sit pre- and post-tests in a scheduled lecture slot yet many failed to use eLearning in their own time (36).

Overall, students appear to be satisfied with eLearning. eLearning was reported to be easy to use and some students indicated a preference for eLearning (30,37,38). Students’ opinions indicated that eLearning was found to be a useful supplement to, but not a replacement for,

traditional learning (39–41). Unless given guidance, students may become overwhelmed and have difficulty selecting the most appropriate resources for eLearning (34).

## Advantages and disadvantages perceived by the educational provider

Although few authors (five of 110 included studies, or 4.5%) formally assessed the costs of eLearning versus traditional methods, many commented on cost as an advantage (9,25,33,39,42–49). As well as monetary savings, advantages include freeing up lecturers' time to "devote to higher levels of cognitive learning such as analysis, synthesis and evaluation" (50) and allowing for "more complex subjects to be covered in tutor-led workshops" (45). In the teaching of practical skills, eLearning allows a reduction in time spent setting up laboratory equipment and repeatedly demonstrating procedures (47). In digital form, teaching material can be updated and edited easily (3,10,15,40,45,51), which can reduce ongoing teaching costs. Nonetheless, development of eLearning resources was suggested to be expensive and time-consuming in the discussions of several studies (4,24,33,41,52,53). However, none of the included studies made an economic evaluation of their own interventions.

Both Internet and CBL can be used to deliver information to a large number of students. eLearning allows more students to undertake the session when there may be a limited number of traditional learning materials (49). This can be used within or across institutions and tailored to local needs (17,54). Because eLearning provides a standardized learning experience, it is particularly advantageous in addressing curricular consistency (1,3,17,26). The portability of web-based eLearning allows for curricular consistency when students are off the main campus (1,55) – for instance, when in satellite clinics and hospitals, which is becoming more and more common (56).

eLearning can also facilitate skill acquisition and allow practising of skills prior to experience with real patients. This is advantageous in improving students' skills at their own pace, allowing repetition and practice, and therefore reducing the number of procedures carried out on real patients (20). eLearning can allow the students to better use the time they have with real patients (13). eLearning can also fill in gaps in experience where patients with unusual or rare conditions are not seen (57) or students are not able to gain experience in every field.

## Advantages and disadvantages in relation to teaching philosophy

The use of eLearning allowed staff contact sessions to be more interactive, directed by student needs (24). The web-based learning environment is more flexible and offers functions that are tailored to individual learners' needs (58). Individualized learning was linked to improved learning outcomes and improved perceptions of self-efficacy (10,20). Better retention was thought to be due to students being able to navigate the learning tool "based on previous knowledge, cognitive capability and learning speed" (53).

A number of authors commented how eLearning may particularly benefit students who may find conventional lectures difficult to keep up with (8,24,25,59,60). This is potentially due to freeing up "more time for the faculty to help struggling students" (25), reducing "pressure on some students to keep up with other students who learn psychomotor skills more quickly" (59) and allowing "students of different abilities and/or levels of training to access individual instruction paths that allow them to learn the same comprehensive materials" (60). eLearning also allows "weaker students to develop, learn and immediately assess their competency without any real risks to patients" (60).

Moreover, eLearning changes the emphasis from instructor-centred learning to learner-centred learning (30) and can fulfil the curriculum requirement for self-directed learning required by some universities and other educational institutions (1,17,41).

eLearning, especially Internet-based delivery, can be interactive and allow "instantaneous feedback to facilitate learning and improve cognitive skills and study habits" (61). Active participation, feedback and the ability to self-pace are "likely key contributors to module users' superior knowledge and skills performance" (20). Interactivity offered by eLearning is thought to "encourage better, deeper learning" (55) and allows learners to "act as an active participant rather than a passive receiver of information" (62). Instantaneous feedback offered by eLearning packages can help students to develop and reinforce their competence (35,59,60).

eLearning may not benefit every field of medicine and allied health professional education. For instance, two studies mentioned that teaching communication skills requires "real group meetings" (31) and "face-to-face interaction" (14).

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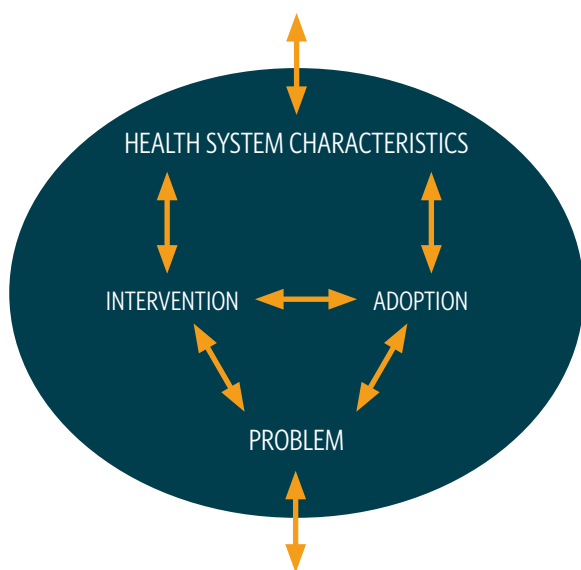
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# Critical success factors for the implementation and adoption of eLearning interventions

## Analytical framework background

The implementation and adoption of eLearning interventions are strongly influenced by five key elements: the problem addressed by the eLearning intervention, the characteristics of the intervention, the adopting system, health-system characteristics, and broad contextual factors (1). An analytical framework developed by Atun and colleagues (1,2) was used to identify the key factors influencing the implementation and adoption of eLearning interventions (Figure 6.1). This framework allows for a holistic analysis of the adoption of interventions within an educational system, and can assist with the planning of interventions to improve health outcomes, efficiency and equity (1).

**Figure 6.1. Conceptual framework for analysing integration of targeted health interventions into health systems**



Within each of these elements, several critical success factors (CSFs) have been identified to represent the fundamental features necessary for the successful implementation and adoption of eLearning interventions. The following dimensions have been acknowledged in the literature as being highly influential in the successful implementation of eLearning interventions in different contexts - organizational setting, technological infrastructure, instructional systems design, curriculum development, and delivery (3) - and have shaped the initial identification of the key CSFs in the current review.

## The problem

A key issue to consider when analysing the integration of eLearning within an educational context is the problem of its being addressed through the proposed intervention. The perceived need for innovative methods of learning within the health sciences shapes the receptivity of the interventions within the adopting educational institutions and wider health system.

Several factors have emerged regarding the diverse range of problems being addressed by eLearning. The rapid development of technology and the associated accessibility to educational material online has created a push for new methods of teaching and delivery (4,5), along with pressure to increase off-site training (6,7), in an attempt to accommodate geographically dispersed learners. Increased pressure to introduce eLearning within the existing curriculum (8,9), improve the quality of learning through technological innovations (10), and respond to limited staff availability (11-13) and resources (14-16) following budget and funding concerns were also cited as factors for implementing eLearning methods. Given the pedagogical challenges associated with teaching the skills necessary for clinical practice within a traditional learning format, eLearning has been introduced in

response to a need for novel methods to assist with reducing stress (7), improving competency (7,17–19) and confidence (20) within clinical training. eLearning has also been introduced in response to reported learner difficulties, particularly in relation to insufficient clinical reasoning (21), problem-solving (22) and self-assessment (23,24).

## The intervention

The perceived attributes of an eLearning intervention strongly contribute to its successful implementation within an educational system. The relative advantage of eLearning, as compared to traditional didactic classroom learning, plays a substantial role in how the adopting institution perceives the need for a shift in the existing system, particularly when the quality or effectiveness of an intervention is increased. The compatibility of the proposed eLearning technologies with the existing infrastructure also plays a significant role, as organizational changes may be required for the associated pedagogical shifts in curriculum development and delivery to take place. Several CSFs emerged when analysing the eLearning interventions, and have been conceptualized under two key domains: curriculum development and system design, and intervention delivery.

## Instructional systems design and curriculum development

### CSF: skilled IT workforce

Technological support systems were cited as a key element in ensuring student and staff familiarity with the range of technological tools required for eLearning technologies (7,12,25–27). Contextual analysis is necessary to determine if interventions with high levels of user engagement or complex technological specifications would succeed in diverse settings, as research in Thailand (7) and Taiwan, China (25) reported low levels of faculty and student familiarity with technology. Several studies cited the assistance of a learning technologist and information services departments for the provision of technical support in the development of eLearning modules (12,26,27). Ensuring that organizations are continuously building and maintaining a skilled IT workforce to reflect the constant changes in technology and various technological innovations is of key importance in the successful adoption and long-term sustainability of eLearning.

### CSF: time considerations for eLearning curriculum development

The implementation of eLearning within the health sciences faces unique challenges associated with staff availability (10,12,15,22,23,25,28) and scheduling for curriculum development and course load, given the high presence of faculty members with dual roles in practice and academia (12,22,25). Given the shift associated with eLearning from the role of teacher to the role of facilitator, the findings are mixed in terms of the effect on staff commitment to curriculum development. Several authors reported a reduction in time pressure for teaching staff (15,23), while others highlighted an increased time commitment for the development and design of eLearning technologies (8,25,29,30), especially when traditional face-to-face lectures were provided in conjunction with eLearning technologies (30).

Institutional transformation, in terms of personnel and infrastructure required, must be considered prior to the introduction of eLearning, as institutions need to determine whether additional staff time is needed to restructure the curriculum for an electronic environment. This would require changes in the content of traditional lectures, as well as the creation of interactive tools and supplemental resources, which can be time-consuming for an already time-burdened staff. In order to prepare for the additional time commitments, institutions can develop strategies to implement eLearning within existing curriculum on the basis of the institution's familiarity with eLearning (early adopters) and structural capacity to provide the technological infrastructure and staff support.

## INTERVENTION DELIVERY

### CSF: eLearning tutorial

A number of studies provided participants with a detailed tutorial prior to having access to the program (12,24,26,31–36). This initial orientation allowed for a detailed overview of the program's specifications, its purpose, and how to use the program to reach the best learning outcomes. In an intervention to assess the use of PDAs for undergraduate nursing students, Goldsworthy and colleagues (31) provided two 60-minute orientation sessions to allow students to become familiar with the software and equipment. The orientation was conducted with support from researchers, IT support personnel and a representative of Elsevier Publishing, and students were provided with contact information, email and telephone numbers for additional assistance (31).

### **CSF: student support to enhance eLearning literacy**

Provision of IT support was offered to students in several of the included studies. Technological support was provided to assist students with problems relating to computers or software (16,31,33,37,38) as well as navigational issues associated with the eLearning program (27).

Several of the included papers highlighted the benefit of web-based eLearning interventions because of the availability of pedagogical support for students through the use of an eLearning platform (39–41). Raupach and colleagues (39,40) trained postgraduate teachers as online tutors to provide assistance to students throughout the use of the web-based learning tool. Similarly, Wang and colleagues (39) ensured teacher availability for discussion, both online and face-to-face, in order to increase accessibility for student support.

### **Adopting system**

The adopting system is characterized by a diverse range of interests and values, often from a wide range of stakeholders. Whether from an organizational or managerial level, stakeholders bring distinct perceptions of the potential value or risk of a proposed intervention (1). Research (2) has shown that one of the main reasons why the adoption of innovations is slow is way the problem is perceived by the adopting system. As each stakeholder brings forward a variety of motivations pertaining to the benefits and risks of an intervention – such as economic, technological, or pedagogical legitimacy – the shared views of the many actors involved in the adoption of eLearning interventions ultimately shape how well-received the intervention is within the proposed institution (1).

## **Organizational setting**

### **CSF: institutional support for eLearning**

Of the 48 computer-based studies, eight of the eLearning interventions were reportedly adopted within the curriculum (14,42–48). Of the 59 web-based studies, seven were adopted within the curriculum (49–55). The successful implementation and adoption of eLearning requires careful navigation through the existing institutional arrangements of an educational setting and consideration of the wide range of stakeholder goals and incentives.

Several organizational factors emerged as playing an influential role in the implementation of eLearning. Institutional readiness was found to be a commonly cited theme, highlighting the increasing use of technology in

education within the university setting, as well as the medical curriculum (22,30,38,45,56–59). Several authors reported the previous implementation of eLearning technologies within the faculty as contributing to the adoption of the interventions (46,60). The eLearning software used in Palmer and Devitt's study (60) was previously integrated within the faculty, suggesting an institutional policy that supports innovative technologies in education. Similarly, an eLearning intervention conducted by Holt and colleagues (46) was introduced as part of a larger curriculum-wide project on increasing interactive learning for medical students.

Flowers and colleagues (10) pointed out that an accreditation in computer skills was a core requirement for the Accreditation Council for Pharmacy Education (ACPE), and thus the College of Pharmacy reflected the need for this skill in its pharmacy curriculum. A recommendation by the Association of American Medical Colleges to increase innovative and effective educational technology to improve clinical medical education was cited as an organizational factor contributing to the introduction of eLearning within the medical education setting (50,55,61). These findings highlight the influential role of eLearning champions, as well as the powerful influence of accrediting bodies, as key stakeholders in the implementation process.

## **HEALTH-SYSTEM CHARACTERISTICS**

The implementation of interventions into health systems is dependent on the alignment between stakeholder expectations and the critical functions of the health system and, as such, is often a non-linear process (1). Integration is also dependent on whether the integration process can occur at local, regional or national levels, and can vary according to the diverse characteristics of the health system in which the intervention is being implemented – including financing functions, organization and governance, resource allocation, and service provision (1). Given that governments worldwide are exploring ways to reduce financial contributions to universities by encouraging commercial investment, partnerships and economies of scale (62), health systems play a significant role in aligning the need for a skilled health workforce within a competitive education market.

## **BROAD CONTEXT**

The context in which the adoption of an innovation occurs includes political, economic and social considerations. Social considerations for the adoption of eLearning interventions were highlighted in a number of studies, particularly due to the growing use of technology among younger generations (58) and the idea that teaching methods should mirror these

changes (63). Casquel and colleagues (9) emphasized the slow adoption of IT within nursing educational programmes in Brazil compared to North America. The authors stressed that nursing programmes in Brazil need to incorporate more innovative computerized instruments to play a role in teaching, research and care (9). Following the launch of a national informatics initiative to promote distance learning in Taiwan, China, in 1994, 60 of the 143 educational institutions of Taiwan offered a distance-learning course in 2002, highlighting the importance of the government policy in the adoption of interventions (25). As stated by Atun and colleagues (1), "...even when evidence on the benefits of an intervention exist (providing technical and economic legitimacy), the prevailing political economy and socio-cultural norms (affecting cognitive and normative legitimacy) will influence the desirability of the adoption and assimilation of the intervention".

## Technological infrastructure

The availability and functionality of the technological infrastructure supporting the eLearning environment were found to be essential CSFs for the implementation and adoption process. In order to achieve successful implementation of an eLearning intervention within an adopting entity, the technological infrastructure must be able to support the hardware, software and connectivity features required. In addition to the necessary technological requirements on the part of the adopting institution, technological requirements are also present with respect to the individual student. In particular, the hardware necessary for program software to run efficiently and the access to high-speed Internet to access learning materials online both play significant roles with regard to the equity and effectiveness of the eLearning technology. The following CSFs represent key characteristics surrounding the technological readiness of the wider context to support the implementation of the innovation.

### CSF: hardware and software

A key requirement of eLearning interventions is the availability and accessibility of computers. Both the computer-based and Internet-based interventions were conducted with personal computers or computers that were made available to students, typically in computer-equipped laboratories. Contextual considerations are necessary to ensure that adopting institutions have the capacity to provide the equipment necessary to conduct eLearning interventions, and that the hardware and software are equipped with the necessary technological specifications to run the eLearning program (64).

Standard hardware and software specifications were reported in the included studies, including Intel®-based computers using Windows® operating systems, as well as Apple computers using Mac OS (33,38,58,65–67). Commercially available software was reported for the development of eLearning technologies, including Adobe (18,58,68–70) and QuickTime (69,71) which most computers today are outfitted with. The complexity of the eLearning technologies, based on the number and nature of technologies implemented combined with the level of user engagement required for both module designers and students, also contributes to the relative success of implementation (1).

### CSF: broadband connectivity

The compatibility of the proposed eLearning technologies with the existing infrastructure also plays a significant role, as structural changes may be required for the introduction and maintenance of new learning technologies. Internet connectivity was reported as a key feature for the success of eLearning, particularly among the web-based interventions (10,29,54,72,73). Connectivity failures reported in several studies (9,31) highlight the importance of ensuring adequate bandwidth access on national, regional and local/institutional levels.

Several studies (72,74,75) provided students with CD-ROMs of the software required for the intervention, in addition to Internet access to the programs if broadband Internet access was limited or had an insufficient speed. Ensuring that the adopting system has the ability to provide Internet services to students is a key feature of the implementation process, as it predicts the functionality of the eLearning tool and can be detrimental to learning outcomes if insufficient or unavailable.

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# Strategies to introduce eLearning equitably and effectively

A systematic literature search was conducted using Google Scholar to identify the main factors that enhanced or hindered the introduction of eLearning within an educational institution. This search, along with the key findings from the current systematic review, helped to form the foundation for eLearning implementation strategies aimed at equitably and effectively introducing eLearning.

## Systems approach

The process of implementing and adopting eLearning interventions is shaped by a wide range of factors. The broad context surrounding the intervention, the characteristics of the health system in which the intervention is being implemented, the various adopting institutions and the actors within these institutions all play a considerable role in the adoption and diffusion process (1). When applying systems thinking to eLearning, the successful implementation of a particular eLearning tool is dependent on the complexity of the tool, the technological infrastructure of the adopting entity, and the various policies and regulations influencing the configuration of the eLearning environment (2).

The introduction of eLearning technologies requires structural, cultural and organizational transformation, and often faces with resistance owing to the somewhat radical nature of change necessary for the adoption of eLearning within traditional university settings (3,4).

Additional support systems are required to assist students with new educational technology tools that may be unfamiliar. In addition, teachers are pressured to implement changes to their teaching style and delivery, and may require additional assistance in the creation of innovative eLearning methods (5). As such, an approach that encourages systems thinking is valuable for planning the introduction of eLearning interventions (1,3).

Using a systems approach allows for a holistic analysis of how the adoption of an eLearning intervention is shaped by a wide range of contextual and institutional factors, and can assist with the initial planning of the introduction

of the intervention in order to improve health outcomes, efficiency and equity (1). Understanding the wider contextual limitations facing the introduction of an intervention through a complex adaptive systems framework would allow for a more informed and prepared implementation approach (6). MacKeogh & Fox (7) highlight that educational institutions influence, and are influenced by, a range of actors with diverse roles and responsibilities. As such, it is necessary to ensure that dialogue exists between the included actors to prevent potential barriers in the introduction of eLearning. Systems thinking can assist with this process by encouraging collaboration between multiple stakeholders, in addition to developing a comprehensive strategy that incorporates the many different goals of the included parties (3).

## Building eLearning into the education workforce

### eLearning champion

The value of nominating an eLearning champion was highlighted by several authors (3,8,9) as a way to promote eLearning within academic departments, and award faculty for adopting eLearning teaching methods. In the implementation approach of Sharpe and colleagues (8), eLearning champions were asked to develop an eLearning strategy within their respective schools given their experience as early adopters of eLearning, and/or familiarity with the process of designing and implementing eLearning tools, as well as because of their understanding of staff/professional development needs (8). Appointing an eLearning champion was also thought to contribute to the establishment of a school or department undertaking, as it allowed for discipline-specific eLearning strategies within each of the academic schools (8). This approach contributed to the development of eLearning methods that were more relevant to the particular needs of the range of academic faculties.

Champions can be applied in a top-down manner through top-level senior management, as well as through a bottom-up approach by individual staff members (9). Cummings and colleagues (9) proposed a middle-out approach that introduces eLearning champions from a mid-level

management position. Staff in this position may be in teaching and learning centres or information technology support; the authors suggest that managers at this level have both the autonomy and resources to promote change within the existing system (9).

## eLearning technologist

The appointment of school-based eLearning technologists was suggested by several authors (3,8,10) as a means to assist individual departments with eLearning technology and equipment. The initiation of weekly meetings with the learning technologists across all departments was employed in the research of Sharpe and colleagues (8) in order to ensure that the eLearning technologists' presence was felt across the entire institution, in addition to providing an opportunity for staff development.

## Professional development

Research suggests that professional development is considered to play a major role in the successful implementation of eLearning (3,8,11–13). The transition from traditional didactic teaching to eLearning requires a shift in the way teachers facilitate their lectures to accommodate the diversity in the learning styles of students. Professional development can aid in this process by informing teachers of eLearning methods that best suit the varied needs of learners, as well as providing information on how to incorporate eLearning tools within the curriculum (14). Given that teachers play a vital role in the success of eLearning, researchers (5) suggest that course facilitators should be provided with training to resolve hardware and software issues at a basic level.

## eLearning ownership and responsibility

Nichols' qualitative analysis of eLearning diffusion (13) found that ownership of eLearning was a contributing factor to a successful diffusion process. Ownership was found to be a significant lever of change as it allowed for a coordinated approach to decision-making at all levels of the institution. However, it was also noted that centres of power played a significant role in the diffusion process, as they were typically linked with allocation of resources and funding by senior management (13). As stated by O'Neill and colleagues (5), "when staff are 'forced' down the eLearning route as a consequence of management directives and mission statements the creation of sound pedagogic practice is often flawed or missing completely" and results in an increased focus on technology, as opposed to the learners' advancement. In support of this argument, Salmon (15) highlights that, when engaging faculty members, it is essential that they feel ownership of both content

and pedagogy within their respective departments while also recognizing that there are larger institutional support systems in place to manage the transition to eLearning.

These findings suggest that both top-down and bottom-up strategies are crucial for ensuring support from both top-level management and individual faculty members for the enhancement of eLearning developments (7). However, the difficulty lies in finding the balance between centralized strategies to ensure that resources are allocated to departments equally to support eLearning, and methods that encourage faculty engagement and a sense of ownership and responsibility.

## Maximize technology within the existing infrastructure

Engelbrecht's review on different eLearning models (16) found that increasing technological infrastructure investment should be an essential element of an eLearning implementation plan, as it is a necessary component for the enhancement of the quality of the teaching and learning process. The success of the eLearning software, hardware, servers and accessibility all contribute to the successful learning process for students. Ensuring the functionality of these systems prior to implementing eLearning would allow for improvements in the necessary technological infrastructure before it creates a barrier to learning (5).

Given that many universities are slow to adopt innovations due to institutional legacies and top-level decision-making, the life span of many available eLearning tools is ultimately reduced as a result of delay (15). In an attempt to bypass this process, Salmon (15) suggests that institutions should maximize the key capabilities of their existing resources rather than attempting to change the underlying technological infrastructure in an attempt to follow the increasing pace of technological change. Salmon (15) proposed an eLearning strategy that aims to capitalize on an institution's core strengths, directing innovation towards those areas where the institution has existing assets, as opposed to following market-led approaches. However, introducing eLearning interventions within educational settings requires a strategy that can accommodate the diverse needs of students and the financial capacity of the institution (16), while also aiming to improve quality, effectiveness and equity.

The implementation of technological solutions also requires strategies to facilitate the changes associated with the increased focus on technology within the educational setting. Organizational systems would experience transformation through the implementation of eLearning, particularly due to the changes in human resources following the increased focus on IT staff, as well

as the changing role of lecturers. Technological solutions will not be successful on their own, as the adoption of eLearning is strongly influenced by the complexity of the institution, sociocultural factors, and organizational and national policies (1,15). Thus, an analysis of the various systems involved in the introduction of eLearning will assist in facilitating the transition to eLearning through a comprehensive consideration of the many systems involved in the implementation and adoption process.

## eLearning policies

In order for eLearning interventions to be accessible in diverse contexts with varying sources of funding and infrastructure capacity, institutional and national policies are necessary to ensure a smooth transition from traditional learning to a learning modality that involves a higher usage of educational technology. Policies are needed to assist a university's instructional support system with copyright, intellectual privacy and property ownership issues (17), as well as ensuring licensing capabilities to utilize commercial and open-source learning platforms (18).

In Anderson and colleagues' review of national eLearning strategies (3), the authors identified three distinct stages of the development of eLearning policies within an educational system. The first stage consisted of government efforts to introduce eLearning into an educational system, often drawing on early adopters of eLearning. Within this stage, policy initiatives included strategies to develop the necessary physical infrastructure to ensure the accessibility of eLearning through adequate broadband connectivity. The second stage involved mainstreaming eLearning in the existing system, with a focus on ensuring quality in eLearning. Policy initiatives included provision of support to teachers and learners, leadership development and the creation of high-quality educational content. This stage was also characterized by policy initiatives pertaining to the adoption of a systems approach to implementing eLearning through increased collaboration between institutional sectors, development of demand for eLearning, and support to research and policy. The third stage was characterized by a change in views towards eLearning within the adopting system, as well as an effort to increase sector efficiencies through integration of IT systems and synergies between diverse institutional endeavours (3).

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# Institutionalizing and sustaining eLearning

This chapter addresses the process of institutionalizing and sustaining eLearning within an educational setting, and offers key strategies for organizational transformation and change. The chapter draws on empirical and theoretical research in organizational and innovation studies, and applies the principles of institutionalization from a range of academic disciplines to educational systems. Financing strategies for eLearning are provided, as is an overview of the literature on the cost-effectiveness of eLearning technologies.

## Institutionalization: key concepts

Institutionalizing eLearning refers to the process by which a technological innovation in education becomes a fundamental, sustainable component of an organization's structure, process and culture (1). The concept of institutionalization, also referred to as "embedding" (1,2), is commonly used to refer to the concluding phase of the process of adoption and diffusion of innovation, whereas "adoption" refers to the uptake (at individual or organizational level) and "diffusion" refers to the process of communicating an innovation in order to increase usage over time (1,3). Institutionalization is the only one of these processes that results in long-term sustainability of an innovation within an organization.

Sustainable eLearning refers to the process by which eLearning becomes a normative practice that can survive the present and future needs of the learner, in addition to political, regulatory and social demands (4). The sustainability of eLearning has many different dimensions; it can relate to an organization's capacity to maintain eLearning financially with regard to funding programmes as well as to the infrastructure necessary to support the technological innovations required to facilitate eLearning programmes.

It is widely recognized that institutionalizing innovations within higher education is a complex task (1) and is often an extremely time-consuming process (5). Given that universities differ in staff and student numbers, boundaries between faculties, and policy and regulatory systems, it is

of vital importance that close consideration is given to how universities will respond to institutional transformation and change (5,6).

Universities now exist in a digital age (7). The growing use of information and technology sources has drastically changed the context of teaching within higher education. However, teaching methods and management to reflect the growing use of IT have initiated change at a much slower pace (5). As a result, educational technologies have begun to transform the way educators teach, often without the necessary infrastructure, training and IT systems to support the transition (8).

## University context

The successful institutionalization and sustaining of eLearning programmes is strongly dependent on the context of the organization. It depends on the level of change that is tolerated by staff, as well as the development of procedures to support staff and students in managing the change. Institutional characteristics play a crucial role in this process, as higher education is a composition of social systems with a diverse range of norms, values and authorities (1) acting semi-autonomously through faculties, departments and schools, each with their respective boards and stakeholders. As such, Casanovas (1) has referred to this situation as "organizations within organizations" given the relative autonomy of schools and departments (1).

Within the education sector, institutionalizing and sustaining eLearning require careful navigation of the political, social and legal obligations of the organization and require strategic commitment from multiple stakeholders in top-level institutional positions as well as from lower-level teaching and support systems (9). Educational systems worldwide are traditionally directed by a range of actors, including state agencies and private organizations. These have significant influence over educational policies and regulations, including funding, curriculum development and quality standards. As such, the process of institutionalizing eLearning requires increased dialogue and strategic negotiation between actors,

particularly among top-level management, executive boards, key stakeholders and faculty (4).

Recent globalized trends, technological advancements and declines in public funding from government actors have resulted in what Krucken & Meier (10) refer to as the transition from a university to an “organizational actor”. This transition to the new “globalizing university model” is characterized by organizational accountability, the development of a university’s “own” goals through mission statements, and the transformation of university management into a profession (10). This transition is illustrated by recent trends to shape universities into key decision-makers with strong institutional management and governing capabilities at national level (10).

The structure of a university contributes to the way the process of change occurs, as it is closely tied to decision-making procedures within the institution. Teaching and research faculty are typically presented with a democratic, bottom-up structure in which they are free to develop course methods and materials. Similarly, as departments within universities are relatively autonomous bodies, faculties and departments have significant freedom to decide how they wish to allocate funds and resources (11). This structure co-exists with the bureaucracy of central administrative staff and management, as decision-making is often conducted in a top-down process between presidents, deans and heads of departments. Atkinson & Gilleland (12) refer to this arrangement as “academically federal and administratively centralized” in view of the complexity in the way educational organizations are structured and power is exercised.

Several external pressures, particularly the reduction in government funding in education, have led leaders to reconsider the role and function of universities worldwide (11,13,14). Many existing universities require drastic change with regard to technological infrastructure, staff development and training, and financing models in order to accommodate for the growing use of IT within education. This has resulted in increased partnership and collaboration between public and private organizations. The changing role of private entities and corporations in higher education and the growing use of business models for educational services have prompted the use of a new discourse in higher education, as students are referred to as “consumers” (15,16). However, such partnerships may also require a renegotiation of power and governance, as shifts in the structure of universities also contribute to changes in decision-making, leadership and management.

## Organizational transformation and change strategies

Institutionalizing change within a university context has often been a reactive process, as many universities have failed to keep up with the growing pace of technological change and the accompanying need for innovative teaching methods (17). Institutionalizing eLearning in an educational context is not a simple transformation but a dynamic, ongoing process in which universities need to constantly adapt to changes over time. However, the inherent structure of universities and the historical traditions in which their governance, leadership and decision-making procedures occur, are often resistant to change (17).

It is beyond the scope of this report to summarize the expansive literature on organizational transformation and change, but it is important to identify several of the key strategies for generating change within a university setting. Within the organizational change literature, collaboration was found to play an important role in the process of institutionalizing of eLearning within a university context (16–18). Collaboration is a concept that is valuable on both a university system level – incorporating all levels of faculty, administration and teaching staff – as well as across institutions and partnerships. In Rossiter’s (16) study on the embedding of eLearning in higher education, collaboration was found to play a significant role through the use of cooperative projects between departments and strategic alliances between universities. It was found that collaboration strongly contributed to the sustainability of innovations through the discussion of new ideas and exchange of resources (16). However, due to the increasing access and demand for education, competition between universities is also growing (17) and has resulted in a strategy of “collabotition” (collaboration and competition) in order to compete in the higher education business market (17,19).

Organizational culture was also found to play a key role in the process of change within an organization (20–22). Organizational culture refers to the deeply rooted behaviours, assumptions and ideologies that characterize an organization and its members (23). Marshall (21) argues that the organizational culture within a university has the potential to act as an asset for innovation as well as a barrier to it and plays a significant role in the extent of organizational change achieved. Cameron and Quinn highlighted that, despite the many change techniques employed by organizations today, many organizations fail because they do not change their fundamental organizational culture. The authors contend that the failure in achieving change is likely to be due to the values and goals of an organization remaining constant despite changes in procedures and strategies (24).

## Change process

It is widely recognized that organizational transformation and change strategies are not easily accomplished (25–27), as research suggests that nearly 70% of organizational efforts to achieve change result in failure (28). Numerous theories and models have been proposed to assist organizations with managing change to improve performance in a variety of industries (3,29,30). Research by Greenwood & Hinings (31) suggests that incidence and pace of organizational change vary between different sectors as change is highly dependent on the internal dynamics of an organization.

Todnem By (32) has argued that the high failure rate associated with organizational change may be due to a reliance on a large body of theories and approaches which lack empirical evidence (32). Similarly, Gunn (33) highlights that findings from initial development phases of eLearning innovations discourage management bodies from continuing eLearning projects in view of their limited short-term success. Cameron & Quinn (24) highlight that failure in achieving change strongly influences the culture of an organization, often reducing morale and increasing frustration. As such, it is essential that strategies to implement institutional change within an educational context are initiated at the appropriate pace and scale, and are designed to accommodate the various aspects of the complex culture and systems of universities.

Collins and Moonen (34) have proposed three stages representing the process of institutionalizing eLearning within higher education. The first stage is characterized as a pre-initiation/initiation stage, in which bottom-up strategies are employed. Research has shown that bottom-up change strategies, including the utilization of eLearning champions and promotion of cross-disciplinary institutional collaboration, have been found to contribute significantly to successful organizational change (20,33). This is followed by an implementation stage that is a more strategic, organizational approach, such as developing eLearning policies on an institutional level or increasing technological infrastructure investment (34). The development of institutional eLearning policies at a high level of management highlights a university's support and strategic ownership, thus contributing to the diffusion of eLearning and commitment to change (20,35). The third and final stage, institutionalization, is achieved when the changes proposed through the educational innovation become a core part of the institution and its processes (1,34). However, given the complexities within and between universities, the process of institutionalization is highly dependent on internal and external pressures and realities and is often not a simple step-by-step procedure for all institutions.

While there are several theories regarding appropriate change strategies, particularly top-down and bottom-up debates, there seems to be some consensus on the key features that enable change, including a systems approach which incorporates willingness and flexibility from all stakeholders as well as strategic planning (1). In addition, it has been argued that the nature of change should depend on the size of the institution and the scope of the change required, ultimately depending on institutional factors such as the existing infrastructure, management styles and funding availability (4,35).

Within the process of change, Kotter & Schlesinger (26) have proposed three steps for managing change successfully. The first step, conducting an analysis of situational factors influencing the change process, allows for an exploration of how contextual factors, urgency and resistance can have an impact on the change process. For instance, it is vital to have a strong understanding of the level of resistance expected across all levels of power, as well as the possible stakes involved (26). Following a detailed situational analysis, the authors suggest using this information to determine the pace of change required, as it is strongly dependent on the context in which the change is being implemented. Lastly, it is necessary to decide on the methods to use to manage the change – including education, participation, facilitation, negotiation and/or coercion, depending on the situation, and the pace of change necessary (26).

## eLearning: disruptive or sustaining innovation?

The dilemma facing higher education institutions today deals not only with engaging in change processes to accommodate the increasing pace of technological change, but also with the key decision of whether institutions need to change their role within the current competitive education market (17). The question of whether universities should continue to modify their existing, traditional model or whether universities should redesign their entire system to attract a completely different market, is of crucial importance as it determines the future success of the organization.

The concept of disruptive innovation allows for an analysis of how the growing use of educational technologies can act as a disruptor to the traditional university system. Disruptive innovation, a concept identified by Christensen (36), describes a process by which a product traditionally found at the bottom of a market moves up the market, ultimately superseding recognized competitors. When applied to eLearning, innovations in educational technologies can either be sustaining or disruptive. A sustaining innovation is one that attempts to improve the functionality of an

existing system or product, yet does not deviate far from it. An example of a sustaining innovation would be the use of electronic Microsoft® PowerPoint® slides made available through a VLE compared to the distribution of traditional paper printouts (21).

A disruptive innovation is one that creates an entirely new market through a new service (37), displacing the need for the traditional service. As summarized by Marshall (21), Christensen (38) argues that Internet-based eLearning innovations have often failed as they provide to the same group of students (as opposed to non-consumers) an inferior learning experience that is in direct competition with the traditional learning model. As such, in order for eLearning to be a disruptive innovation, the changing landscape of higher education must be able to target non-consumers as well as providing a service that is different from traditional face-to-face learning. In addition, applying the concept of disruptive innovations to eLearning allows for a deeper analysis of how eLearning is closely related to educational equity concerns, as eLearning has the potential to provide learning opportunities to populations previously not targeted as consumers because of constraints on affordability or accessibility.

A key element of disruptive innovations when applied to eLearning is that many universities are aware of the need to make drastic changes to the existing educational model in order to incorporate innovative educational technologies. However, in order to initiate changes to the existing structure of the university system, institutional leaders and managers must be able to understand the capacity and capability of their organizations to experience change, and how the existing values, internal processes and resources contribute to the change process (37).

## Financing

Funding is arguably one of the most difficult issues associated with institutionalizing and sustaining eLearning (13). Marshall (21) contends that most of the recent changes in universities are driven by financial accountability of the public funds allocated within the education sector. Recent trends in post-secondary education financing have led to a decrease in government spending in education due to competing priorities across sectors and an increase in public-private linkages to capitalize on market-based funding methods (21). These trends have contributed to the need for university administrations and managers to transform the financial model supporting higher education institutions worldwide.

## Sources of financing

Following recent reductions in public funding for education worldwide (13,39), a number of funding sources have been proposed to address growing concern as to how eLearning will be supported. A report by the United Nations Educational, Scientific and Cultural Organization (UNESCO) on national strategies for eLearning within the higher education and training sector provided several funding strategies for the sustainable financing of eLearning, including the reallocation of existing government funds, targeted short-term grants and increased government baseline funding (13). Conole and colleagues (5) contend that eLearning funding has traditionally been in the form of short-term methods. However, while providing opportunities to develop and introduce eLearning, short-term funding does not provide opportunities to assess long-term sustainability of programmes once initial funding has been depleted (5).

Intel (40) has suggested consideration of public-private partnerships, including government-backed loans, bundled service agreements and microfinancing methods, in addition to technology grants for hardware, software and training. However, the transition from an "allowance model" of financial management to one that generates revenue comes as a shock to universities (41) and requires a complete shift in how the university financing system is structured and how power is distributed. Questions remain with regard to the level of influence financing sources have, and how this contributes to management issues (4,5).

## Sustainable financing

Research into financing mechanisms for eLearning (42) has shown that external funding sources play a significant role in the introduction of eLearning. However, it is often unclear what happens when initial start-up funding is used up and the financing of eLearning is dependent on external funding. White (25) has shown that increases in technology and associated decreases in hardware costs have resulted in an increase in eLearning funding for the initial stages of eLearning programmes. However, once the initial funding for the project uptake was used, little was done to maintain the project's post-funding phase. In a report by MacKeogh & Fox (2), the authors found that universities are still struggling to institutionalize eLearning as a result of issues relating to funding support dependency, as eLearning is only one of the many competing priorities for university funds.

In order for eLearning to be institutionalized within an organization, a key requirement is that it is self-sustaining and can still perform following initial funding arrangements.

In addition, questions must be addressed in relation to how funding eLearning contributes to power relationships between those who fund the programmes and those who develop and facilitate teaching and learning, as different priorities and incentives of stakeholders strongly influence learner outcomes.

## Application of financing

The allocation of funds from funding agencies and the distribution of funds to university initiatives is a complex process that differs between universities. Research has shown that key differences exist between universities that are primarily research-intensive versus those that are teaching-intensive, since those that receive financial autonomy through external funding for teaching or research excellence may also prioritize innovative teaching methods such as eLearning, resulting in an unequal balance of the diffusion of innovations across a university setting.

Thus, institutions that are more financially inflexible may provide the necessary conditions for widespread institutional change compared to those that are more financially autonomous, as the latter may require more incentives or rewards to build eLearning innovations on an institution-wide level (25). However, when funds are allocated in a bureaucratic, top-down fashion, complications for eLearning initiatives may arise if institutional support is not present, as funding may be inadequately distributed (25). Obtaining educational grants may provide educators with more flexibility to initiate eLearning but concerns over programme sustainability persist. In addition, when funding is minimal and limited funds are distributed among many competing parties, significant concerns arise as underfunded initiatives have major implications for the quality of the learning experience.

## Cost-effectiveness

A number of factors have provided motivation for educators and top management to introduce eLearning within universities, including pedagogical and learner-focused needs as well as increasing pressure for technological innovations in education (43). Evidence regarding the cost-effectiveness of eLearning compared to traditional learning is varied (13,41,44). Research has suggested that there is often great difficulty in analysing cost-effectiveness given the significant differences in programme development costs between departments/universities and fluctuating costs of hardware, software and licensing of eLearning equipment (41).

Bates (13) has identified critical factors that have an influence over the costs of eLearning. The factors include the start-up costs for the initial development and delivery of eLearning, which is ultimately more time-consuming and is done in isolation, reducing economies of scale (45). The maintenance costs of eLearning are higher compared to traditional print-based material, but research has shown that the costs can be made up over the course of use (13). In addition, costs of the development of multimedia sources used in eLearning can vary dramatically according to the level of sophistication and the size of classes using the materials (13).

Many of the early models for the cost of eLearning were based on the idea of the "infinite lecture hall", as the more student numbers a university had the lower the cost of eLearning would be (43). This idea is reinforced by the concept of economies of scale, in which traditionally the higher the number of students enrolled in a course, the less expensive the course would be to maintain. In a study comparing the costs of computer-mediated instruction (CMI) and CBL, Bates (46) found that, regardless of the complexity of the CBL method (whether it was designed from start in a university or bought off-the-shelf), each involved high initial start-up costs and resulted in low variable costs. These findings confirm the idea of economies of scale, as the cost of the educational technologies used decreased as the student numbers increased (46). However, for the computer-mediated instruction (CMC) learning methods that were characterized by high levels of interactivity between students and instructors, the costs rose proportionally with the rise in student numbers. The author suggests that if the learning is to be effective more staff will be required to interact with the students, which ultimately becomes the highest cost associated with the eLearning method (46).

## Solutions for the cost of eLearning

Given the significant role that the cost of eLearning plays in the institutionalization and sustainability of eLearning, Weller (43) proposed the use of learning objects as a solution. Through the use of learning objects, educators can reduce the cost associated with eLearning through three key elements: reusability, rapid production and ease of updating (43). These elements can assist with the cost-effectiveness dilemma facing educators by reducing the time commitment required for staff in the development and delivery of eLearning. Other solutions have been proposed, including the use of VLE, engaging in more collaboration to reduce the human resource capacity for eLearning development, and utilizing off-the-shelf materials to reduce costs (13).



Research has suggested that eLearning innovations that respond to the educational needs and learner preferences of students, and that have a low level of technological complexity/appropriate technology usage, are more likely to be cost-effective and have long-term sustainability (41). The authors highlight that these factors contribute to the programme's sustainability regardless of the funding capacity of the institution, as it is of more importance that programmes are designed effectively for the use of learners.

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# Quality of eLearning

Knowledge drives productivity and economic growth (1). Governments are therefore interested in knowledge transmission. In the United Kingdom the rapid increase in student numbers and concern for public expenditure and a push to improve public services has focused public attention on the quality of education; increased competition for resources within the educational sector has highlighted the “tension between efficiency and quality of education” (2).

Before discussing how the quality of eLearning material used in undergraduate health professional education is assessed, one first has to consider what quality of education is, what aspects it covers and how this applies to the field of eLearning. One can then evaluate whether quality of eLearning is considered in the articles identified in the systematic review.

## What is quality of education?

Despite attempts to define quality of education, as described in Cheng et al. (3), a consensus on a single definition does not exist. Because the concept of quality is itself grounded in values, cultures and traditions, the interpretation as to what defines educational quality might be specific to a given community, educational institution, course, learning activity or even an individual student (4) and may also change over time.

The complexity of defining what quality of education is already starts with the word “quality” itself. Harvey & Green (5) grouped the different conceptualizations of quality into the following five “discrete but interrelated” categories:

- exceptional, or in other words “something special” (variations of this definition include being distinctive, exceeding very high standards, or meeting of set of minimum criteria);
- perfection or consistency, focusing on the flawless process as well as “getting things right first time”

- fit for purpose, or the extent to which the product or service “does the job” it is aiming to do (although we need to define whether the purpose is determined by the student or the provider);
- value for money, including cost-effectiveness;
- transformation, focusing on enhancing and empowering the student.

Different indicators of quality of education can relate to any of these definitions, or to a combination thereof.

Vlasceanu, Grünberg & Parlea defined quality as a “multi-dimensional, multi-level, and dynamic concept that relates to the contextual settings of an educational model, to the institutional mission and objectives, as well as to specific standards within a given system, institution, programme, or discipline” (6). Quality is a relative concept because its definition depends on the user and the context in which it is used (5). However, absolute definitions of quality may be used for benchmarking and quality assurance activities. There are thus different meanings of quality which are further described below.

## Quality as a culture-specific and dynamic concept

Definitions of quality change with changes in pedagogy. For a long time, teacher-centred approaches have been used in education. Assessing the quality of such teaching focuses on (i) the quality of the content that the teacher transmits in the material and in face-to-face sessions, and (ii) the quality of the mode of transmission of such knowledge. Hence, in this respect the “best teacher is one who transmits the best possible body of knowledge in the best possible manner” (7).

Recent educational literature, particularly from western societies, concentrates on learning-centred approaches. In this context, quality assessment focuses on what the student has actually learned. The assessment then

considers first the quality of the learning as an output of the teaching, and secondly the quality of the enhanced learning capability as an output of the teaching (7). Assessing the quality of any programme or educational material that is used in the framework of a student-centred approach would benefit from a broader range of indicators of quality than teaching-centred educational methods.

There are wide variations in the teaching philosophy in different countries and institutions, which relate to different pedagogical theories (see Introduction and Annex 1). The teaching philosophy may vary within an institution, and may even vary within a programme, course or module.

Even if they have similar titles or descriptions, different learning programmes or activities may have been designed to meet different learning outcomes (8). Direct comparison of the quality of different learning programmes or activities is thus meaningful only if the learning outcomes are comparable or their differences considered. The characteristics of the educational environment, the target audience and the time period in which they occurred need to be clearly defined for this purpose.

### Quality as a multidimensional and multilevel concept

Early approaches assessed the quality of education by using proxy measures such as “increases in financing and other inputs in the level of educational provision”. Later approaches to the quality of education focused on assessments of measurable outcomes. These comprise knowledge (“the cognitive achievements that all learners should reach”), values (including tolerance and mutual understanding), skills or competencies (“a secure command of how to solve problems, to experiment, to work in teams, to live together and interact with those who are different, and to learn how to learn”) and behaviours (“the willingness to put into practice what has been learned”). More recent approaches to the assessment of quality take a multidimensional and multilevel perspective and also consider the learning environment (9).

UNESCO considers quality of education from the perspective of human and other rights, defining five key dimensions at the level of the learner and five at the system level (9). At the level of the learner, UNESCO considers that a good quality education is one that is “seeking out learners” and is thus inclusive, welcoming the learner and adaptable to meeting learning needs. A good quality education should take into account “what the learner brings”. It should have content that is relevant to today’s society and that

embraces rights, equality and diversity. A good quality education should enhance learning processes. In addition, the “learning environment” should not only respect health and safety but should also offer a suitable psychosocial environment. UNESCO also distinguishes five dimensions of quality that refer to the system level: the “managerial and administrative system” that offers the education must support effective learning, which must be based on the “implementation of good policies”, education must take place within an “appropriate legislative framework”, have “sufficient resources”, and methods to “measure learning outcomes” must be in place. Dimensions of quality defined by the United Nations Children’s Fund (UNICEF) (10) largely overlap with those defined by UNESCO (9).

Ehlers defines the quality of education through the interaction between learners and their learning environment, whereas the organizational processes surrounding the delivery of education influence its evaluation. He therefore regards quality development as a “co-production between learners and their learning environment” (11).

Quality indicators can relate to the “input (human and physical resources), output (graduates) or the process of learning and teaching itself” (2). Several largely comparable classifications of these quality indicators exist. Ehlers, for example, distinguished the following five categories of quality (12):

- structure
- context
- process
- output
- Impact.

### Quality as a user-specific concept

External and internal stakeholders in education are likely to view quality differently (3,6). External stakeholders, such as governmental, regulatory or professional bodies or employers, usually focus on quality control or assurance processes. They require educational providers to demonstrate accountability and provide evidence that the standards and quality of education provision meet agreed standards. Internal stakeholders, including students, academic staff and administrative staff, are more likely to focus on quality enhancement. For instance, when evaluating quality, students consider not only the content of their education and how well it is taught (as well as their employability after graduation) but also their entire student experience, including their interaction with staff, the study environment, career advice and opportunities for extracurricular activities, among other factors.

Different stakeholders will therefore answer the question “Why is quality of education important?” differently. For example, governments may be more interested in supporting programmes that offer value for money and are cost-effective than other stakeholders. Educational providers may be more concerned with student attendance and retention, which will be affected by how well the subject is taught, and how much knowledge and skills the student gained. Teachers and others are interested in whether learning outcomes have been achieved. Students are interested in whether they enjoy studying, whether the knowledge and skills they gained are relevant, and what their prospects are after graduation.

The mission and objectives of the relevant stakeholder should thus be considered when presenting indicators of quality of learning.

## Applying the concepts of quality to eLearning

In the subsections below, the general concepts of quality of education are applied to eLearning. Indeed, an “understanding of the broader quality of the activity of learning” is needed to be able to determine accurately whether an eLearning course is effectively designed, developed and deployed (13).

Because different stakeholders are interested in different levels at which quality is assessed, these more specific considerations are discussed according to the level to which they apply.

Quality of eLearning at the level of institution and educational context

In many countries, it is becoming more common to assess quality of eLearning at the level of institution, considering the institution’s capability to sustainably develop, deploy and support eLearning. Two models/sets of criteria that can be used to do so are described below: the eLearning Maturity Model (eMM) (14,15) and the European University Quality in eLearning (UNIQUE) criteria (16). Both have been developed following extensive research into quality certification of technology-enhanced learning, consultations with researchers, quality experts and stakeholders, and testing (14,15).

The eMM, which was developed in New Zealand, can be used to provide institutions with insight into their capability to sustain and deliver eLearning. The model also allows the

direct comparison of this capability in different institutions. The eMM model specifies five process categories:

- learning – processes that directly impact on pedagogical aspects of eLearning;
- development – processes surrounding the creation and maintenance of eLearning resources;
- coordination and support – processes involved in the day-to-day management and support of eLearning delivery;
- evaluation – processes surrounding the evaluation and quality control of eLearning through its entire life cycle;
- organization – processes associated with institutional planning and management.

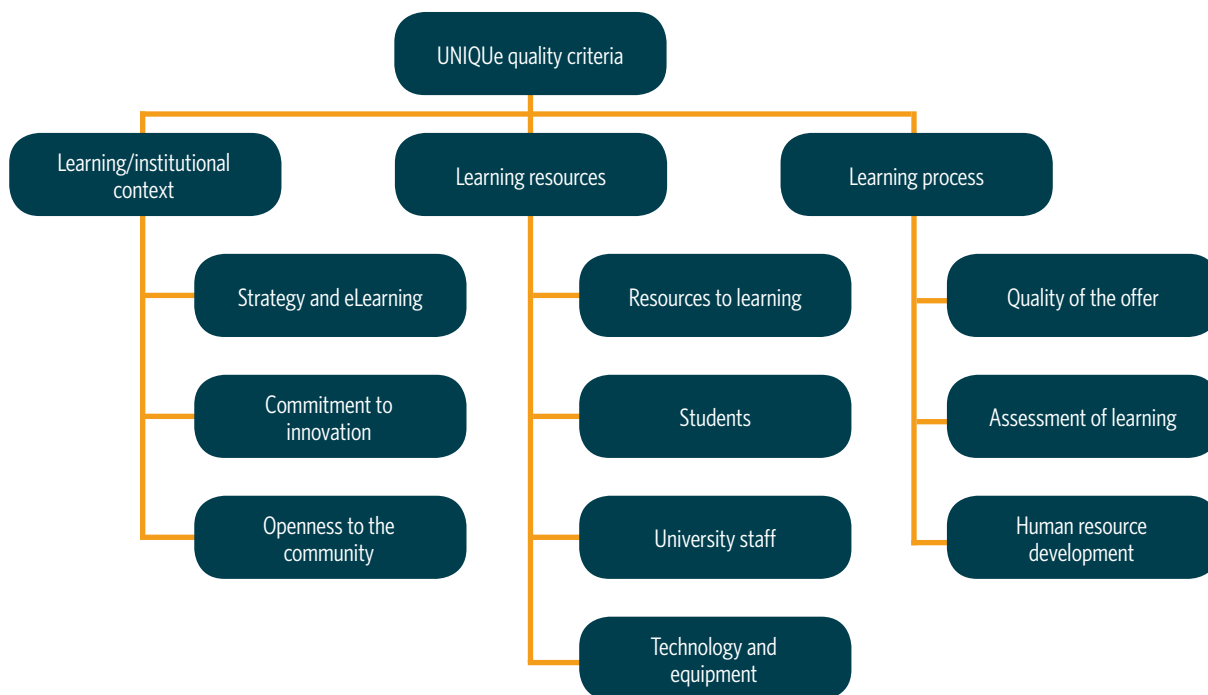
These process categories are further subdivided into 6–10 subcategories each. In the current version of the eMM, five different dimensions are specified: delivery, planning, definition, management, and optimization. From the perspective of each dimension, the processes are further broken down into practices that aim to achieve the outcomes of the process. After indicating whether or not they are “essential” for doing so, their level of adequacy is judged (14,15).

The UNIQUE criteria (16) were developed for the certification purposes of institutions. The criteria focus on specific domains rather than on processes. The main criteria are depicted in Figure 9.1.

The criteria described in Figure 9.1 are further broken down into subcriteria to allow assessment of quality of eLearning. Whereas all criteria are relevant, UNIQUE identified the following subcriteria as essential for an institution to be certified:

- “Evidence is available that eLearning/TEL is an integral part of the institutional strategy.
- The institution chooses the course delivery methods based on criteria of pedagogical appropriateness, social sensitivity and cost-effectiveness.
- Systemic collaborative working procedures and tools are employed in order to share knowledge developed with the community.
- All technology-based procedures are appropriately tested according to industry best-practice.

Figure 9.1. Breakdown of the UNIQUe quality criteria (25)



- Course design and delivery guidelines are available for relevant staff.
- Flexible pedagogic and learning delivery models are adopted in order to meet different users' needs.
- Tools and procedures for evaluation of the outcomes of the learning process – including using data collected from stakeholders and graduates – are taken into consideration for improving the quality of the offer.
- Continuous efforts are made to promote an optimal learning environment.
- Both formative and summative assessment are used.
- Training services and materials (e.g. guidelines) for the staff in charge of learner's services are available in order to support them (if required) in the process of moving from conventional teaching to (fully or partially) on-line teaching." derived from the UNIQUe website) (6)

In addition to the general accreditation bodies relevant to undergraduate education, several others specialize in accreditation of eLearning. These bodies also release

guidelines on quality of eLearning material at the institutional level.

In addition to models that evaluate the quality of eLearning directly, a related family of models aims to improve a programme or product rather than assessing quality per se. Stufflebeam's widely used Context, Input, Process, Product (CIPP) approach is an example of such a model (17). This model specifies a series of questions that allows planning decisions or defining objectives (context evaluation); structuring decisions and programme design (input evaluation); monitoring, controlling and refining of programmes (progress evaluation); and facilitates the judgement of programme attainments while informing transfer and dissemination (product evaluation) (17,18).

### Quality of eLearning at the level of the learning resource

#### DIDACTIC QUALITY

The quality of eLearning material should be assessed in the context of its purpose. Hence, eLearning material that does not target the learning outcomes for which it was designed, or is not designed at the required level of its users, should

be regarded as having no quality for that purpose, even though the material might be of good quality for use in other settings. This includes the requirement that both learners and instructors should have the ability to use the technology to make use of eLearning material; without such, quality education cannot be provided.

### TECHNICAL QUALITY

Any eLearning material should be functional and free of bugs in order to have potential quality. This should apply to all operating systems and browsers on which the resource is run. In addition, in order for the material to be used lawfully, the copyright permission should allow the educational provider to do so. It is therefore useful for the source to be stated (19). The provider of the eLearning material should also specify the required equipment and technology.

The SCORM criteria are a set of related technology standards, specifications and guidelines for eLearning accessibility, interoperability, durability and reusability (20). They advise programmers on how to write code so that it is compatible with other eLearning software. The SCORM criteria are the industry's current standard, and accreditation processes of eLearning material therefore regularly specify that the latest SCORM criteria should be met (e.g.19).

### Quality of eLearning at the level of the learning process

A commonly used taxonomy for assessing the quality of eLearning, mainly at the level of the learning process, is Kirkpatrick's evaluation taxonomy (21), the updated version of which focuses on the following:

Reaction - "to what degree participants react favourably to the training" (this refers to customer satisfaction, engagement and relevance).

Learning - "to what degree participants acquire the intended knowledge, skills, attitudes, confidence and commitment based on their participation in a training event" (this refers to knowledge, skill, attitude, confidence and commitment).

Behaviour - "to what degree participants apply what they learned during training when they are back on the job" (this also considers the required drivers).

Results - "to what degree targeted outcomes occur as a result of the training event and subsequent reinforcement" (this refers to leading indicators).

Several adaptations of this taxonomy also consider eLearning. An example of such an adaptation can be found in Hamtini et al. (22).

It is important to assess the reaction of the learner because student motivation drives learning (12). Examples of measurable aspects of quality include feedback forms and questionnaires as well as student surveys, which all measure the reaction of the student. However, learners define quality differently from educational providers. Learners focus, among other things, on whether they liked the learning activity (e.g. if it was boring or not, if the level was appropriate), whether they like the learning context, and the extent to which they feel supported.

Several authors conducted exploratory factor analysis on users' preferences to gain insight into what learners find important in eLearning. Jung, for instance, identified seven dimensions that are relevant to evaluating the quality of eLearning from the user's perspective: staff support, institutional quality assurance mechanism, institutional credibility, learner support, information, and publicity (23). Using survey data, Ehlers identified 30 dimensions of learners' preferences, which variously belong to the fields of tutor support, cooperation and communication in the course, technology, cost/expectations/value, information transparency, course structure and didactics. Analyses of the data identified four groups of users with different preference profiles, namely: individualists who are content-oriented, the result-oriented who are independent and goal-oriented, pragmatists who are need-oriented, and avant-gardists who are interaction-oriented (12). This classification may have to be taken into account in preference evaluations.

Whether or not eLearning resulted in gain in knowledge and skills was discussed in the systematic review. The assessment of knowledge and skills should ideally refer directly to the extent to which the learners achieved the intended learning outcomes. This can be done by evaluating pass rates or grades and also the extent to which the learners demonstrate the skills and knowledge in practice. Pre-testing and post-testing are also useful tools for assessing the gain in knowledge and skills.

Behaviour can be assessed only over time through observation, self-report or interview. Using such data, the sustainability of the change of behaviour can also be measured and its relevance judged.

Use of indicators of quality of eLearning in literature on undergraduate health professional education

The articles identified in the systematic review focus mainly on the efficacy of eLearning. They measure the efficacy in terms of “increase in knowledge” or “improvement of skills”, such as through pre- and post-testing (e.g. Jang et al., 24) or midterm and final examinations (e.g. Frith et al. 25). Student satisfaction is also measured in many articles, as previously discussed.

However, the educational environment and culture in which the intervention took place were seldom – and if so, hardly – described in the studies included in the systematic review.

Whether or how the educational institution supported the delivery of an eLearning intervention was therefore unclear. The articles also did not clearly explain whether or not the eLearning material used was flexible enough to cater for the diverse learning needs of individual students – i.e. taking into account their learning styles, their preferences and individual background knowledge.

Thus, aspects of quality of eLearning were assessed in the literature on undergraduate health professional education but were not described in a way that allowed assessment of the quality of the provided eLearning in a more holistic way.

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# Part Four

Discussion,  
conclusions and  
future directions

e LEARNING

The review is based on a rigorous search, analysis and presentation of data that provides decision-makers with an up-to-date picture of current knowledge on eLearning for undergraduate professional education.



# Summary of key findings

The use of eLearning and blended learning to support the delivery of learning objectives has become a common feature in health professional education, offering the potential to help tackle the shortage of labour in the global health workforce. The aim of this report is to identify and evaluate the different forms of technology that have been used in the past decade to deliver undergraduate health professional education. For this purpose a systematic review of peer-reviewed literature was conducted, as well as a literature review of grey literature. The forms of technology were assessed as to the impact they have on important learning outcomes: knowledge, skills, students' attitudes and students' satisfaction.

On the basis of the technologies employed, five broad categories of eLearning and blended learning were identified, namely:

- non-networked computer-based;
- Internet and local area network-based;
- psychomotor skills training;
- virtual reality;
- digital game-based learning.

This report focuses on non-networked computer-based and Internet and local area networked-based interventions. The main reason for this is that these forms of technology are most likely to be available in a multiplicity of settings, including low- and middle-income countries. In addition to addressing the form of technology, the studies included in this systematic review fell into two additional categories: those comparing eLearning to traditional learning methods, and those comparing different modalities of eLearning to each other.

## Studies comparing eLearning to traditional learning

In terms of knowledge acquisition, only 33% of the studies comparing CBL to traditional learning found significantly

higher knowledge gains among students using the computer-based intervention. Moreover, 63% of these studies found no significant differences between these two methods. Similarly, 29% of the studies comparing web-based eLearning to traditional learning found significantly higher knowledge gains in those students using the web-based interventions, while 64% of these studies did not find significant differences between the two methods.

With regard to skills acquisition, 62% of studies comparing CBL to traditional learning found significantly higher skill gains in students using the computer-based intervention, while 38% of studies did not find significant differences between the two methods. Additionally, 40% of studies comparing web-based eLearning to traditional learning found significantly higher skill gains in students using the web-based intervention, while 27% of these studies found no significant differences between the two methods. Unlike studies assessing computer-based studies, four studies in the web-based group found significantly higher knowledge and skill gains in those students exposed to traditional learning methods.

Due to the high degree of methodological and clinical heterogeneity, it was not possible to conduct a meta-analysis and obtain an overall effect estimate for each form of technology. However, the findings from the systematic review suggest that both non-networked computer-based and network-based eLearning are at least not worse than traditional learning and that they can be equivalent and perhaps even superior to traditional learning in terms of knowledge and skills gained. In addition, they offer a more convenient, and possibly more cost-effective, alternative for facilitating competency development and the training of health-care professionals around the globe. There was significant variation in terms of type of eLearning (i.e. full eLearning versus blended learning), delivery channels, duration and frequency of exposure to the intervention, measures of outcomes, type of degrees, and seniority of students.

In terms of students' attitudes, approximately 42% of studies comparing computer-based to traditional learning found that a significantly higher proportion of students favoured the computer-based intervention, while 58% of these studies found no differences in students' attitudes. None of the studies comparing network-based eLearning to traditional learning found any significant differences in students' attitudes.

In terms of satisfaction, 56% of the studies comparing computer-based studies to traditional learning found higher satisfaction rates among those exposed to the eLearning methods, as compared to 22% among those exposed to traditional learning methods, and 11% found no difference between the two methods. For web-based eLearning, only 14% of the studies found higher satisfaction levels among students exposed to the eLearning method, 4% (one study) found higher satisfaction among those exposed to traditional learning methods, and 69% of studies found no significant differences.

These findings provide a mixed picture of attitudes towards, and acceptance of, eLearning interventions. These factors should be taken into account as they could affect

the effectiveness of eLearning on knowledge and skill acquisition. In particular, it is important to explore in more detail the specific determinants of the levels of acceptance among the student population and consider these factors in the design and implementation of future eLearning initiatives.

## **Studies comparing different modalities of eLearning**

Studies comparing different forms of eLearning modalities are ideal for understanding the specific design features of these interventions that can result in better learning outcomes. The interventions we identified in this systematic review fell into two separate categories: active (e.g. those including more interactivity) and passive interventions. For both non-networked computer-based and Internet and local area network-based eLearning, there was no clear trend favouring either category. This may be a reflection of the high levels of clinical and methodological heterogeneity, and further explorations should aim to evaluate those studies that are most similar across the domains previously mentioned.

# Strengths and limitations of the systematic review

## Strengths

Systematic reviews are increasingly used by policy-makers as such reviews provide quality synthetic, objective, evidence-based data selected from a wide range of scientific literature. They help identify beneficial and harmful interventions as well as gaps in knowledge (1), thereby providing guidance for both future policy and research. Their strength derives from a standard set of stages, practices and tools, such as an extensive literature search, an explicit and rigorous methodology, relevance and applicability to decision-making.

The probability of identification of all relevant literature was optimized by conducting the search in a variety of peer-reviewed databases without imposing language restrictions as well as by screening references of the selected articles. To enhance data quality, every identified article was screened independently by two persons, and their results were compared and discussed. The same procedure applied to the data extraction of the selected articles, which was further enhanced by using a standardized form for recording (Annex 6).

While individual studies may contain conflicting results restricted to specific settings, the systematic review confronts, combines and synthesizes those results in order to provide an up-to-date overall picture of the best available data. The systematic review not only provides a comprehensive evaluation of the effects of eLearning on students' knowledge, skills, attitudes and satisfaction, but also took advantage of the available data to identify the perceived advantages and disadvantages of eLearning. In addition, the reviewed articles allowed the researchers to identify and discuss critical success factors for the implementation and adaptation of eLearning interventions on the basis of an established framework. An even broader perspective on the topic was obtained by considering strategies for introducing eLearning equitably and effectively, institutionalizing and sustaining eLearning, and ensuring the quality of education.

The distinction between undergraduate and postgraduate education, and the focus on the former, aimed to increase the applicability of the results. The learning process at postgraduate level tends to be different, involving bedside learning and more in-depth exploration of the content. Additionally, patient outcomes are usually used as a proxy measure of the effectiveness of educational interventions in postgraduate education.

An additional strength was that the search resulted in the inclusion of both developed and developing countries based on the World Bank classification of countries. Special attention was paid to developing countries in view of their specific needs in relation to eLearning technologies.

The review included only RCTs and cRCTs, which are considered the best standard of scientific evidence. Nevertheless, bias, imprecision and errors can still occur in these studies. Specific methodological tools were used to identify them and to control for them by considering a study's risk of bias when interpreting results (2).

Finally, the review followed the preferred reporting items for systematic reviews and meta-analyses (PRISMA), a framework tool used to set the minimum evidence-based items to be included when conducting and writing systematic reviews. This contributed to ensuring the completeness, transparency and accountability of the reporting of findings, particularly when evaluating complex interventions such as eLearning.

## Weaknesses and limitations

Despite its strengths, the methodology used in this report also presented some limitations, and the available evidence has some weaknesses. These include:

- The lack of consistency between studies in terms of evaluation techniques, tools and measures. Such heterogeneity did not allow for conducting a meta-analysis which could have provided a stronger quantitative synthesis and summary of evidence (3).

However, the combination of very heterogeneous data may have undermined the validity of the meta-analysis findings (4) and therefore called for a narrative synthesis. We addressed some of the sources of the heterogeneity in the findings and discussion sections but did not carry out an in-depth analysis.

- The possible occurrence of publication bias resulting from the higher probability that more studies with positive results have been published than those with negative or neutral results, resulting in the exclusion of unpublished studies that might have been included in our review. However, this factor is common to any systematic review.
- The exclusion of several study designs, particularly qualitative studies, which may have provided additional relevant insight into the topic.
- The lack of reporting in some of the included studies, resulting in the restricted level of detail in the analysis of certain outcomes of interest. In particular, the pedagogical approach could not be considered in more detail because of the incomplete reporting of pedagogical methods within the included studies. The analysis of the content delivered in the reported interventions was also limited owing to the lack of data relating to the methods used to develop content, and the lack of a standardized model and availability of content to rate the quality. Finally, the financial and resource-related aspects of eLearning interventions were rarely assessed and usually not even mentioned, making impossible any cost-effectiveness evaluation of such interventions.
- The restriction to non-networked CBL and networked web-based eLearning studies in the review meant that the scope of the review was reduced, since no studies were included on psychomotor skills trainer, virtual reality environments and digital game-based learning although these had also been retrieved. However, the excluded eLearning interventions are often specific to particular groups of students, and it is therefore unlikely that this exclusion significantly affected the general relevance of the findings.
- The classification of studies into non-networked CBL, networked web-based eLearning and the other three categories is not an established classification, and other authors may suggest other groupings. However, eLearning remains a recent field in which the definitions, concepts, evaluation tools and measures still lack consensus (5).
- The decision to include articles from 2000 onwards only might also be challenged. However the choice of 2000

can be justified by the rise in the interest in eLearning illustrated in part by several national and international reports and publications on the topic from this year onwards. These more recent reports are likely to have used more modern forms of eLearning than older reports and are thus considered more timely.

- The lack of clarity of one or more aspects of the methodology used in the majority of the included trials, and in some cases the occurrence of attrition. Although authors were contacted in an attempt to obtain the missing information, some authors did not reply to the request and others did not know the answers.
- The inability to draw a robust conclusion allowing for generalization to all undergraduate students around the world due to the study selection process and the limitations of the included studies.

Such weaknesses, rather than hindering the validity of the methodology and results employed in this report, provide indications on the use that should be made of them. The systematic review, as conducted, still offers a broad and general overview of available and eligible studies, indicating the global impact of specific interventions and the aspects that require further research. The review is based on a rigorous search, analysis and presentation of data that provides decision-makers with an up-to-date picture of current knowledge on eLearning for undergraduate professional education.

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# Contextualizing the findings in wider literature

There is a wide variation in the context as well as in the understanding and definition of related terms across and within published systematic reviews (1–16) on the effects of information technology-based teaching strategies on learning outcomes. These earlier reviews generally did not examine eLearning technologies in a uniform sense – i.e. selecting studies with the same study design or balanced intervention groups, measuring the same outcomes, or comparing eLearning interventions with the same type of delivery or pedagogical mode. The huge variability of eLearning terminology combined with the many different types of eLearning delivery and pedagogical mode makes the assessment of its effectiveness quite ambiguous.

Despite being regarded as a relatively new field, eLearning stretches back decades. In the nursing literature, the history of eLearning or computer-based learning has been divided into phases (1,2):

Phase 1. The earliest text-only systems before 1980.

Phase 2. Interactive CBL, which combined text and limited graphics, from the early 1980s to mid-1990s.

Phase 3. The use of highly advanced systems from the mid-1990s to mid-2000s.

Phase 4. The introduction of virtual reality to master technical skills in virtual clinical settings from the mid-2000s.

With the evolution of eLearning technologies, there has been a major shift in the role of the computer from a standalone device used mainly as a multimedia tool (with or without interactive features) to a fully networked machine imparting connectivity at any time and anywhere. The reviews found span from 1988 (3) to 2012 (2,4). One can only deduce that the eLearning technologies alluded to by each review pertain to the prevailing technology around the time of publication.

## Non-networked computer-based eLearning

Of the 12 studies included in a systematic review of RCTs on computer-aided learning (CAL) in dental education, including both undergraduate students and dentists (5), five showed significant differences favouring CAL over comparison groups in terms of test scores and clinical performance. Six did not detect significant differences, and one showed higher test scores for the comparison group. Although Rosenberg et al. (5) included studies that were all (except one) published before 2000 and were therefore not assessed in the present review, there were similar results in this systematic review of undergraduate students (5). On the basis of a review of 12 randomized studies, Greenhalgh concluded that the efficacy of CAL in medical education is reasonably well established (17). However, she also stressed that most of the studies included in her review had methodological issues such as lack of power, attrition and a high risk of contamination. These methodological concerns were to a certain extent still present in the studies in the present review, despite its being published a decade after that of Greenhalgh (17).

The rest of the earlier published reviews did not specify RCTs as an inclusion criterion. A review of the effect of computer-based instruction (CBI) on knowledge and attitudes of health professions students showed that the average student exposed to CBI scored at the 66th percentile of one who was exposed to traditional teaching (6). In that review, 13 of the 14 studies that showed statistically significant results favoured CBI. In the same review, of the four studies that compared students' attitudes to the method of instruction, three studies demonstrated that CBI students had more positive attitudes to their instructional method than students exposed to conventional teaching. The results were less positive with regard to CBL and generally showed no difference in knowledge and attitudes between the intervention groups.

Depending on the study design, this discrepancy could perhaps be explained by the fact that the students felt more obliged to answer positively if the outcome assessment was not blinded. The subjective outcomes, attitudes and satisfaction were found to be very heterogeneously assessed in the included studies and, to keep the results as homogeneous as possible, the present review assessed only the results relating to attitude and satisfaction that dealt with the difference between eLearning and traditional learning. Since Cohen's review (6) is more than two decades old, the difference in results could also simply reflect a difference in opinion between different cohorts of students, although one would have expected that more recent cohorts would have been keener to pursue eLearning than earlier cohorts.

A similar review of computer-assisted instruction (CAI) in nursing education (3) showed that, while a typical student receiving traditional instruction scored in the 50th percentile on a test of immediate achievement, the average student receiving CAI scored in the 68th percentile. Four out of ten studies in that review reported significantly better results for CAI than for traditional instruction. Another four studies suggested better results for CAI although the difference

was not statistically significant. The same review also showed that students who had used CAI tended to have positive attitudes towards it, although no significant differences were found between groups for studies that measured attitude. Nevertheless, two of the studies showing significantly better results for CAI compared traditional learning with CAI-augmented traditional learning. This does not prove that pure CAI is superior to traditional learning, but it provides evidence of benefits of the addition of eLearning to traditional learning (3). An important methodological flaw was also encountered whereby additional material was available to the eLearning group but not to the control group in five of the studies included in the present review (18–22).

Lewis et al. (1) reviewed 19 studies published between 1966 and 1998 assessing the effect of CBL on students' attitudes and found that 17 showed favourable results for CAL. Two studies examining satisfaction showed that CAL was better than conventional teaching. These findings are to a certain extent in contrast to what was found in the present review of non-networked CBL, where five out of nine studies favoured eLearning while two favoured traditional learning. Many of the studies included in Lewis' review had important design flaws which could potentially account for the difference in conclusions. Furthermore the review of Lewis et al. included studies with various study designs

published several decades before the studies included in the present review and therefore the reviews are not perfectly comparable (1).

A systematic review (4) of seven studies on blended learning for allied health, medicine and nursing students, published in 2012, reported that in all but one of the studies improvement in students' competencies, clinical skills, self-efficacy and clinical reasoning was seen when blended learning was used. This review included a very heterogeneous sample of studies with both network-based and non-networked computer-based blended learning. Some of the studies were controlled trials and some were not. Also, this review excluded all studies that did not report methods or results sufficiently or properly (4). The present review yielded a less positive conclusion, perhaps due to the fact that it employed a different design, where all studies were considered regardless of quality to assess the full body of evidence. Due to these important differences it is not surprising that different results were reached.

Findings from other reviews have generally suggested favourable results for non-networked CBL compared to conventional methods of instruction. Authors of these reviews have attributed these results to a number of factors. Lewis et al. (1) pointed out that computer-based learning provides students who have differing learning styles with alternative representations of knowledge and methods for assimilating this knowledge. Another advantage cited is that CBL enables students to learn at their own pace (5). This allows students to review the material multiple times versus the "one time only" exposure in the lecture hall.

Furthermore, non-networked computer-based modules can be used at any convenient time, at the student's own pace when he or she is free from distractions, alert and ready to learn (3,5). It was also suggested that positive attitudes developed towards non-networked CBL may increase motivation to learn and, as a result, may increase the amount of learning that takes place (3).

Contrary to these favourable findings, this systematic review, conducted using rigorous and thorough methodology, suggests that there is no difference between non-networked CBL and traditional learning. However, as some of the reviews discussed above also pointed out, several of the included studies investigating CBL employed methods that were not of high quality and some suffered from insufficient reporting that made assessment of methods and results difficult and sometimes infeasible.



## Internet and local area network-based eLearning

Currently the Internet is widely used in medical education (23). Within the first decade of the web's existence, 35 studies evaluating web-based eLearning were published (7). Internet and local area network-based eLearning can not only facilitate education at students' preferred place and time, but can also support instructional methods that might be difficult in other formats, and have the potential to customize learning to individual learners' needs (24–26). Therefore, It is not surprising that network-based eLearning has been so popular among the medical education interventions in the last decade (7,27). Several previous systematic reviews and two meta-analyses have compared the effectiveness of web-based education with traditional learning methods (7,8,10,13,27–29). A recent meta-analysis (7) on Internet-based learning in the health professions reported that Internet-based instruction was typically a substantial benefit for learner satisfaction and changes in knowledge, skills and behaviour compared with no intervention. However, there was substantial heterogeneity (I<sup>2</sup> = 93.6%) among the included studies, and the meta-analysis was unable to account for the complexity of interactions among the studies (7). Another meta-analysis of 266 studies comparing network-based eLearning to traditional or other educational methods by Cook et al. described the variation in configurations, instructional methods and presentation formats. It revealed that 24% of courses used blended network-based and non-computer-based instructions. The meta-analysis also showed that the Internet format was equivalent to non-Internet format in terms of learner satisfaction and changes in knowledge, skills and behaviour. However, the authors noticed a lack of valid statistically significant data confirming the advantages of network-based eLearning (11).

In this review, out of a total number of 98 reported comparison results among the 50 included studies on traditional learning versus eLearning, there were 22 comparison results (22%) in 18 different studies (36%) favouring eLearning over traditional learning (Table 4.1). Nevertheless, most of these studies had at least one risk-of-bias item rated as high risk. There were six comparisons (6%), in five different studies (10%) that favoured traditional learning, and four comparisons (4%) in three different studies (6%) that reported mixed results. Most of the comparisons reported a statistically insignificant difference between the two groups. Fifty-five comparison results (56%) that occurred in 37 different studies were statistically insignificant. The protocol design decision to include more balanced studies in terms of design, where eLearning was compared with another learning intervention

instead of nothing, seems to be justified by the fact that the present results are similar to those of Cook et al. 2010 (11) instead of Cook et al. 2008 (7).

There are several reviews in the literature assessing network-based eLearning in medical education (10,12–15,30). Each of these studies reported some methodological flaws, where the study quality could not be accessed or the statistical pooling was not explicitly stated. In the present review, similar problems were faced. Only one of the included studies was classified as being of high quality and had all risk-of-bias items classified as low risk (31), while many of the studies reported their educational outcomes comparison narratively, without reporting a statistical analysis of the results. Also, out of a total of 98 reported comparison results among the 50 traditional learning versus eLearning studies included, there were 12 comparison results (12%) in eight different studies (16%) that were not reported at all in the results sections of the articles (Table 4.1).

Integrating network-based eLearning interventions in medical education depends on their appropriateness and effectiveness. Cook noted that the appropriateness of web-based learning as a tool varies according to the instructional context and objectives. Web-based learning may be a good way to teach neuroanatomy but may be only moderately effective for teaching examination of the cranial nerves, and entirely ineffective for teaching a student how to tell a patient that he or she has cancer (25). Studies were found comparing network-based eLearning with various different interventions. Network-based eLearning has been assessed in comparison to course materials (32–34), practice guidelines (35,36), face-to-face lectures (37,38), workshops (39,40), self-guided slide shows (41) and small group sessions (42). This large variance in the instructional methods used (self-assessment questions, simulated patients, group sessions, etc.) made it quite difficult to assess which component of a network-based intervention produced the observed results. Hence, it is not possible to make a global statement comparing network-based eLearning to face-to-face or any other instructional medium.

Network-based eLearning has many advantages. Ubiquity is the fundamental feature separating network-based eLearning from other computer-assisted eLearning methods and enabling network-based eLearning to facilitate the teaching of students scattered across different practice sites in the same city (35), different cities (43) and even different countries (37,44). It can also offer flexibility in the timing of participation (45). In contrast to attending lectures given at fixed time, learners can access a network-based eLearning tutorial any time of the day or night. This way students are

provided with constant updates of content, individualized learning (16,46), novel instructional methods (47), automated assessment and documentation (35).

The present systematic review was designed and conducted using a thorough methodology. The results suggest that there may be no significant difference between network-based eLearning and traditional learning. Nevertheless, several of the included studies were not of the highest quality and, even more importantly, some of them suffered from insufficient reporting, making assessment of methods and results difficult and sometimes infeasible.

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# Practice and policy implications

The shortage of health-care workers at global level has forced educational institutions to turn to innovative ways of teaching and learning. One of the paths that shows the most promise is ICT which offers new modes of delivery of education – eLearning.

The potential seen in eLearning is high, especially since it may change the way we see education by:

- reducing the costs associated with delivering educational content;
- facilitating the development and scalability of educational interventions;
- breaking down the geographical and temporal barriers that limit access to, and availability of, education;
- improving access to relevant experts and novel curricula;
- allowing for personalization of eLearning based on learner behaviour;
- facilitating “immersive learning” through augmented reality and 3D learning environments;
- ubiquitous learning through mobile learning and cloud learning environments (1–4).

The strengths of eLearning as a new educational tool have already been recognized by policy-makers and relevant stakeholders in many countries, as well as by international organizations such as WHO, UNESCO and UNICEF (5–7). Recently, the USA’s Department of State launched a new initiative, a MOOC Camp, to host facilitated discussions on massive open online courses around the world (8). The World Bank has also shown a keen interest in eLearning and has become one of partners of Coursera (9), an education company partnered with a growing number of internationally renowned universities which have begun offering their courses online. Correspondingly, EdX is now offering MOOCs and online classes from world-class universities such as Harvard, Berkeley and Massachusetts

Institute of Technology (10). However, these examples of major international policy-makers showing a strong interest in eLearning is only the tip of the iceberg. For instance, the eGranary platform offers a digital library with over 30 million Internet resources to institutions that lack adequate Internet access. It is installed in more than 650 schools, clinics and universities in Africa as well as in Bangladesh, Haiti, India and other locations, using a basic software technology (11). On a local level, Village Telco in South Africa creates VoIP local networks through analogue lines (12).

Thus, eLearning forms a bridge between national and international policy, research and business. Policy-makers and those who deal with education in practice should therefore look at eLearning not only as a tool that may help bridge the health workforce gap, but also as an instrument of partnership. Moreover, active involvement and collaboration of all stakeholders is important to minimize the potential adverse effect of the shift from traditional learning to eLearning. Building on international and national clustered institutional partnerships could prove prudent since it would enable better and more efficient allocation of resources and expertise.

However, to achieve this there must be careful consideration of the implementation of eLearning, as well as of the advantages and disadvantages of eLearning compared to traditional learning methods, the characteristics of the adopting institution, country-specific health system needs and cultural considerations. The critical success factors identified in this review (see Chapter 6) highlight the elements that “must be done correctly” for a successful implementation and adoption process (13). The functionality of the technological infrastructure, support services for students and staff, institutional support, and policies to facilitate eLearning are critical to the success of the eLearning implementation and adoption process.

This systematic literature search has highlighted the main factors that contributed to, and hindered, the implementation of eLearning within an educational setting. Key strategies for the equitable and effective introduction of eLearning were provided, including:

- implementing a systems approach to allow for a holistic analysis of the implementation and adoption process in diverse contexts and settings;
- building eLearning into the workforce through the appointment of eLearning champions and learning technologists, and the provision of professional development opportunities;
- ensuring ownership of, and responsibility for, eLearning innovations, providing a coordinated approach for decision-making at all levels of the institution;
- maximizing technology with the existing infrastructure and building on institutional strengths when implementing eLearning interventions;
- introducing policies at institutional, regional and national levels to ensure accessibility to eLearning platforms and broadband connectivity as well as policies to promote the eLearning in diverse contexts to ensure equitable distribution and availability.

It is important to remember that many eLearning interventions begin in a bottom-up fashion, largely in the periphery of the university setting through implementation of new techniques and teaching methods by individuals and eLearning champions (14). However, in order for eLearning to be formally institutionalized within a university setting, organizations must consider the best approach for incorporating eLearning into existing structures, systems and culture. They often adopt top-down processes to introduce eLearning on a larger scale. This task is often difficult and time-consuming, and failure is common. Findings from early eLearning introduction studies confirm that focusing too much on the technological aspects of change will result in failure if pedagogical and organizational changes are not made simultaneously to accommodate the transformation (6). However, no two universities are the same, and careful consideration of contextual variables is necessary to ensure that the change processes applied within a university are closely aligned with the institution's goals and priorities.

The findings of this report have shown that eLearning can be as effective as traditional learning. This presents a potential incentive for policy-makers to encourage the development of eLearning and for teachers to see eLearning as a new tool that can add to the quality and variety of

their academic endeavours. The evidence presented in this report also shows the potential of eLearning in developing countries where problems of workforce shortages are most apparent. Even without Internet connectivity, computer-based learning can help those in remote locations to access knowledge which they would otherwise struggle to find.

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# Gaps in the available evidence and recommendations for future research

This report contributes to the evidence base for assessing the scope for, and potential impact of, eLearning in undergraduate health professional education and training.

The research available to date has tended to focus on educational institutions in high-income countries rather than in low- and middle- income countries (as defined by the World Bank). None of the included studies from the WHO African Region and Eastern Mediterranean Region were eligible for inclusion in the investigation of the impact of eLearning interventions on the specified outcomes. Although most results of the systematic review are generalizable to other WHO regions, important differences in addressing the needs and challenges facing these populations may have been encountered. The potentially different educational background of students from these regions may also result in differences in their perception and experience of eLearning, and therefore may have an impact on the effectiveness of eLearning. An appropriate suggestion for further research would be to assess the outcomes of eLearning in health-care education and training specifically in these regions.

All included studies took place in university settings with little investigation into the impact of eLearning interventions in vocational-based learning environments or rural communities. There was a clear lack of included studies from outside the field of medicine (such as dentistry or nursing), with none of the studies looking at the effects of eLearning in other health-allied professions such as medical health assistants or community health assistants. These roles have become increasingly prevalent in the health systems of low-income, middle-income and high-income countries. Because shortages of staff also occur in health-allied professions, studies focusing on these professions should also be conducted.

The included studies also had some limitations that did not allow a more in-depth evaluation to be made of the available evidence. For example, the learning material was not always described in depth, nor was access to it generally provided, which prevented assessment of whether

the learning material was sufficiently flexible to cater for the different needs of different types of students (such as students with different learning styles and background knowledge). Future studies should therefore provide more insight into the learning material that being evaluated and should ideally provide access to it.

As in the case of the study prepared by Cook and colleagues (1), the general methodological quality of the studies included in the systematic review was quite low, with most studies being classified as having a high risk of bias, and particularly attrition bias. Interventions varied widely in their approach, contributing to a large heterogeneity in both the non-networked computer-based and network-based research themes.

The existing evidence has yet to show the different contributions of eLearning as part of the educational curriculum and educational system, as part of a module or as a replacement for one, or as part of a blended learning arrangement or as a standalone intervention. However, the scope of this report does not allow for a more detailed investigation into the mode of delivery. Particular elements of eLearning may be more effective than others, or only in some settings, and additional research would be beneficial in exploring these characteristics, including the different types of intervention and the methods used to deliver them. To facilitate the latter, future studies should also report on the educational environment and the culture in which the intervention took place. These were rarely described in the studies included in the review. Whether or not the educational institution supported the delivery of an eLearning intervention, and if so how, was therefore not clear. The capability of an institution to develop sustainably, deploy and support eLearning can affect the impact of the intervention and is therefore relevant to report on.

The available explorations of eLearning have focused upon the efficacy of the intervention, mainly through administering tests close to the end of the intervention (i.e. post-tests). Future studies should include both pre-tests and post-tests in order to assess the effect of eLearning on

knowledge and skills accurately. In addition, future studies should also evaluate the impact of eLearning on long-term retention of knowledge and skills by following up with students at several intervals after the completion of the trial.

Perhaps the most important omission in the available evidence so far is the lack of cost-effectiveness studies and lack of reporting of economic considerations in the comparisons of eLearning interventions - including production costs and energy usage. Also, little information has been reported on the design and development of the eLearning intervention in the study, including the timescale needed to implement it.

Addressing these points would be advantageous to the implementation of eLearning interventions, not only in undergraduate health-care teaching but also post-registration practice within continued professional development, and to the sustainability of eLearning in the future.

Overall, eLearning technology should not be just another medium for the delivery of undergraduate health professional education. Rather, it should facilitate wider change in health professional training - in the amount of information that could be delivered and the number of people these methods could reach in order to increase both the quantity and quality of education. Although many

studies have been conducted to investigate non-networked computer-based and Internet and local area network-based eLearning, several of these studies suffer from methodological problems and are therefore not indicative of the true effect of eLearning. An analysis including only studies of high quality and those with only minor problems is likely to give a better indication of whether there is a true difference between eLearning and traditional learning. However, such an analysis would have restricted the scope of the current review unacceptably as only few of the published studies meet these criteria.

Future studies should be carefully designed to avoid caveats such as contamination, high attrition rates and volunteer bias. A reporting protocol specific to the field of eLearning interventions is also needed. It is the only way to support research that aims to determine which factors affect the effectiveness of an eLearning intervention.

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# Formative work on eLearning and blended learning

## eLearning

In recent years higher education providers have had to cope with increasing demand for access to education and changes in the workforce needs of specific industries (1,2). Traditional ways of delivering education are not adaptable enough to satisfy these demands; as a result of this, education providers have started implementing eLearning interventions (1).

The use of eLearning presents many opportunities for higher education providers including reduction of the costs associated with delivery of educational outcomes (1), improving scalability of educational developments (2), increasing access to and availability of education by breaking down geographical and temporal barriers, and allowing access to relevant experts and novel curricula (3).

In order to understand the potential impact of eLearning interventions on learning we need to: (i) provide a clear definition of eLearning, and (ii) identify its scope. In practice, however, there is not a single definition of eLearning due to the multidisciplinary nature of this field. Definitions include those focusing on access to learning resources (4), those focusing on time, motivation, knowledge and teaching (5), and those that focus on the technological aspects of the interventions (6,7).

In an effort to reach consensus, Jisc (formerly known as Joint Information Systems Committee), a higher education research committee on ICT in education in the United Kingdom, has proposed the following definition (8):

“E-learning can be defined as ‘learning facilitated and supported through the use of information and communications technology’. It can cover a spectrum of activities from the use of technology to support learning as part of a ‘blended’ approach (a combination of traditional and e-learning approaches), to learning that is delivered entirely online. Whatever the technology, however, learning is the vital element.”

In a similar effort, Sangra and colleagues (9) have employed Delphi techniques to reach the following definition:

“E-learning is an approach to teaching and learning, representing all or part of the educational model applied, that is based on the use of electronic media and devices as tools for improving access to training, communication and interaction and that facilitates the adoption of new ways of understanding and developing learning.”

This last definition identifies the key features of eLearning, including pedagogy, delivery approach of learning, interactivity and delivery, and technological realization of eLearning delivery and has therefore been used to frame the discussion in this report relating to the evaluation of educational interventions.

## Pedagogical principles in eLearning

Pedagogy is the science and art of teaching. By adopting existing pedagogical principles, eLearning interventions could be used to engage learners effectively and facilitate the acquisition of knowledge, skills, and attitudes (10) in a rich and complex learning process (11).

The relationship between technology, pedagogy and content knowledge (12) is key to the successful delivery of educational outcomes using technology. In eLearning, however, the focus is often placed on the use of educational technology rather than on the application of educational technology to the process of teaching and learning (13). By failing to consider pedagogical principles in the design of educational interventions, eLearning is simply the use of technology to deliver educational content (12,13) rather than an approach to learning (9).

The application of pedagogy to eLearning and blended learning environments is considered in more detail below.



## Delivery approach of eLearning

An important feature of the definition proposed by Sangra and colleagues (9) relates to the fact that eLearning may represent all or part of the delivery of the educational objectives. In this context, as proposed by Bates and Poole (14), eLearning lies on a continuum from full eLearning to the face-to-face traditional classroom environment with various degrees of eLearning activities between these two modalities. Any activity on this spectrum, other than traditional learning, can be included in this definition of eLearning. Therefore, the delivery approach of learning can be traditional, full eLearning or blended learning.

Traditional learning is any learning activity that (i) is undertaken in the traditional classroom environment, (ii) is typically co-located, and (iii) involves face-to-face instruction and practical work. However, it is important to note that traditional learning may sometimes incorporate the use of technology to reinforce this co-located classroom learning, but not as an essential part of knowledge construction.

In contrast, a full or complete eLearning approach is defined as learning with no face-to-face component, that relies entirely on the use of eLearning technology and methods for the delivery of learning. Full eLearning can be distributed geographically and/or temporally, and communication between student and teacher is handled electronically.

A blended approach is a mix of the traditional and online methodologies where some of the learning that is required to achieve a learning objective is undertaken in the traditional classroom environment but the use of eLearning technologies and methods is also applied to the learning that is undertaken. This delivery approach is discussed in further detail in the following section.

## Interactivity and delivery mode

eLearning activities are those activities that contribute wholly or partially to the achievement of a learning objective. A learning objective may consist of several activities using a variety of delivery approaches (full, blended or traditional). Paulsen (15) proposes that eLearning activities be classified according to their level of interactivity. Thus, eLearning activities can be classified into:

- many-to-many: group discussions, debates, games and simulations, webinars, group chat sessions;
- one-to-many: synchronous lectures, questions and answers (Q&A) sessions;
- one-to-one: joint assignments, online tutoring, online chat; and
- one-alone: learner interacts only with technology.

Additionally, eLearning activities may be delivered synchronously or asynchronously:

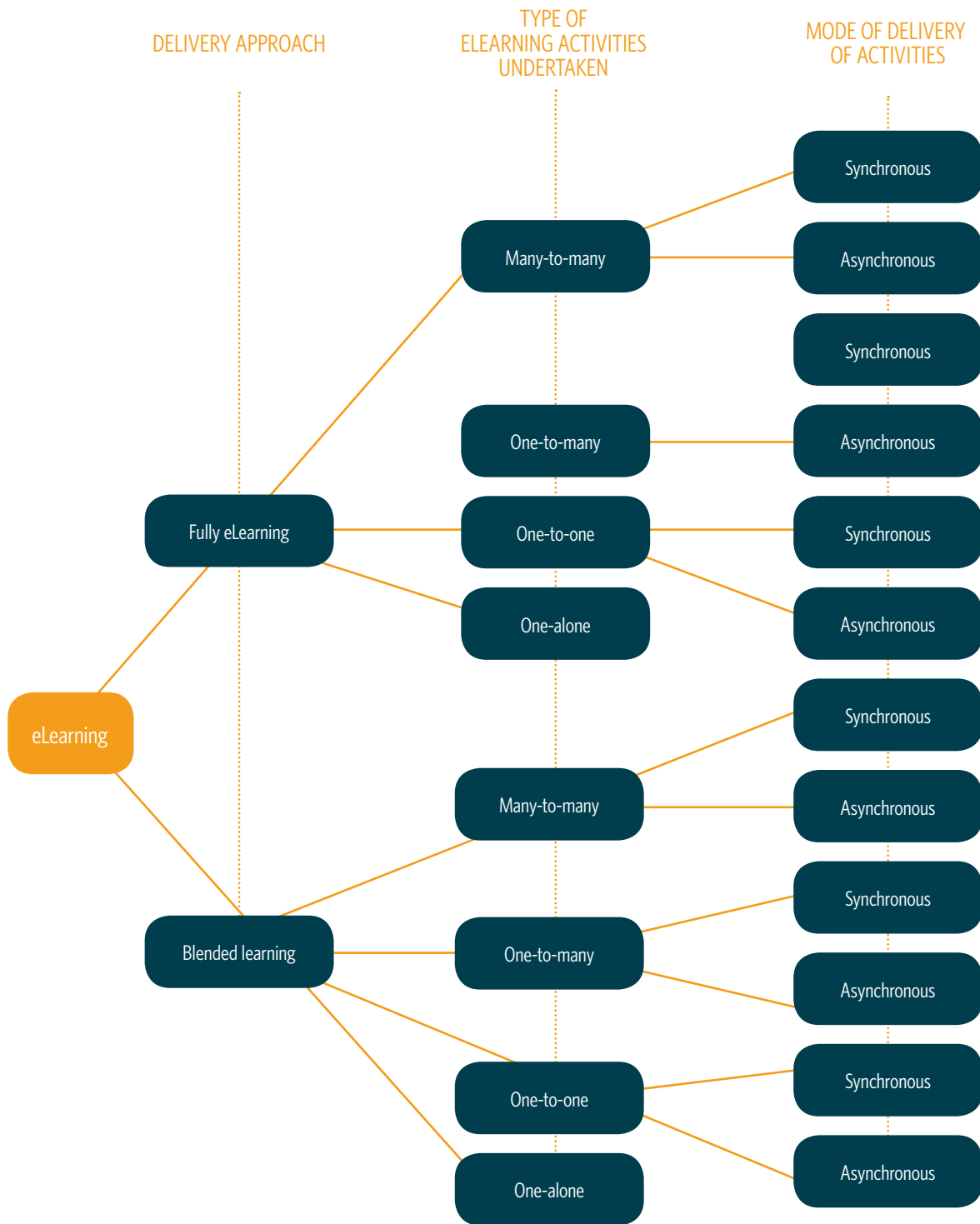
- Synchronous activities are activities occurring at the same time. The learner(s) and teacher(s) interact and communicate in real time to achieve a predefined learning objective, and are supported by a range of technologies.
- Asynchronous activities are activities that do not occur in real time. Communication and interaction are supported by using technologies such as email and forums.
- The latter can be used in conjunction with Paulsen's taxonomy<sup>15</sup> in order to classify eLearning activities (see Figure A1.1).

## Technological realization of eLearning delivery

The scope and applications of eLearning are closely linked to the capabilities afforded by ICT, which allow new possibilities for facilitating and supporting the learning process (16). Thus the evolution of ICT can help us to understand the ways in which eLearning can support both teachers and learners.

Many of the essential elements of what we now call eLearning have been evident in higher education since the early 1980s when the first computers became a financially viable option for these institutions (17). At that time computers were not commonly found in homes, and students were typically learning in classrooms and laboratories. The first courseware was proprietary and was often developed by IT or subject- area enthusiasts.<sup>16</sup> This courseware was loaded to dedicated computers, usually located in classrooms and laboratories (18).

Figure A1.1. Characteristics of eLearning



As the processing power of computers increased, commercial and increasingly user-friendly software was developed. PCs with CD-ROMs became widely adopted, enabling the use of the CD-ROM as an effective delivery channel for educational material. This was initially implemented on individual machines, evolving to the client-server model still in use today, to support learning in Intranet environments where external internet access was not a possibility.

In the 1990s, coinciding with the increasing availability of web technology, the first LMS and online training courses were implemented. Early web technology, or Web 1.0, was typically read-only or static (19), allowing for monodirectional delivery of information. eLearning technology became able to support asynchronous communication using email or basic discussion functionality, thus enabling the uploading of prerecorded lectures and text content.

### Ubiquitous learning: enabling mobile learning and Cloud Learning Environments (CLEs)

Despite the rapid growth in learning technology in recent years, educators in rural and/or developing areas may have access only to the most basic, early generations of technology compared to that widely adopted in developed countries (22). The implications of this and other factors relating to the adoption of eLearning in developing countries are considered in more detail below.

### EVALUATING EDUCATIONAL INTERVENTIONS

Educational interventions are designed to meet predefined learning outcome(s) and there are many indicators which affect their success or failure. Evaluation seeks to identify the aspect(s) of intervention delivery that could significantly predict the achievement of learning outcomes. Using eLearning to deliver interventions differs from traditional face-to-face classroom teaching in many ways. It is necessary to identify the differences between delivery approaches and how they can affect learning outcomes. Therefore, it is also necessary to adopt a framework that allows for the identification and evaluation of the specific aspects of intervention delivery that can influence the eventual success of an eLearning intervention, such as curriculum integration, resource availability, and institutional and student readiness (see Figure A.1.2) (11,12). Kirkpatrick's evaluation framework (10) has been widely adopted for the evaluation of outcomes of educational interventions in the context of health-care workforce training. This model identifies four levels of evaluation:

Reaction: perceived outcomes include satisfaction scores and perceptions and reaction to the eLearning experience.

Learning: intellectual outcomes resulting in the acquisition of new knowledge or skills. Outcomes can be classified as cognitive, affective or psychomotor (23) and are generally linked to the learning objectives of the educational intervention.

Behaviour: outcomes related to changes in work-related attitudes or behaviours.

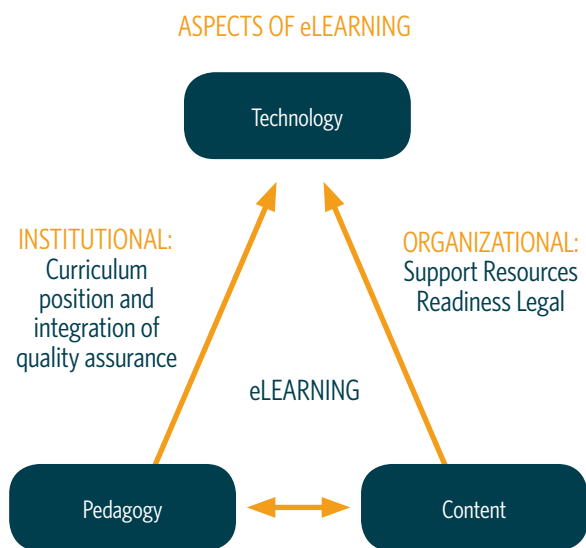
Results: long-term workforce results.

Therefore, Kirkpatrick's framework offers insight into the effectiveness of different delivery modalities of learning intervention at a high level (24).

Further analysis could be undertaken to identify the significant factors in the achievement of outcomes to provide a detailed understanding of all aspects of eLearning delivery.

For the framework adopted for the purposes of this report, see Chapter 1.

Figure A.1.2. Defining the context and inputs



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## Blended learning

Sharpe and colleagues (1) first suggested the use of the term “blended learning”, highlighting its acceptance in higher education. As with the eLearning literature, a large number of blended learning definitions, and variations in blends, have been discussed (2,3). The majority of these definitions focus on the combination of eLearning technology and methods with traditional face-to-face instructor-led teaching (1,4,5). Some definitions, however, move away from the application of technology in education and focus more on pedagogical<sup>6</sup> and/or design principles (7,8).

“Flipping the classroom” is another model that has gained ground in recent years. It refers to making class time more engaging and student-centred, leaving course-related materials as homework (9,10). It has been argued that flipping the classroom is not a new instructional technique since in traditional class-based learning teachers expect students to prepare before class. However, the advances in instructional technology make a big difference in the way students can prepare before class through technology-enhanced learning (11). As Papert (12) said, the computer is the Proteus of the machines: it is flexible, it adapts to different learning styles and levels of learning offering powerful ubiquitous access.

Several authors (13–17) have highlighted the suitability of blended learning for health-care training due to the need to combine hands-on skills-based training at practical level, as well as self-directed learning.

### Blended learning design

The steps followed in the design of blended learning programmes are vary varied. Some authors focus the design on a combination of different media, instructional methods and web-based technologies (2). Others also emphasize the combination of various delivery modalities (off-line, web-based and self-guided) (14,18).

Alebaikan & Troudi (19) point out that a programme should be blended in design and not just in delivery. They highlight the lack of guidelines and design frameworks to help support and simplify the task of implementing blended learning. A good pedagogical design must ensure that there is “constructive alignment” or no inconsistencies between the intended curriculum, the teaching methods, the learning environment and the assessments methods implemented (23).

Mayes & de Freitas (24) emphasize the importance of carefully selecting the learning outcomes followed by the selection of learning and teaching activities in addition to

assessment methods in order to accomplish the intended learning outcomes.

### Pedagogical principles in blended learning

Designing for learning is a complex task which requires a holistic approach. According to Mayes & de Freitas (24), the implementation of blended learning should consider learning at three different levels: as behaviour, as construction of knowledge, and as a social practice.

The behaviourist learning theory (25,26) suggests that we learn by receiving a stimulus that consequently produces a response. It therefore concentrates on low-level cognitive tasks or psychomotor skill learning (27). According to Mayes & de Freitas (24), behaviourism focuses on a detailed analysis of the intended learning outcomes aligned to assessment, emphasizing active learning-by-doing reinforcing feedback. Self-guided online learning activities generally follow a drill-and-practice approach based on task analysis. The learning activities used encourage the repeated application of a series of similar tasks which drive learners to automate skills. According to Horton (28), drill-and-practice activities are useful when learners need to learn automated procedures that must be performed and applied without much conscious thought as part of higher-level activities (28).

In contrast to the behaviourists’ approach, the cognitivists focus their attention on how students gain and organize their knowledge (27). Piaget (29) and his constructionism theory of knowledge has been particularly influential with his assumption that conceptual understanding can be reached through intellectual activity rather than by merely absorbing information. The cognitive perspective emphasizes the process of reaching “understanding” through an active process of creating hypothesis, application of knowledge and reflection (30).

Collaborative learning focuses on the importance of discussion and reflection as part of the process of learning. Social constructivism is largely attributed to the work of Vygotsky (31) and Wertsch (32). Mayes & de Freitas (24) emphasize the similarities of the behaviourist tradition based on learning-by-doing and the importance of feedback with the constructivist approach. Constructionism seems to have developed not so much in the Piagetian sense as a reaction to the behaviourist/ instructionist bottom-up approach but as a reaction to the traditional transmission of information in a didactic way.

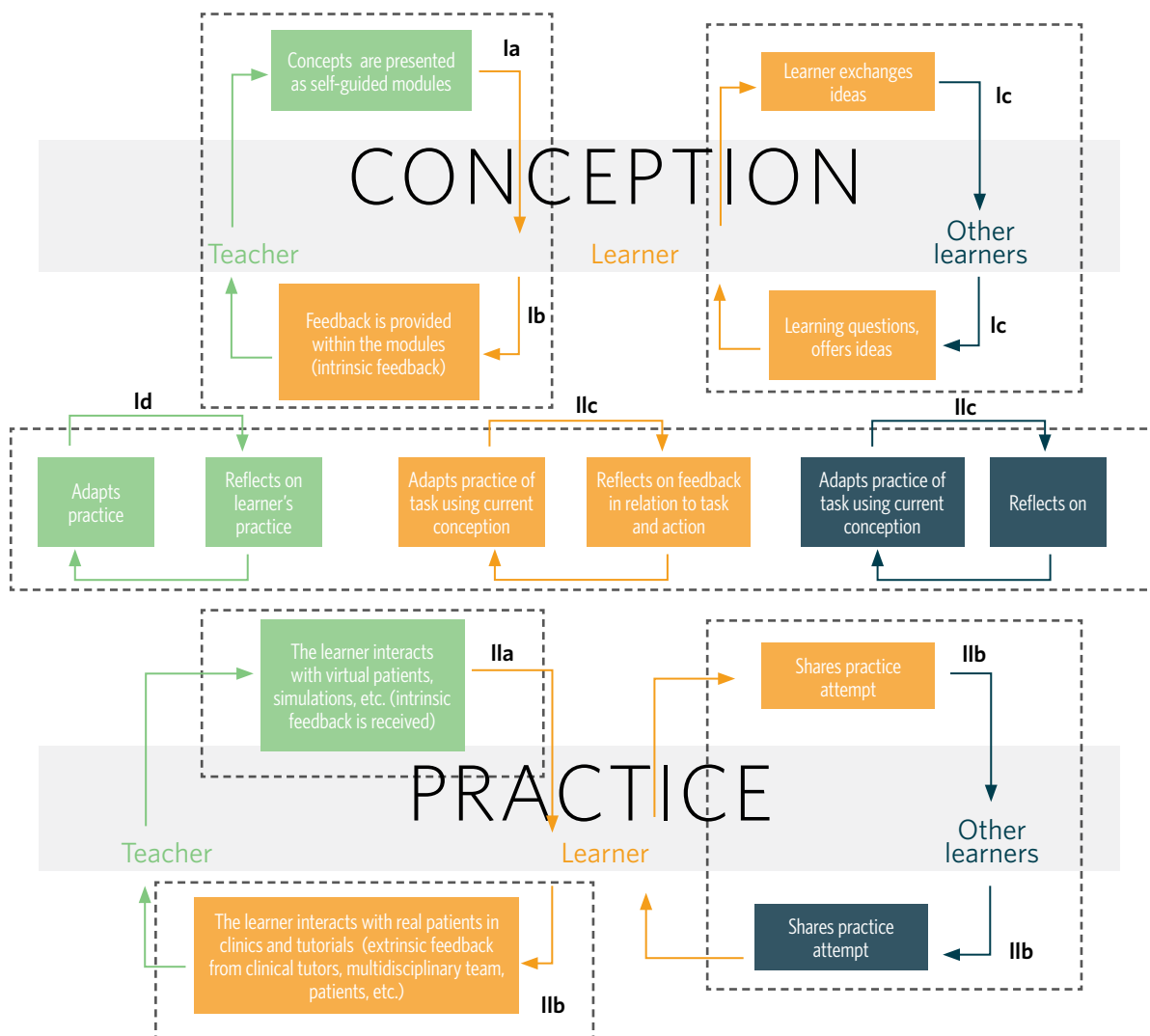
Laurillard’s conversational framework (33,34) integrates the theories discussed so far. According to the conversational framework (34), learners need interaction with their teachers,

their own practice and their peers at two different levels: conceptual and practical. The former allows the discussion and articulation of theory, ideas and forms of representation. The practical level allows experimentation and practice on goal-oriented tasks. These two levels must be connected for learning to take place, and it is where the adaptive and reflective aspects of the learning activity are found. Actions are adapted in the light of understanding, and reflection on practice informs theory and/or concept development.

Laurillard (34) emphasizes the need to provide extrinsic and intrinsic feedback. Extrinsic feedback is that received directly by teachers, peers and patients, which guides learners on their progress. Intrinsic feedback is embedded in the interaction with different tasks, which inform the learner how close he/she is to the goal. Laurillard's

framework has been used to conceptualize the use of different theories of learning within a blended learning approach for medical education (35). It is based on Pask's analysis of learning as a form of conversation. Figure A.1.3 shows an adaptation of the conversational framework (34) based on the delivery of medical education following a blended learning approach. It highlights the introduction of self-directed learning (conceptual) as well as hands-on skills-based training (practical) showing several interactions between the learner, tutors, patients, health-care team, and the learner's own practice and peers (35). The dotted lines in Figure A.1.3 also highlight the prevalence of some of learning theories discussed in the content of the conversational framework (34).

**Figure A.1.3. Conversational framework applied to the delivery of medical education based on a blended learning approach.**



Source: Adapted from Laurillard (34).

## Blended learning design and learning outcomes

The different learning theories underpinning the development of blended learning activities have been discussed and conceptualized within the conversational framework (34). However, when it comes to the identification of the actual “blend” of online versus face-to-face activities, it is necessary to focus on the intended learning outcomes. Bloom’s taxonomy (38) has been used as a general system for the classification of learning outcomes. It was originally developed to classify questions used in assessment under different levels of complexity.

Different levels or domains have been discussed by different theorists. The cognitive domain includes basic cognitive competences such as knowledge, comprehension, application, analysis, synthesis and evaluation (38). The

psychomotor domain focuses on manual and physical skills, and has been discussed by Dave (39), while the affective domain focuses on attitude (40). Adaptations of these frameworks (39–41) have been proposed for learning activities that focus on each of these domains (see Tables 1–3).

Learning outcomes should be clearly identified before selecting tools that facilitate their achievement (15). The verbs from Bloom’s taxonomy (Table A.1.1) can assist practitioners in the design process. However, in practice, “constructive alignment” is usually carried out after teaching decisions have been made (24). This highlights the importance of having systematic and easy-to-use frameworks to assist the process of identifying the learning and teaching activities that best fit the intended learning outcomes.

**Table A.1.1. Adaptation of Bloom’s taxonomy for learning activities that focus on knowledge development (cognitive domain)**

Cognitive domain	Description: descriptive verbs
Factual knowledge	Essential facts, terminology or elements that learners must be familiar with in order to understand a discipline: retrieving, recalling, or recognising.
Procedural knowledge	Knowledge that helps learners to perform something specific to a discipline or subject. It refers to methods of enquiry, techniques, and particular methodologies: distinguishing, differentiating, organising, executing, implementing.
Conceptual knowledge	Knowledge of classification, principles, models, structures related to a discipline: explaining, interpreting, classifying, summarising, inferring, comparing.
Metacognitive knowledge	Level of reflective knowledge gained which allows learners to solve problems and cognitive tasks: assessing, critiquing, reorganising, generating, planning, and producing.

**Table A.1.2. Classification of learning activities that focus on the development of attitudes (40)**

Affective domain	Description
Receiving phenomena	Awareness and willingness to hear or listen to others with respect.
Responding to phenomena	Being active to the stimuli or phenomena. In this case the learning outcome may emphasise the willingness to respond or the satisfaction in responding.
Valuing	The value that a person attaches to a particular object, activity or behaviour.
Organisation	Comparing, relating and synthesising values.
Internalising values	The behaviour of the learners that focuses on consistency and predictability.

**Table A.1.3. Classification of learning activities that focus on the development of skills (39)**

Psychomotor domain	Description: descriptive verbs
Imitation	Observing and replicating behaviour after someone else.
Manipulation	Being able to perform a certain number of actions by following instructions and practicing.
Precision	Becoming more effective and refining the activity with few errors.
Articulation	Being able to coordinate a series of actions in a consistent and harmonious way.
Naturalisation	Being able to perform the activity naturally, having a high level of performance.

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## eLearning and blended learning for undergraduate health professional education in developing countries

Developing countries are undergoing a rapid epidemiological transition. While infectious diseases remain the major cause of death, development, industrialization, urbanization, investment and ageing are drivers of an epidemic of noncommunicable diseases (1). It is predicted that, by 2020, noncommunicable diseases will cause seven out of every 10 deaths in developing countries (2). Moreover, developing countries are largely unprepared to cope; they lack the necessary funds, technology, infrastructure and trained health workers that are needed to provide basic health-care services (3).

Health workers are fundamental in ensuring equitable access to health services and achieving universal health coverage. Many countries continue to experience a severe health workforce shortage due to a lack of adequate training and the impact of migration. As identified by the World health report prepared in 2006, 57 countries face critical health workforce shortages (4). WHO estimates that 2.4 million physicians, nurses and midwives and 1.9 million health aid workers, pharmacists, technicians and auxiliary personnel are needed to meet the Millennium Development Goals (MDGs) set for 2015. eLearning could help tackle the estimated 4.3 million global shortage in health workers, whose ranks must be increased sufficiently if the MDGs are to be achieved (5).

### Delivering eLearning in developing countries

Rapid technological advancement coupled with the growth of the Internet has made a significant impact on how knowledge transfer and learning are conducted (6). eLearning has started to make headway in developing countries and is believed to have huge potential for governments struggling to meet a growing demand for education while facing an escalating shortage of teachers (7). International organizations such as the United Nations and WHO have acknowledged eLearning as a useful tool in addressing educational needs in the health-care sector in developing countries, while the MDGs have articulated the significance of the use of ICT to address education and health problems in developing countries (8,9).

These views have also been reflected in literature. According to Barry (10) increasing Internet access in developing countries can save lives and revolutionize health-care quality for a major proportion of the world's populations. However, access to technology has been identified as a

major challenge for the implementation of technology-enhanced teaching in developing countries (11).

In order to access online learning materials, individuals need access to a PC or a smart device (tablet or phone), as well as access to the Internet. According to the International Telecommunication Union (12), 2.7 billion people are using the Internet, which corresponds to 39% of the world's population. In developing countries only 31% of the population is online compared to 77% in developed countries.

Today, 90% of the 1.1 billion households not connected to the Internet are in developing countries. However, in 2013, mobile-broadband subscriptions increased from 472 million in 2011 to 1.16 billion in developing countries. Africa has shown the highest growth rates (from 2% in 2010 to 11% in 2013) (12), which indicates the potential for mLearning in developing countries. There is increasing evidence of effective use of eLearning in health-care education in developing countries (13,14). In a recent study by Safie and colleagues (6), a survey was conducted among United Nations University - International Institute for Global Health (UNU- IIGH) learners in order to understand the utilization of eLearning in health-care learning and knowledge transfer, focusing especially on developing countries. The study showed that 77% of learners were from the health-care workforce in developing countries, with 44% from Asia and 25.6% from the African Region. A recent review of literature prepared by Frehywot and colleagues (15) showed that low- and middle-income countries such as Brazil (5), Egypt (15), India (5) and South Africa (15) have published the most content on eLearning in medical education. The majority of the literature from these countries has focused on physician training (63%) and a small portion (5%) focused on postgraduate medical education.

In terms of the eLearning approaches that were described in the same literature review (15), blended educational approaches were most common; 49 articles presented various formal blended learning approaches. Computer-assisted learning (CAL) accounted for the majority of the blended learning approaches (45 articles). Three articles presented e-resources such as the eGranary Digital Library. Of the relevant 38 pure eLearning articles found (i.e. eLearning used not in conjunction with other traditional techniques), the most commonly highlighted were simulations and the use of multimedia software (20 articles), web-based learning (14 articles) and eTutor/eMentor programmes (three articles).

## Cost of eLearning technology and platforms

Technology-mediated learning can provide cost savings for both learners and providers. Technologies used in eLearning can vary from a simple audio tape or a DVD to sophisticated multipoint videoconferencing facilities supported by simulation and online applications (16).

Many eLearning platforms (both LMS and LCMS) currently available are based on either proprietary eLearning software (PES) or open source eLearning software (OSS). OSS usage in implementing eLearning systems is emphasized more in developing countries due to the challenges faced when implementing the PES. Bygbjerg (1) describes two characteristics of PES that make it ill-suited for use in developing countries. First, the rapidly escalating cost of proprietary software leaves too little of an institution's ICT budget available for creative exploration once the software has been installed and minimally supported (2). Second, reduced flexibility to adapt to institutional culture, teaching practices and disciplinary uniqueness occurs when software development is driven by mass-market economics (17).

OSS offers the potential to reduce the cost of the software while providing a university with greater control over its destiny. Elimination or reduction of licensing leaves more budgets available to invest in adapting and managing the software. OSS offers reliability, performance and security over proprietary software due to the availability of the source code, which allows vulnerabilities to be identified and resolved by third parties and is easy to customize. Some of the most widely used OSS programs are Claroline and Moodle (17).

## eLearning and blended learning initiatives

Several initiatives led by key Internet players such as Facebook, Google, Wikipedia and others are currently taking place. These initiatives could eventually have a significant impact in the way online health education is delivered. In August 2013 Facebook announced the project Internet.org in partnership with some of the biggest social media and mobile delivery companies to cut the cost of delivering basic Internet services on mobile telephones, especially in developing countries (18).

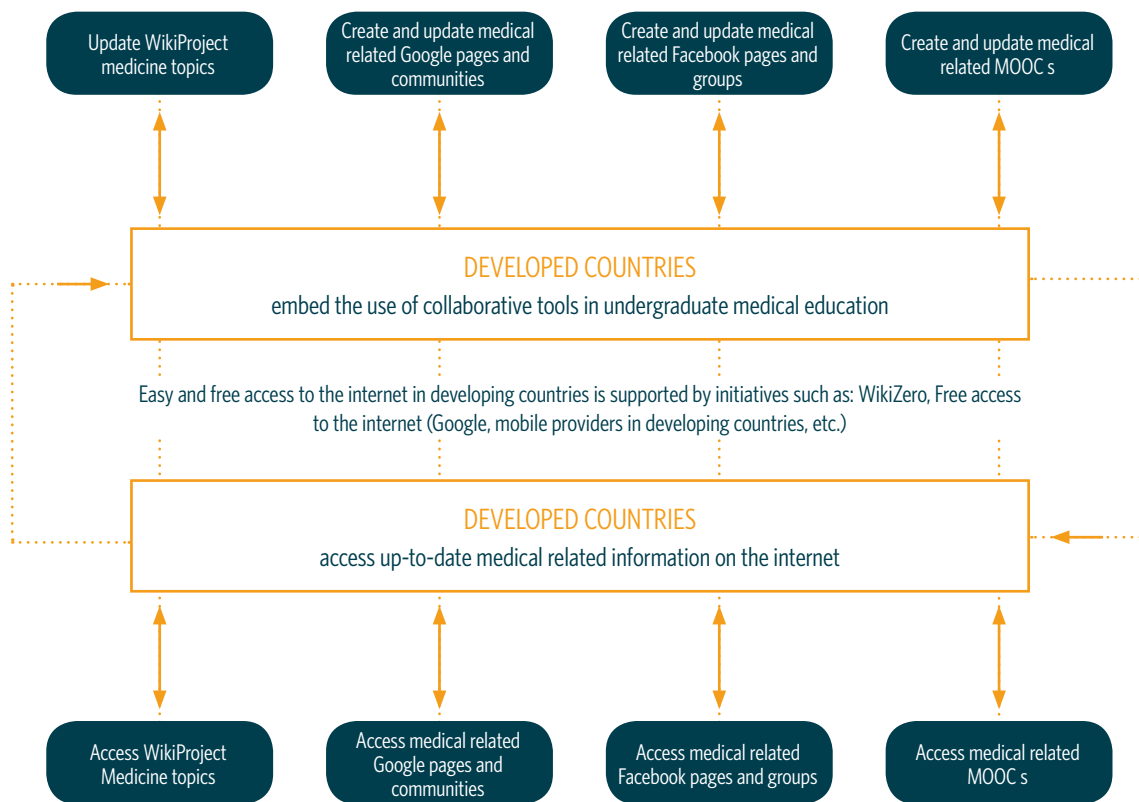
Similarly, Wikipedia Zero has been setup by Wikimedia Foundation to enable free mobile access to Wikipedia content in developing countries (19). WikiProject Medicine (20) is another Wikipedia initiative aimed at quality control of health-related content on Wikipedia. Health related content on Wikipedia currently accounts for some 25 000 articles in English accessed about 200 million times a month, making it the most popular health-content website in the world (21).

MOOCs have been recognized as potentially powerful tools in developing countries (22). Some of the main MOOC providers in the USA such as Coursera, EdX and Udacity, and FutureLearn in the United Kingdom are already playing a key role in the development and support of world health education. Access to MOOCs could also be harnessed by the use of distribution networks such as Facebook. Matt Perault, head of global policy development for Facebook, has mentioned how Facebook could partner with MOOC providers to bridge the gap between MOOC's content in remote communities in developing nations (23).

The design of blended learning programmes in medical education may include the use of some of the tools provided by the organizations mentioned above, with the aim of maintaining online health-related content and keeping it up to date. For instance, the School of Medicine at the University of California is offering a month elective for fourth-year undergraduate medical students. The elective involves improving important medical topics selected by WikiProject Medicine (24).

Figure A.1.4 shows a blended learning model for the delivery of world health education in the 21st century. The model shows how developed countries may embed the use of Web 2.0 tools in undergraduate medical education - i.e. updating WikiProject Medicine topics, creating Google pages and communities, MOOCs etc. - in order to help health professionals in developing countries to access up-to-date medical-related information. The blended learning model also highlights the importance of supporting initiatives such as Internet.org that are focused on the development and expansion of Internet access in developing countries.

**Figure A.1.4.. A blended learning model for the delivery of online world health education in the 21st century**  
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# Systematic review methods

## Criteria for considering studies for this review

### Types of studies

We included parallel RCTs and cRCTs. We excluded any other type of study design.

### Types of participants

We included studies on participants enrolled in an undergraduate, health-related university degree course or a basic, health-related vocational training programme. We defined undergraduate education or basic vocational training as any type of study leading to a qualification that: (i) is recognized by the relevant governmental or professional bodies of the country where the studies were conducted, and (ii) entitles the qualification-holder to apply for entry-level positions in the health-care workforce. For this reason, graduate medical education courses from the USA were included in this systematic review.

We considered studies on candidates for the professions of medicine and dentistry. Professions that fell outside these fields were categorized under the umbrella term “medical allied professions”, which includes professions that provide assistance or expertise in the treatment of patients.

We excluded studies on participants studying for postgraduate and/or advanced specialist qualifications, i.e. any type of study or training listing a primary health science qualification as one of the entrance requirements. We also excluded studies on individuals undertaking studies in traditional and complementary medicine.

### Types of interventions

We included studies in which eLearning interventions were used to deliver the learning content of the course. These included studies in which eLearning methods were the sole means by which the intervention was delivered, or in which eLearning methods were part of a complex, multicomponent intervention.

We included only studies that compared eLearning methods to (i) traditional education, (ii) other forms of eLearning, or (iii) no intervention.

### Types of outcome measures

To be eligible for inclusion, studies had to report at least one of the following primary or secondary outcomes:

#### Primary outcomes

- students' knowledge, measured using any validated or non-validated instrument (e.g. pre-test and post-test scores, grades, perceived knowledge survey scores);
- students' skills, measured using any validated or non-validated instrument (e.g. pre-test and post-test scores, time to perform a procedure, number of errors made while performing a procedure, perceived up-skilling);
- students' attitudes, measured using any validated or non-validated instrument (e.g. self-efficacy, satisfaction, acceptability);
- student satisfaction with the eLearning intervention, measured using any validated or non-validated instruments (e.g. retention rates, drop-out rates, survey satisfaction scores).

#### Secondary outcomes

- health economic properties of the eLearning intervention (e.g. implementation cost, return on investment);
- adverse and/or unintended effects of eLearning.

We considered studies to have measured attitudes or satisfaction only if they met all of the following criteria: (i) they compared the differences between intervention and control groups for these outcomes, (ii) the content of the survey questionnaires related to the teaching method (i.e. eLearning method, blended learning or traditional learning),

and (iii) the adjectives used in the survey questionnaires accurately described attitudes and/or satisfaction.

## Search methods for identification of studies

### Electronic searches

A preliminary search of MEDSUM (1) using the keywords “eLearning” AND “health sciences” AND “education” retrieved only one record published before 2000. Therefore, we limited our electronic searches to records published on, or after, this year.

We searched MEDLINE (Ovid SP) using the search strategy outlined in Annex 3. We did not exclude studies on the basis of their original language of publication. We adapted this search strategy for use in Embase (Ovid SP), PsycINFO (Ovid SP), Cochrane Central Register of Controlled Trials (CENTRAL), Web of Science and Educational Resources Information Center (ERIC) (ProQuest).

We searched the electronic bibliographic databases during 16–20 August 2013. We documented the search results for each database and included them as Annex 4.

### Searching other resources

We checked the reference lists of the included studies and systematic reviews identified by our electronic searches for additional references. This allowed us to identify one thesis dissertation that was not identified by the electronic searches.

## Data collection and analysis

### Selection of studies

All the references identified by our search strategies were imported into EndNote X5 (2) and duplicated records were removed using the built-in function of this program. Additional duplicate records were identified during the screening of titles and abstracts and were removed from the EndNote library. Review authors examined the titles and abstracts and identified potential relevant studies. Subsequently, review authors screened the full-text reports of all potential relevant studies and assessed them against the inclusion criteria for this systematic review (See criteria for considering studies for this review). Review authors completed these tasks independently and met to compare their results and reach consensus. Any discrepancies between review authors were resolved through discussion; if no agreement could be reached, a third review author acted as an arbiter.

## Data extraction and management

Each selected study was allocated to a pair of review authors, with 10 review authors participating. Each review author independently extracted data from the included studies using the structured data extraction sheet shown in Annex 5. Each pair of reviewers then compared their completed data extraction forms and followed up any discrepancies with reference to the original publication. The large number of authors working on this resulted in some of the assessed categories being interpreted differently by some reviewers. Consequently, three reviewers went over the entire data extraction once again to ensure that the data extraction was done in a uniform way, and made amendments where necessary after consensus.

We contacted authors of studies containing incomplete data in order to request the missing information. Some authors did not reply to our request for additional information, while other authors could not provide the answers to our questions. For one study (3), however, the response obtained from the author resulted in the subsequent exclusion of the study from this systematic review.

## Assessment of risk of bias in included studies

We assessed the risk of bias for all included studies using the Cochrane Collaboration’s tool for assessing the risk of bias in RCTs (4). Therefore, we assessed the risk of bias across the following domains:

- random sequence generation
- allocation concealment
- blinding of participants and personnel
- blinding of outcome assessment
- incomplete outcome data
- selective outcome reporting
- other bias.

Other sources of bias included the comparability of intervention and control groups, characteristics at baseline, validation of outcome assessment tools, reliability of outcome measures, and protection against contamination. For all the included studies we attempted to locate the original study protocol or study registration record in order to compare the planned methods and outcomes against those that were reported in the final publication.

We assessed the risk of bias for cRCTs across the following domains (4):

- recruitment bias
- baseline imbalances
- loss of clusters
- incorrect analysis.

Two reviewers independently assigned each domain of each individual study to one of three categories: low, high or unclear risk of bias. For each study, we created a risk-of-bias table.

### Measures of treatment effect

We compared the characteristics of the included studies to determine the feasibility of conducting a meta-analysis. For dichotomous outcomes, we calculated the risk ratio (RR) and 95% confidence intervals (CI). For continuous outcomes, we calculated the mean difference (MD) and 95% CI. If studies used different measurement scales, we calculated the standardized mean difference (SMD).

### Dealing with missing data

As described earlier, we contacted the original authors to request missing data. Because this yielded insufficient information we used an available case analysis.

### Assessment of heterogeneity

We assessed heterogeneity in the results for the primary and secondary outcomes by qualitatively comparing the characteristics of the participants and of the interventions between the included studies. Because of the substantial clinical and methodological heterogeneity, we did not conduct a meta-analysis. For this reason, we did not use a statistical test to quantify heterogeneity.

### Assessment of reporting biases

To minimize language biases, we included studies published in any language. In order to minimize the risk of publication bias, we conducted a comprehensive search of multiple bibliographical databases.

### Data synthesis

Because conducting a meta-analysis was not appropriate, we performed a narrative summary (5) of the evidence. For this purpose, we adapted the narrative synthesis framework proposed by Rodgers and colleagues (6):

- grouping of studies by types of intervention;
- description of the PICO elements together with the findings for each included study;

- exploring (i) the relationship between the characteristics of each included study and their reported findings; and (ii) the relationship between the findings of different studies;
- description of suspected mediators or moderators of the intervention effects.

### Subgroup analysis and investigation of heterogeneity

We planned the following subgroup analyses: delivery approach of the eLearning interventions (i.e. full eLearning and blended learning); whether the interventions were industry-funded or not; field of study; and the duration of the exposure to the intervention. However, since conducting a meta-analysis was not appropriate we did not perform any subgroup analysis.

### Sensitivity analysis

We planned to conduct sensitivity analyses if one or more studies were dominant due to their size, if one or more studies had results that differed from those observed in other studies, or if one or more studies had quality issues that might have affected their interpretation or the results. However, since we did not conduct a meta-analysis we did not conduct sensitivity analyses.

---

### References

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# Search strategy for use in MEDLINE

Source: Ovid MEDLINE® In process & other non-indexed citations, and Ovid MEDLINE® 1946 to present

Date of search: 16 August 2013

Limits: Year - 2000

Filter: Cochrane Highly Sensitive Search Strategy for identifying randomized trials in MEDLINE: sensitivity-maximizing version (2008 revision); Ovid format

1. exp Education, Distance/
2. educat\$.mp.
3. learn\$.mp.
4. train\$.mp.
5. instruct\$.mp.
6. 2 or 3 or 4 or 5
7. "computer assisted".mp.
8. Internet.mp.
9. distance.mp.
10. web.mp.
11. online.mp.
12. virtual.mp.
13. "mobile phone".mp.
14. "cell\$ phone".mp.
15. smartphone
16. smart-phone
17. 7 or 8 or 9 or 10 or 11 or 12 or 13 or 14 or 15 or 16
18. 6 adj3 17
19. exp Computer-Assisted Instruction/
20. eLearning.mp.
21. e-Learning.mp.
22. mLearning.mp.
23. m-Learning.mp.
24. "virtual learning environment".mp.
25. 1 or 18 or 19 or 20 or 21 or 22 or 23 or 24
26. exp Education, Medical, Undergraduate/
27. exp Education, Nursing/
28. exp Medical Staff/
29. exp Physicians/
30. doctor?.mp.
31. physician?.mp.
32. exp Physician Assistants/
33. exp Nurses/
34. nurse?.mp/
35. exp Nurses' Aides/
36. exp Allied Health Personnel/
37. exp Community Health Workers/
38. exp Health Personnel/
39. exp Health Manpower/
40. 26 or 27 or 28 or 29 or 30 or 31 or 32 or 33 or 34 or 35 or 36 or 37 or 38 or 39
41. 25 and 40
42. Randomized controlled trial.pt.
43. Controlled clinical trial.pt.
44. Randomized.ab.
45. Placebo.ab.
46. Drug therapy.fs.
47. Randomly.ab.
48. Trial.ab.
49. Groups.ab.
50. 42 or 43 or 44 or 45 or 46 or 47 or 48 or 49
51. exp animals/ not humans.sh.
52. 50 not 51
53. 41 and 52
54. Limit 53 to yr="2000 -Current"

# Results of the electronic searches

**Table A.4.1. 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

# PRISMA flow diagrams

Figure A.5.1. Non-networked computer-based eLearning PRISMA flow diagram

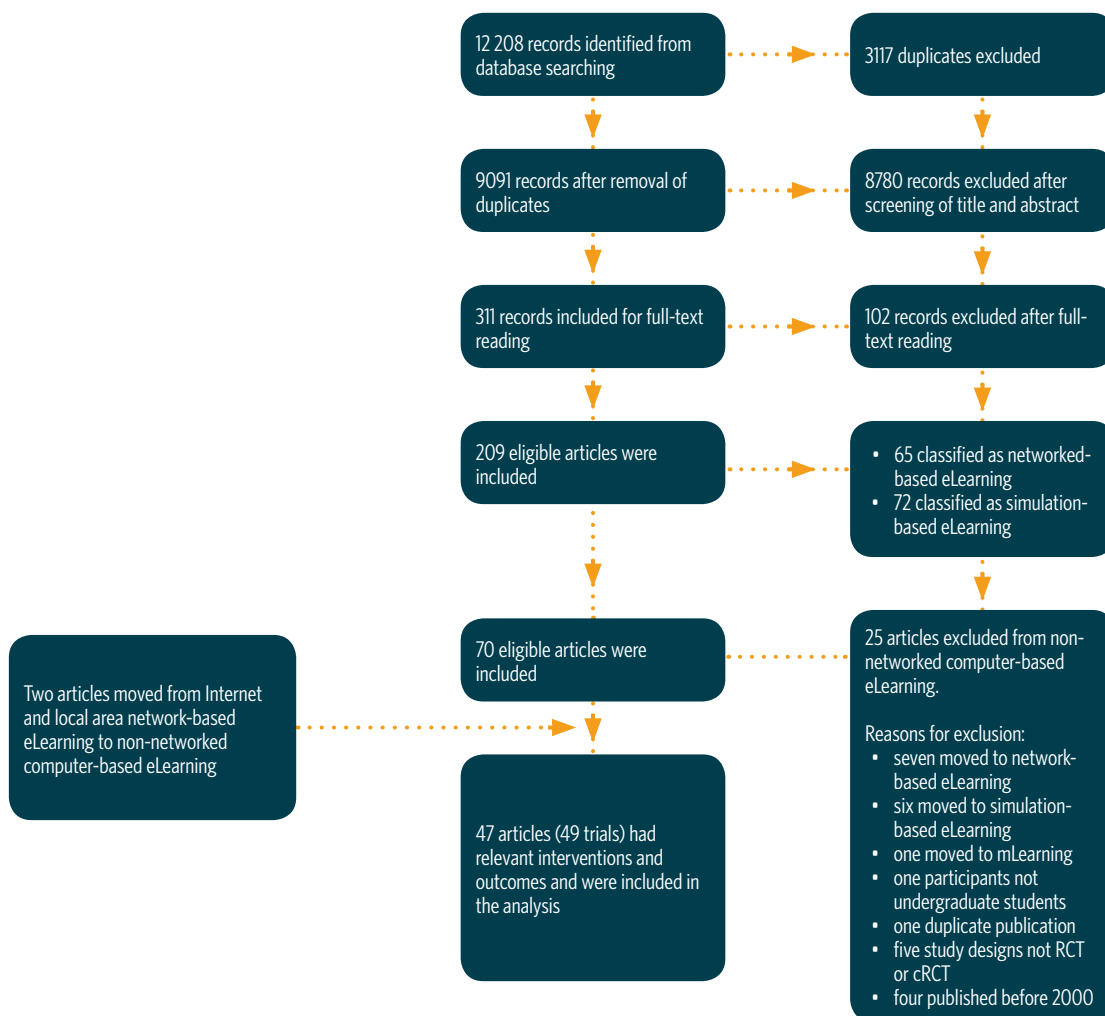
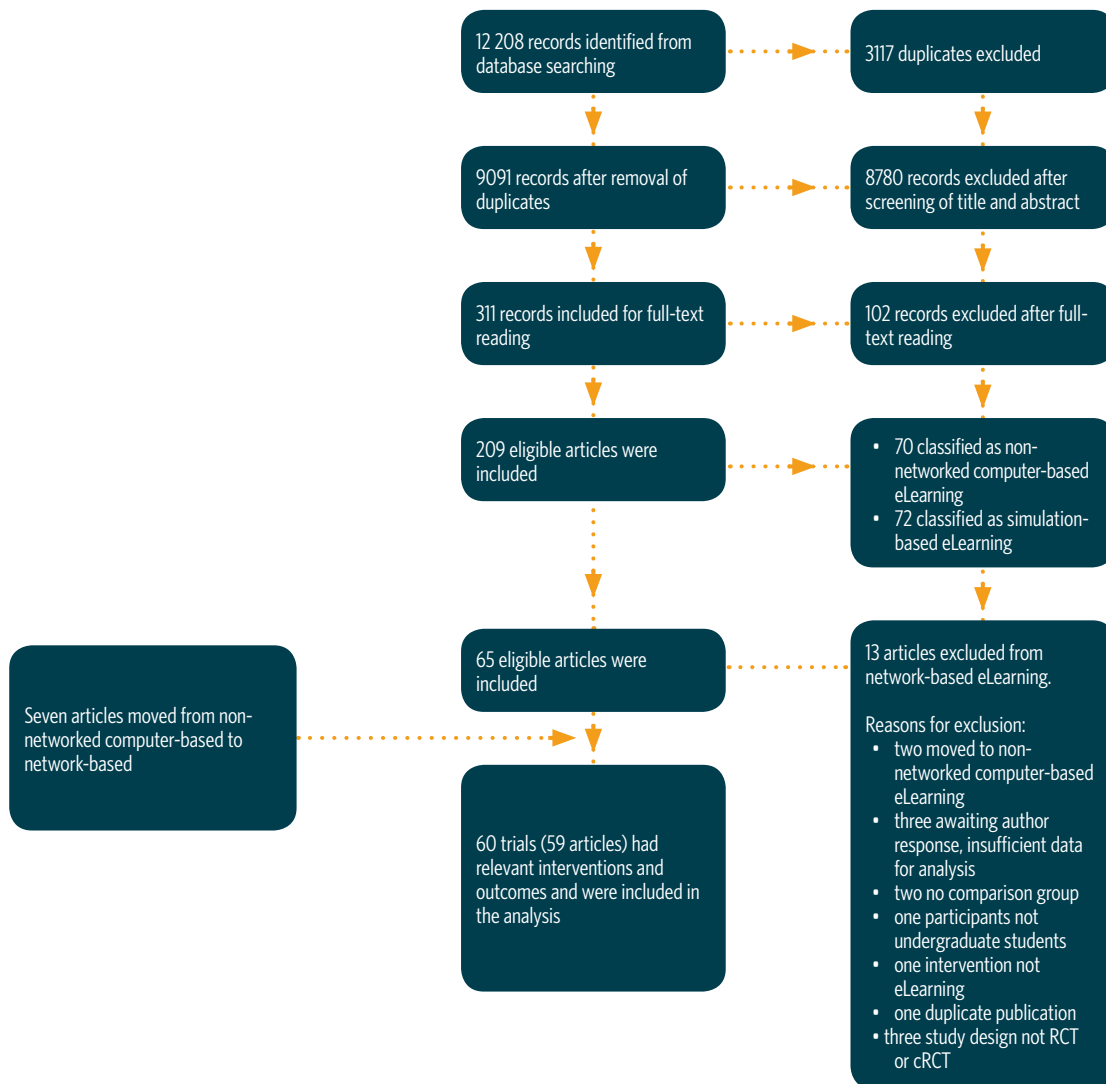


Figure A.5.2. Internet and local area network-based eLearning PRISMA flow diagram



# Fields included in the data extraction form

1. Study identification (ID)
  - 2.1. Journal in which the study was published
  - 2.2. Type of publication
  - 2.3. Authors' affiliations
  - 3.1. Study design as specified in the report
  - 3.2. Study aims and objectives
  - 3.3. Countries in which 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 randomized
  - 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 four 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, licence 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 organizational 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)
- 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)
- 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)
- 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)
- 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. Organizational 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



# Characteristics of included studies

**Table A.7.1. Characteristics of studies for non-networked computer-based eLearning**

STUDY ID	Methods			Participants			Interventions		
	STUDY DESIGN	LOCATION	COMPARISON	TOTAL NUMBER	YEAR OF STUDY	HEALTH-CARE SPECIALITY	CHARACTERISTICS	TIME AND TECHNOLOGY	TEST/OUTCOMES
Ackermann 2010	RCT	Germany	eLearning vs. traditional learning	19	Third year	Medicine	CG: students were given conventional learning material, access to the library and Internet IG: students were given a software CD for installation on home PC	<ul style="list-style-type: none"> <li>1 week (for intervention group 6 hours within 1 week)</li> <li>CD-ROM</li> </ul>	Knowledge: MCQ, X-ray interpretation skills
Amesse 2008	RCT	USA	eLearning vs. traditional learning	36	Third year	Medicine	CG: students were given paper-based tutorial session IG: students were given computer-based learning tutorial session composed of real-time video segments as well as audio and interactive components	<ul style="list-style-type: none"> <li>90 minutes</li> <li>IBM ThinkPad laptop, CD-ROM</li> </ul>	Knowledge: 34 fill-in-the-blank style questions, 2 equivalent examinations (test 1 consisted of 22 computer-posed questions and 12 paper-written questions. Test 2 consisted of 12 computer-posed questions and 22 paper-written questions)
Armstrong 2009	RCT	United Kingdom	eLearning vs. traditional learning	21	Fourth year	Medicine	CG: students were given lecture version of the eLearning tutorial, presented in a didactic form IG: students were given interactive slide show of a blood gas interpretation tutorial	<ul style="list-style-type: none"> <li>time N/A (during 1 week, probably only 1 lecture/tutorial)</li> <li>Microsoft® PowerPoint®</li> </ul>	Knowledge: 5 MCQ
Bains 2011	cRCT	United Kingdom	eLearning vs. traditional learning	90	Fourth year	Dentistry	CG: students were given teacher-led tutorial (face-to-face learning) IG I: students were given online tutorial with no teacher (animated learner-controlled didactic program) IG II: students were given online tutorial with no teacher followed by teacher-led tutorial G III: students were given teacher-led tutorial followed by online tutorial with no teacher	<ul style="list-style-type: none"> <li>45 minutes (2 x 45 minutes for IGs II and III)</li> <li>WebCT® version 3.8</li> </ul>	Knowledge: 10 MCQ Attitudes: Likert scales and focus groups
Bloomfield 2010	RCT	United Kingdom	eLearning vs. traditional learning	223	First year	Nursing	CG: students were given conventional learning with a standardized teaching pack: a set of lecture notes, a set of black and white overhead transparency slides, the handwashing demonstration video, and a list of additional reference material. Following a short lecturer-led presentation, participants watched the video and were then offered the opportunity to practise the recommended handwashing technique IG: students worked independently through a self-directed CAL module via an individual computer terminal in an on-campus computer room. The theoretical content was identical to that of the conventional teaching session. Interactive activities; animated multimedia, high-quality photographs and links to relevant websites were also included to stimulate interest and promote learner engagement. The handwashing demonstration video was embedded within the module	<ul style="list-style-type: none"> <li>90 minutes</li> <li>Computer, CAL module</li> </ul>	Knowledge: 20 MCQ Skills: OSCE

STUDY ID	Methods			Participants			Interventions		
	STUDY DESIGN	LOCATION	COMPARISON	TOTAL NUMBER	YEAR OF STUDY	HEALTH-CARE SPECIALITY	CHARACTERISTICS	TIME AND TECHNOLOGY	TEST/OUTCOMES
Boet 2010	N/A	France	eLearning vs. learning	42	N/A	Medicine	CG: students were given a conventional institutional didactic instruction lecture IG: students were given a conventional institutional didactic instruction lecture plus a virtual fiberoptic intubation CD-ROM (developed from reconstructed images, recreating the 3D environment of the airway)	<ul style="list-style-type: none"> <li>1-hour lecture time (CD-ROM exposure was within 2 weeks, no measure of exposure time)</li> <li>A virtual multimedia simulator, the "virtual fiberoptic intubation" computer</li> </ul>	Skills: ability to perform an intubation, primary endpoint being success within 4 minutes; evaluations were done in real time by the investigator
Bogacki 2004	RCT	USA	eLearning vs. traditional learning	45	First year	Dentistry	CG: students were given traditional dental anatomy lecture IG: students were given tooth morphology program (text, photographic images, illustrations, and lectures to teach morphology of adult dentition)	<ul style="list-style-type: none"> <li>6-week course</li> <li>CD-ROM and computer</li> </ul>	Knowledge: examination
Bradley 2005	RCT	Norway	eLearning vs. traditional learning	168	Tenth semester	Medicine	CG: students were given 5 half-day workshops IG: training relied on CAL, mainly using an English-language CD-ROM (and accompanying workbook). The CD-ROM consisted of 5 modules: course notes and interactive exercises that posed questions and gave automatic feedback on answers, checklists to appraise articles, a glossary of terms, several sample articles to appraise, and links to key Internet sites. The accompanying workbook included all the necessary source material, including several additional examples of scientific articles to appraise, further exercises, references, and checklists to appraise them. Because the workbook was in English, it was supplemented with non-interactive Internet pages in Norwegian. The Internet resource contained a glossary of terms, checklists to appraise articles, and further references. In addition, tutors (1 clinical epidemiologist and 1 librarian) were available at 5 specified teaching sessions lasting 3 hours	<ul style="list-style-type: none"> <li>5 half days</li> <li>CD-ROM, PC, access to Internet site</li> </ul>	Knowledge: 7 MCQ and critical appraisal of a scientific paper Attitudes: Likert scale
Davis 2008	RCT	United Kingdom	eLearning vs. traditional learning	179	First year	Medicine	CG: students were given a standard lecture IG: students were given computer-based learning (recording of the lecture, plus PowerPoint® presentation, plus Internet links)	<ul style="list-style-type: none"> <li>40 minutes</li> <li>PC, headphones, CD-ROM</li> </ul>	Knowledge: 5 questions (2 structured and 3 MCQ)
Feeg 2005	RCT	USA	eLearning vs. traditional learning	91	N/A	Nursing	CG: students were given a journal article IG: students were given a CD-ROM-based tutorial plus a journal article	<ul style="list-style-type: none"> <li>2 weeks (within this the intervention group spent on average 28.7 minutes)</li> <li>PC, headphones, CD-ROM</li> </ul>	Knowledge: 20 MCQ (18 used for analysis)
Gelb 2001	RCT	USA	eLearning vs. traditional learning	107	N/A	Medicine	CG: students were given a print version of the tutorial containing the same information as the computer tutorial IG: students were given computer tutorial	<ul style="list-style-type: none"> <li>8 months</li> <li>computer</li> </ul>	Knowledge: MCQ

STUDY ID	Methods			Participants			Interventions		
	STUDY DESIGN	LOCATION	COMPARISON	TOTAL NUMBER	YEAR OF STUDY	HEALTH-CARE SPECIALITY	CHARACTERISTICS	TIME AND TECHNOLOGY	TEST/OUTCOMES
Glicksman 2009	RCT	Canada	eLearning vs. learning	47	First year	Medicine	CG: students were given instructions and a quiet location for reading the article IG: students were given CAL module designed with identical content to the article	<ul style="list-style-type: none"> <li>time N/A</li> <li>computer, a program was designed using Articulate Presenter® which turns PowerPoint® presentations into Adobe® Flash®-based computer and web modules that run in a web browser</li> </ul>	Skills: the time taken to pack the nose was measured in a standardized manner: videotape analysis using a previously validated global rating system adapted for the present study (7 outcomes, including respect for tissue, time and motion, instrument handling, flow of operation, knowledge of procedure, overall performance, and quality of final product, each based on a 5-point Likert scale). A checklist modelled on a previously-validated human reliability assessment tool was used (6 items for the tampon pack and 8 items for the formal pack) Attitude: questionnaire
Goldsworthy 2006	RCT	Canada	eLearning vs. traditional learning	25	Second year	Nursing	CG: students were given paper version of the same resource as the IG IG: students were given a PDA containing laboratory and diagnostic reference, a drug reference book, a medical-surgical procedure resource from Elsevier Publishing, and 2 60-minute sessions for orientation	<ul style="list-style-type: none"> <li>potentially 8 weeks</li> <li>PDA: Hewlett-Packard iPAQ was chosen. Software: Elsevier Publishing</li> </ul>	Knowledge: written examination (10-item general self-efficacy instrument and a safety tool for medication administration developed by the author)
Green 2011	RCT	USA	eLearning vs. traditional learning	121	Second year	Medicine	CG: students were given an advanced care-planning packet (brochure and living will form) IG: students were given Making your wishes known, planning your medical future, an interactive, computer-based program	<ul style="list-style-type: none"> <li>time N/A</li> <li>Making your wishes known, planning your medical future, an interactive, computer-based program</li> </ul>	Knowledge: 17-item true/false and MCQ test Satisfaction: a measure of global satisfaction (1 item, 10-point scale) and satisfaction with particular aspects of the advance care-planning process (4 items, 5-point scale)
Holt 2001	N/A	United Kingdom	eLearning vs. traditional learning	108	First clinical year (third year)	Medicine	CG: students were given standard lectures IG: students were given CAL, using exactly the same visual material as the standard lecture and an edited recording of the lecturer's voice. The CAL was available in the CAL laboratory between 09.00 and 17.00 on weekdays, throughout the study period	<ul style="list-style-type: none"> <li>6 lectures (each 60 minutes in CG, average 83 minutes in IG)</li> <li>visual material and an edited recording of the lecturer's voice</li> </ul>	Knowledge: MCQ (34 items, each with 5 true-or-false questions)
Howerton 2002	RCT	USA	eLearning vs. traditional learning	59	First year	Dentistry	CG: students were given standard lectures IG: students were given interactive a computer-assisted instructional module on CD with no time restriction	<ul style="list-style-type: none"> <li>time N/A</li> <li>extension cone paralleling device (XCP). Authoring software (Macromedia Director 8)</li> </ul>	Knowledge: radiographic interpretation (University of North Carolina Full Mouth Series radiographic criteria) Satisfaction: Likert scale
Hu 2010	RCT	Canada	eLearning vs. eLearning	100	Years 1-4	Medicine, dentistry, physical therapy	CG: students were given standard written instructions and the group was provided with text/images/structures in 2D format on a computer screen IG I: students were given a 3D educational computer model IG II: students were given computer and 3D educational computer models developed with an Amira 4.1 software package by Visage Imaging Inc	<ul style="list-style-type: none"> <li>45 minutes</li> <li>computer, 3D educational computer model, web-based platform WebCT Vista</li> </ul>	Knowledge: 20-item web-based test Satisfaction: Likert scale

STUDY ID	Methods			Participants			Interventions		
	STUDY DESIGN	LOCATION	COMPARISON	TOTAL NUMBER	YEAR OF STUDY	HEALTH-CARE SPECIALITY	CHARACTERISTICS	TIME AND TECHNOLOGY	TEST/OUTCOMES
Hudson 2004	RCT	Australia	eLearning vs. eLearning	100	Third year	Medicine	CG: no tutorials IG I: students were given a didactic tutorial (text and images in a structured way, minimum interaction with the computer tutorial) IG II: students were given a problem-solving tutorial (the computer asking the user to interact only by choosing appropriate answers in series of MCQ) IG III: the free-text version allowed the user to respond to open-ended questions by typing in natural-language responses, which were compared to answers developed by the author of the tutorial, and feedback was given	<ul style="list-style-type: none"> <li>2 weeks</li> <li>computer, didactic, problem-solving and free-text version of computer tutorial</li> </ul>	Knowledge: MCQ and 27 written questions
Jeffries 2003	RCT	USA	eLearning vs. traditional learning	73	N/A	Nursing	CG: students were given a self-study module, brief lecture, demonstration by an instructor and hands-on experience IG: students were given an interactive CD-ROM in the laboratory computer cluster, embedded with virtual reality and supplemented with a self-study module	<ul style="list-style-type: none"> <li>90 minutes for CG, 2 days (at times scheduled) for IG</li> <li>interactive CD-ROM in the laboratory computer cluster, embedded with virtual reality and supplemented with a self-study module</li> </ul>	Knowledge: 27 MCQ Skills: weighted, 22-item skills competency checklist Attitude: Likert scale Satisfaction: questionnaire
Jowett 2007	RCT	Canada	eLearning vs. eLearning	30	N/A	Medicine	CG: no intervention IG: students were able to attend additional practice: 4 extra 3-minute practice blocks separated by video- captured trials with hand-motion tracking	<ul style="list-style-type: none"> <li>0 and 12 minutes</li> <li>laptop, hand-motion tracking device</li> </ul>	Skills: expert global rating scale; time; number of hand movements; path length
Kalet2012	RCT	USA	eLearning vs. eLearning	143	Second year	Medicine	CG: students were given online module, watch condition (students controlled only the pace of the presentation) IG I: students were given online module, click condition (students used the mouse to trigger animated demonstrations) IG II: students were given online module, drag condition (students were able to click and drag tools in motions simulating actual performance of the task)	<ul style="list-style-type: none"> <li>20 minutes</li> <li>computer-based multimedia presentation</li> </ul>	Knowledge: 17 or 18 item MCQ Skills: standardized patient checklist, patient note
Kim 2003	RCT	South Korea	eLearning vs. traditional learning	75	Third year	Nursing	CG: students were given printed material, self-learning IG: students were given computer software, self-learning	<ul style="list-style-type: none"> <li>1 week, CG 55 +/-30 hours and IG 48.5 +/-27.8 hours</li> <li>CD-ROM, computer</li> </ul>	Knowledge: assessment of theoretical background and concrete methods of applying pressure Skills: checklist based on the steps of the procedure, student psychomotor skills and competency when students applied pressure Attitude: questionnaire Satisfaction: questionnaire
Kong 2009	RCT	China	eLearning vs. traditional learning	90	Fifth year	Medicine	CG: students were given conventional teaching, didactic model IG I: students were given PBL teaching with paper-based case description IG II: students were given PBL teaching with digital format material	<ul style="list-style-type: none"> <li>2 hours twice weekly (total 18 hours)</li> <li>educational websites, multimedia CD-ROM</li> </ul>	Knowledge: theoretical and case analysis examinations Skills: evaluation of students' practice Satisfaction: questionnaire

STUDY ID	Methods			Participants			Interventions		
	STUDY DESIGN	LOCATION	COMPARISON	TOTAL NUMBER	YEAR OF STUDY	HEALTH-CARE SPECIALITY	CHARACTERISTICS	TIME AND TECHNOLOGY	TEST/OUTCOMES
Kurihara 2004	RCT	Japan	eLearning vs. traditional learning	59	Third year	Medicine	CG: students were given traditional textbook learning IG I: students were assigned to computer-based learning with CAI software, cyberPatient IG II: students were assigned to traditional text-book learning combined with cyberPatient IG III: no intervention	<ul style="list-style-type: none"> <li>4 hours</li> <li>cyberPatient: multimedia software. Multimedia software that consists of patient simulation models and special clinical skills learning modules. The abdominal physical examination learning module was used for this intervention</li> </ul>	Knowledge: 40 MCQ (8 excluded for the analysis) Skills: OSCE
Lira 2013	RCT	Brazil	eLearning vs. traditional learning eLearning	68	Fourth year	Medicine	CG: students were assigned to the lecture IG students were assigned to the lecture plus additional PDF article, sent a week before the class	<ul style="list-style-type: none"> <li>time N/A</li> <li>computer, Internet, PDF</li> </ul>	Knowledge: 7 MCQ
Maleck 2001	RCT	Germany	eLearning vs. traditional learning	192	Third year	Medicine	CG: students were given paper version of the cases with the original film radiographs, and option to attend the lecture and using textbook IG I: students were assigned to computer-based cases along with interactive elements (MCQ, free-text questions, drag-and-drop mapping tool), option to attend the lecture and use textbook IG II: computer-based cases but without the interactive elements, option to attend the lecture and use textbook IG III: no intervention, option to attend the lecture and use textbook	<ul style="list-style-type: none"> <li>2 hours, the computer-based cases took 20-30 minutes per case</li> <li>Macintosh Power PC 8200/120 (Computer)</li> </ul>	Knowledge: 14 MCQ and 4 free text questions Attitude: scale (1-6) Satisfaction: evaluation form, scale (1-6)
McDonough 2002	RCT	United Kingdom	eLearning vs. traditional learning	37	Third year	Medicine	CG: after pre-testing and 20-minute preliminary lecture, students received 90 minutes of face-to-face tutorial in small group. Students in the 90-minute tutorial groups (each n=8 or less) worked with MMD through the same 4 questions in an interactive way. IG: students in the FearFighter condition worked alone for 90 minutes exploring the system for instructions on how to answer these 4 questions	<ul style="list-style-type: none"> <li>90 minutes</li> <li>the abridged HTML version of FearFighter; software installed on 20 PCs</li> </ul>	Knowledge: MCQ Satisfaction: rating scale
McMullan 2011 a*	cRCT	United Kingdom	eLearning vs. traditional learning	48	Second year	Nursing	CG: students were assigned to traditional handout learning support IG: students were assigned to non-interactive, self-contained, Internet-independent e-learning PDF drug calculations package, based on cognitive load theory	<ul style="list-style-type: none"> <li>time N/A, self-directed over 12 weeks</li> <li>e-learning PDF drug calculations package</li> </ul>	Knowledge: 20 questions covering the main types of drug calculations Attitude: drug calculation self-efficacy scale Satisfaction: support material satisfaction scale
McMullan 2011 b*	cRCT	United Kingdom	eLearning vs. traditional learning	50	Second year	Nursing	CG: students were assigned to traditional handout learning support IG: students were assigned to an interactive, self-contained, Internet-independent e-learning PDF drug calculations package, based on cognitive load theory	<ul style="list-style-type: none"> <li>time N/A, self-directed over 12 weeks</li> <li>e-learning PDF drug calculations package</li> </ul>	Knowledge: 20 questions covering the main types of drug calculations Attitude: drug calculation self-efficacy scale Satisfaction: support material satisfaction scale

STUDY ID	Methods			Participants			Interventions		
	STUDY DESIGN	LOCATION	COMPARISON	TOTAL NUMBER	YEAR OF STUDY	HEALTH-CARE SPECIALITY	CHARACTERISTICS	TIME AND TECHNOLOGY	TEST/OUTCOMES
Miedzybrodzka 2001	RCT	United Kingdom	eLearning vs. traditional learning	48	Fourth year	Medicine	CG: students were assigned to conventional lectures IG: students were assigned to CAL package with technical (but not academic) support available, using interactive Model Patient approach in which the student is led through an at-risk patient's process of care from presentation to the general practitioner to consultations at the genetic clinic and with screening options available	<ul style="list-style-type: none"> <li>CG 20 minutes, IG average 16.4 minutes</li> <li>interactive multimedia CAL package, Model Patient application via computer</li> </ul>	Knowledge: essays and MCQ Attitude: Likert scale
Morgulis 2012	RCT	Australia	eLearning vs. eLearning	42	Sixth year	Medicine	CG: students were provided with links and encouraged to utilize currently-available e-learning resources on leukaemia IG: students were assigned to a newly-built module	<ul style="list-style-type: none"> <li>2 weeks</li> <li>computer, Internet access</li> </ul>	Knowledge: single best answer MCQ, multiple response MCQ, drag-and-drop Attitude: Likert scale, free-text response
Nance 2009	RCT	USA	eLearning vs. learning	73	First year	Dentistry	CG: students had access to the carving laboratory and were given instructional handouts IG: DVD-only group, students did not receive handouts or attend laboratories	<ul style="list-style-type: none"> <li>time N/A (1 hour for the IG)</li> <li>CAI instructional DVD</li> </ul>	Skills: grading rubric by experts and students, competency examination Attitude: survey
Nola 2005	RCT	Croatia	eLearning vs. traditional learning	85	Sixth year	Medicine	CG: students attended lectures and microscopy sessions with seminars IG: students could attend lectures; seminars were substituted by computer with stored pictorial teaching material (photographs, legends for each chapter, list of key words with explanation, clinical cases with questions and discussion and review questions at the end of each chapter)	<ul style="list-style-type: none"> <li>1 academic year</li> <li>computers, program with pictorial teaching material</li> </ul>	Knowledge: examination
Nousiainen 2008	RCT	Canada	eLearning vs. eLearning	24	First and second year	Medicine	All participants initially underwent a 7-minute training session CG: 6-phase version of the video, watched only once IG I: students were able to access video in a self-directed manner between and during practice attempts IG II: students were able to use the video in the same way as students in intervention I during the first 9 practice sutures; they then had expert instruction (4:1 student to faculty ratio) on suture and knot-tying technique prior to completing the final 9 practice attempts	<ul style="list-style-type: none"> <li>30-40 minutes</li> <li>interactive video via computer</li> </ul>	Skills: Imperial College Surgical Assessment Device and global rating scale by 2 blinded experts
Perfeito 2008	RCT	Brazil	eLearning vs. traditional learning	35	Fourth year	Medicine	CG: students were assigned to the lecture IG: students were assigned to the independent study with a designed program	<ul style="list-style-type: none"> <li>1.5 hours</li> <li>CD-ROM, computer</li> </ul>	Knowledge: MCQ and descriptive questions
Prinz 2005	RCT	Switzerland	eLearning vs. eLearning	172	N/A	Medicine	CG: students could see surgeon's view (video) of the cataract and glaucoma procedure IG: students could see the director's cut of the same procedures, which includes the 3D animations in addition to the surgeon's view sequences identical to those in the CG; both groups had the same narrated comments	<ul style="list-style-type: none"> <li>20 minutes</li> <li>videos, 3D animations, DVD, storyboard, professional software. The presentations were presented over a PC beamer in the same lecture theatre</li> </ul>	Knowledge: MCQ Attitude: questionnaire with 4-level ordinal scale Satisfaction: questionnaire with 4-level ordinal scale
Pusic 2007	RCT	Canada	eLearning vs. eLearning	139	Final year	Medicine	CG: students used linear (PowerPoint®) computer tutorial IG: students used branched version (web based) of a computer tutorial	<ul style="list-style-type: none"> <li>2 hours</li> <li>PC, Internet access</li> </ul>	Knowledge: improvement in the ability to correctly classify 10 CSXRs Satisfaction: Likert scale

STUDY ID	Methods			Participants			Interventions		
	STUDY DESIGN	LOCATION	COMPARISON	TOTAL NUMBER	YEAR OF STUDY	HEALTH-CARE SPECIALITY	CHARACTERISTICS	TIME AND TECHNOLOGY	TEST/OUTCOMES
Qayumi 2004	RCT	Japan	eLearning vs. traditional learning	99	Sixth year	Medicine	CG: no intervention IG I: students used text module IG II: Students used CyberPatient program IG III: Students used both text module and CyberPatient program	<ul style="list-style-type: none"> <li>4 hours</li> <li>computer</li> </ul>	Knowledge: MCQ Skills: OSCE
Roppolo 2011	RCT	USA	eLearning vs. traditional learning	180	First year	Medicine	CG: students attended traditional course with manikin 4-5 hours in duration IG I: students used HeartCode BLS System: web-based, self-directed, self-paced program for cognitive part IG II: students used BLS Anytime for health-care professionals program	<ul style="list-style-type: none"> <li>traditional course 4-5 hours, HeartCode 2 hours, BLS anytime 2-2.5 hours</li> <li>HeartCode BLS system, BLS Anytime system and Laerdal™ Resusci Annie voice activated manikin (VAM) system, HeartCode BLS system</li> </ul>	Skills: adult CPR skills checklist
Seabra 2004	RCT	Brazil	eLearning vs. traditional learning	60	Second and third year	Medicine	CG: students were assigned to the lecture on epidemiology, diagnosis, clinical manifestation and treatment of prostate cancer IG: students were assigned to the multimedia program	<ul style="list-style-type: none"> <li>2 hours</li> <li>computer, multimedia program</li> </ul>	Knowledge: 25 MCQ
Shomaker 2002	RCT	USA	eLearning vs. traditional learning	94	Second year	Medicine	CG: students attended lectures and were permitted to use syllabus notes, outside texts and a 35-mm slide collection IG I: students were assigned to parasitology computer program, syllabus notes and outside texts IG II: the combined group had access to all course material	<ul style="list-style-type: none"> <li>time N/A</li> <li>computer, parasitology computer program</li> </ul>	Knowledge: 42 MCQ and 25 slides Satisfaction: a comprehensive course evaluation
Solomon 2004	RCT	USA	eLearning vs. traditional learning	29	Third year	Medicine	CG: students travelled to the host community campus and attended live lectures with their colleagues who chose not to participate in the study IG: students stayed at their home campus on the same day and completed a parallel set of CD-ROM-based multimedia modules made from digital recordings of the previous year's lectures. They completed these digital lectures in computer laboratories either in the community campus office or in one of the teaching hospitals	<ul style="list-style-type: none"> <li>6 lectures</li> <li>CD-ROM-based multimedia modules</li> </ul>	Knowledge: examination (4-5 questions)
Tunuguntla 2008	RCT	USA	eLearning vs. eLearning	49	First year	Medicine	CG: students used an interactive online model that depicted common home safety issues in static graphs IG: students used an interactive online model that depicted common home safety issues in animations	<ul style="list-style-type: none"> <li>time N/A</li> <li>computer, online model</li> </ul>	Knowledge: competency assessment test
Vichitvejpaisal 2001	RCT	Thailand	eLearning vs. traditional learning	80	Third year	Medicine	CG: students spent their time reading a 275-page textbook IG: students were given access to a room which was well equipped with computers and where a 455-electronic page software program was available for each one (CAI)	<ul style="list-style-type: none"> <li>10 hours</li> <li>computer, CAI program</li> </ul>	Knowledge: 30-item type K examination
Vivekananda-Schmidt 2005 a*	cRCT	United Kingdom	eLearning vs. traditional learning	105	Third year	Medicine	London: students allocated to the intervention were given a verbal introduction to the content of the CD-ROM, and each student was given a CD	<ul style="list-style-type: none"> <li>1 day</li> <li>CD-ROM, computer, video</li> </ul>	Skills: OSCE Attitude: 15-item confidence log

STUDY ID	Methods			Participants			Interventions		
	STUDY DESIGN	LOCATION	COMPARISON	TOTAL NUMBER	YEAR OF STUDY	HEALTH-CARE SPECIALITY	CHARACTERISTICS	TIME AND TECHNOLOGY	TEST/OUTCOMES
Vivekananda-Schmidt 2005 b*	cRCT	United Kingdom	eLearning vs. traditional learning	156	Third year	Medicine	Newcastle: students allocated to the intervention arm were each given a CD followed by 1-hour access time to a computer laboratory during lunchtime (arranged in response to findings of the pilot, which suggested that CD use would be higher if access to computers was better)	<ul style="list-style-type: none"> <li>1 day</li> <li>CD-ROM, computer, video</li> </ul>	Skills: OSCE Attitude: 15-item confidence log
Seabra 2004	RCT	Brazil	eLearning vs. traditional learning	60	Second and third year	Medicine	CG: students were assigned to the lecture on epidemiology, diagnosis, clinical manifestation and treatment of prostate cancer IG: students were assigned to the multimedia program	<ul style="list-style-type: none"> <li>2 hours</li> <li>computer, multimedia program</li> </ul>	Knowledge: 25 MCQ
Shomaker 2002	RCT	USA	eLearning vs. traditional learning	94	Second year	Medicine	CG: students attended lectures and were permitted to use syllabus notes, outside texts and a 35-mm slide collection IG I: students were assigned to parasitology computer program, syllabus notes and outside texts IG II: the combined group had access to all course material	<ul style="list-style-type: none"> <li>time N/A</li> <li>computer, parasitology computer program</li> </ul>	Knowledge: 42 MCQ and 25 slides Satisfaction: comprehensive course evaluation
Solomon 2004	RCT	USA	eLearning vs. traditional learning	29	Third year	Medicine	CG: students travelled to the host community campus and attended live lectures with their colleagues who chose not to participate in the study IG: students stayed at their home campus on the same day and completed a parallel set of CD-ROM-based multimedia modules made from digital recordings of the previous year's lectures. They completed these digital lectures in computer laboratories either in the community campus office or in one of the teaching hospitals	<ul style="list-style-type: none"> <li>6 lectures</li> <li>CD-ROM based multimedia modules</li> </ul>	Knowledge: examination (4-5 questions)
Tunuguntla 2008	RCT	USA	eLearning vs. eLearning	49	First year	Medicine	CG: students used an interactive online model that depicted common home safety issues in static graphs IG: students used an interactive online model that depicted common home safety issues in animations	<ul style="list-style-type: none"> <li>time N/A</li> <li>computer, online model</li> </ul>	Knowledge: competency assessment test
Vichitvejpaisal 2001	RCT	Thailand	eLearning vs. traditional learning	80	Third year	Medicine	CG: students spent their time reading a 275-page textbook IG: students were given access to a room which was well equipped with computers and where a 455-electronic page software program was available for each one (CAI)	<ul style="list-style-type: none"> <li>10 hours</li> <li>computer, CAI program</li> </ul>	Knowledge: 30-item type K examination
Vivekananda-Schmidt 2005 a*	cRCT	United Kingdom	eLearning vs. traditional learning	105	Third year	Medicine	London: students allocated to the intervention were given a verbal introduction to the content of the CD-ROM, and each student was given a CD	<ul style="list-style-type: none"> <li>1 day</li> <li>CD-ROM, computer, video</li> </ul>	Skills: OSCE Attitude: 15-item confidence log
Vivekananda-Schmidt 2005 b*	cRCT	United Kingdom	eLearning vs. traditional learning	156	Third year	Medicine	Newcastle: students allocated to the intervention arm were each given a CD followed by 1-hour access time to a computer laboratory during lunchtime (arranged in response to findings of the pilot, which suggested that CD use would be higher if access to computers was better)	<ul style="list-style-type: none"> <li>1 day</li> <li>CD-ROM, computer, video</li> </ul>	Skills: OSCE Attitude: 15-item confidence log

CG = Control group  
IG = Intervention group  
\*Publication contained two studies



**Table A.7.2. Characteristics of studies for Internet and local area network-based eLearning**

STUDY ID	Methods			Participants			Interventions		
	STUDY DESIGN	LOCATION	COMPARISON	TOTAL NUMBER	YEAR OF STUDY	HEALTH-CARE SPECIALITY	CHARACTERISTICS	TIME AND TECHNOLOGY	TEST/OUTCOMES
Ainsworth 2012 a*	RCT	United Kingdom	eLearning vs. traditional learning	88	First year	Nursing	CG: students did not have access to Authentic World but received all usual support from academic teaching staff IG: students had access to Authentic World, computer software designed to improve problem-solving skills for medication dosage calculation	<ul style="list-style-type: none"> <li>7 months</li> <li>Computer, Authentic World software</li> </ul>	Knowledge: general numeracy test
Ainsworth 2013 b*	RCT	United Kingdom	eLearning vs. traditional learning	89	First year	Nursing	CG: students in the control group did not have access to Authentic World receive all usual support from academic teaching staff IG: Students had access to Authentic World, computer software designed to improve problem-solving skills for medication dosage calculation	<ul style="list-style-type: none"> <li>8 months</li> <li>Computer, Authentic World software</li> </ul>	Knowledge: general numeracy test
Arroyo-Morales 2012	RCT	Spain	eLearning vs. traditional learning	44	Second year	Physiotherapy	CG: books and texts IG: students had access to a website with detailed sections, including videos, images and self-assessment features	<ul style="list-style-type: none"> <li>3 weeks</li> <li>computer, website</li> </ul>	Knowledge: MSQ Skills: OSCE Satisfaction: 5-point Likert scale questionnaire
Baumlin 2000	cRCT	USA	eLearning vs. traditional learning	90	Fourth year	Medicine	CG: students received no CAI IG: students used the EMCyberSchool	<ul style="list-style-type: none"> <li>4 weeks</li> <li>computer, website</li> </ul>	Knowledge: standardized written examination Satisfaction: survey
Beeckman 2008	RCT	Belgium	eLearning vs. traditional learning	214	Final year	Nursing	CG: students received a lecture IG: an eLearning session on pressure ulcers	<ul style="list-style-type: none"> <li>1 hour</li> <li>computer, website</li> </ul>	Knowledge: 2 or more independent assessors assign an equal value during an observation or measurement
Brettell 2013	RCT	United Kingdom	eLearning vs. traditional learning	70	First year	Nursing	CG: students received a face-to-face session which replicated the content and structure of the tutorial IG: students in the intervention group worked through the online tutorial which they accessed via a designated area on the university's virtual learning environment	<ul style="list-style-type: none"> <li>1 hour</li> <li>computer, online access</li> </ul>	Skills: all search skills tests involved a search of the cumulative index to nursing and allied health literature (CINAHL) on a given topic area
Buzzell 2002	RCT	USA	eLearning vs. traditional learning	32	Second year to fourth year	Medicine	CG: students received lectures with no access to the web tutorial IG I: students in the computer group had access to the 4 computer tutorials on the web IG II: students in this group had access to both the lectures and web tutorials	<ul style="list-style-type: none"> <li>time N/A</li> <li>computer with Macromedia Flash, Cold Fusion Studio (Macromedia), RealVideo installed, online access</li> </ul>	Knowledge: cognitive assessment instrument Attitudes: Likert-type assessment
Cantarero 2012	RCT	Spain	eLearning vs. traditional learning	44	N/A	Physiotherapy	CG: students received study sessions and were allowed self-study using documents and books IG: students had access to the web-based intervention entitled Evaluating, assessing, and treating sensitive oral systemic health topics: case studies on oral manifestations of eating disorders	<ul style="list-style-type: none"> <li>2 weeks</li> <li>computer, website</li> </ul>	Skills: OSCE Attitudes: 5-point Likert scale (5: strongly agree; 1: disagree) Satisfaction: 5-point Likert scale (5: strongly agree; 1: disagree)
Chao 2003	RCT	Brazil	eLearning vs. eLearning	34	First year	Medicine	CG: students had access to existing pages on the Internet that were based on the study topics IG: students had access to a multimedia website	<ul style="list-style-type: none"> <li>2.5 hours</li> <li>computer, website: HTML, active server pages (ASP), a database (SQL 7.0, Microsoft®)</li> </ul>	Knowledge: interactive evaluation about melanoma
Chen 2007	RCT	USA	eLearning vs. traditional learning	145	N/A	Health-related major undergraduates	CG: students received no treatment and proceeded directly into textbook reading and assignments IG I: students received a visual advance organizer IG II: students used the text advance organizer presenting the same concepts and explanation as the concept map in a text format	<ul style="list-style-type: none"> <li>1 week</li> <li>computer, a visual concept map software, text advance organizer</li> </ul>	Knowledge: Post-test I: the first part included multiple choice and essay questions. Post-test II: quiz and complete-a-scenario question was administered 4 weeks after post-test I

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Chen 2012	cRCT	Taiwan	eLearning vs. traditional learning	146	Fourth year	Nursing	CG: students received only paper references and no teaching assistance IG: students received online testing which was used as a computer-based assistant tool with which students could perform drills and practise tests to help their learning through autonomous self-evaluation	<ul style="list-style-type: none"> <li>14 weeks</li> <li>computer, online access to the eLearning system</li> </ul>	Knowledge: mid-term and final test
Cox 2008	cRCT	USA	eLearning vs. traditional learning	121	Third year	Medicine	CG: students received identical packets of paediatric clerkship paper materials with no other instruction IG I: students received a screening tool I CARE that was taught as a method for identifying underserved patients' health issues IG II: students had access to web material, including videos and received the I CARE screening tool instructions via the Internet	<ul style="list-style-type: none"> <li>6 weeks</li> <li>computer, website, videos</li> </ul>	Skills: performance examination Attitude: used a 4-point Likert scale (1 strongly disagree to 4 strongly agree)
DeBate 2013	cRCT	USA	eLearning vs. traditional learning	501	N/A	Dentistry	CG: students received no additional training beyond what was delivered in their curriculum IG: students received a web-based training program comprising three interactive intervention components with section overviews and learning objectives. The content material was presented in various interactive forms	<ul style="list-style-type: none"> <li>3 weeks</li> <li>computer, website</li> </ul>	Knowledge, skills and attitudes were all measured using a 52-item Likert-type questionnaire based on the conceptual framework taught
Erickson 2003	RCT	USA	eLearning vs. traditional learning	42	Third year	Pharmacy	CG: students received no intervention IG: students received a web-based tutorial	<ul style="list-style-type: none"> <li>1 hour</li> <li>computer, website, video</li> </ul>	Knowledge: open-ended question describing step-wise process of taking specified medication Skills: mock standardized patient test
Fernandez 2011	RCT	Spain	eLearning vs. traditional learning	116	Second year	Nursing	CG: students were taught in an on-hospital clinical skills room and given a set of slides plus some additional resources IG: students had access to "Mooshak" - for watching videos, listening to recordings, reading text, looking at photographs and linking to relevant websites and questions	<ul style="list-style-type: none"> <li>10 weeks</li> <li>computer, online access</li> </ul>	Knowledge: post-test examination Satisfaction: 5 point Likert scale and open questions
Fleming 2003	RCT	USA	eLearning vs. traditional learning	31	First year	Dentistry	CG: web-based self-instruction and slide/ audiotape self-instruction IG: this group studied the mandibular arch using the slide/audiotape and the maxillary arch using the web-based format	<ul style="list-style-type: none"> <li>time N/A</li> <li>slide and audiotape access, computer and online access for the web-based self-instruction</li> </ul>	Knowledge: post-test fill-in-the-blank questions Satisfaction: preference survey consisted of 25 questions with Likert-style responses
Flowers 2010	cRCT	USA	eLearning vs. traditional learning	79	Fourth year	Pharmacy	CG: students received no intervention on their community placement IG: students in this group were given a website address to access multimedia vignettes which they were required to watch to augment their training and standardize their counselling of patients in the use of inhalers and ear and eye drops	<ul style="list-style-type: none"> <li>1 month</li> <li>computer with PowerPoint® and Impatica 3.0 installed for digital videos and audio, searchable text, web server, CD, DVD</li> </ul>	Knowledge: 12-item post-test
Friedl 2006	RCT	Germany	eLearning vs. traditional learning	126	Fourth year + 1 year of medical training	Medicine	CG: students received a paper booklet providing identical content to the intervention, but replaced media with multiple screenshots and text-based descriptions IG: students received an online multimedia course about aortic valve replacement	<ul style="list-style-type: none"> <li>time N/A</li> <li>computer, website</li> </ul>	Knowledge: 20-item MCQ Skills: 28 standardized tasks and open questions targeted to a procedural understanding of the operation Attitude: questionnaire on current motivation Satisfaction: questionnaire on confidence in the use of computers

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Frith 2003	RCT	USA	eLearning vs. eLearning	75	N/A	Nursing	CG: students received a web-based course on cardiac rhythm interpretation IG: this group worked together on case studies rather than completing them independently. Students in the experimental group also used online chats to enhance their understanding of course concepts	<ul style="list-style-type: none"> <li>6 weeks</li> <li>computer, website</li> </ul>	<p>Knowledge: post-test containing 20-item multiple-choice questions</p> <p>Satisfaction: attitude to computer-assisted instruction (14 bipolar adjectives, each measured on a 7-point scale, and 3 factors, i.e. comfort, creativity, function)</p>
Gerdprasert 2011	RCT	Thailand	eLearning vs. traditional learning	84	Fourth year	Nursing	CG: students received lectures and practical sessions on midwifery IG: students had access to a web-based learning unit on the lecture content for midwifery	<ul style="list-style-type: none"> <li>5 weeks</li> <li>computer capable of supporting interactive graphics, animation and online access</li> </ul>	<p>Knowledge: 15 scenario questions</p> <p>Skills: performance checklist</p> <p>Attitude: 20-item questionnaire, using a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree)</p> <p>Satisfaction: clinical stress questionnaire using a 6-point Likert scale was used for each item ranging from 1 (not stressed) to 6 (highly stressed)</p>
Hauer 2009	RCT	USA	eLearning vs. traditional learning	303	Third year	Medicine	CG: students from the previous year served as historical controls to address the second research question that compared students receiving the intervention to those who did not IG I: students had access to three web-based standardized patient cases IG II: students worked in groups of three and conducted a total of three SP encounters. Students rotated one of three roles in each encounter: clinician conducting the encounter, observer completing the checklist on history-taking and physical examination items, or observer completing the checklist on communication	<ul style="list-style-type: none"> <li>1 hour</li> <li>computer, website</li> </ul>	<p>Skills: checklist</p> <p>Satisfaction: 8-item satisfaction survey with responses on a Likert-type scale of 1 (poor), 2 (fair), 3 (good), 4 (very good), and 5 (excellent)</p>
Jenkins 2008	RCT	USA	eLearning vs. learning	73	Second year	Medicine	CG: students received a traditional lecture and group work IG: students received a computer-assisted instruction tutorial that covered the essentials of skin examination and the terminology used to describe and classify skin lesion morphology and distribution	<ul style="list-style-type: none"> <li>4 days</li> <li>computer, website</li> </ul>	<p>Knowledge: 25-question post-test examination</p>
Juliani 2011	RCT	Brazil	eLearning vs. traditional learning	NA	Fourth year	Nursing	CG: students had to design a manual without the use of the Internet IG: students had to design a nursing schedule via the website	<ul style="list-style-type: none"> <li>time N/A</li> <li>computer, website</li> </ul>	<p>Knowledge: MCQ</p> <p>Satisfaction: research form (interest in the topic)</p>
Kandasamy 2009	Canada		eLearning vs. traditional learning	55	Second year	Medicine	CG: students were presented with the review articles on paediatric stridor IG: this group was given an online computer-assisted module that covered paediatric stridor	<ul style="list-style-type: none"> <li>9 minutes on average</li> <li>computer with online access with WebCT Vista</li> </ul>	<p>Knowledge: MCQ and time completed the online material</p> <p>Satisfaction: questionnaire</p>
Kerfoot 2008	RCT	USA	eLearning vs. eLearning	211	Third year	Medicine	CG: students received web-based training covering benign prostatic hyperplasia and erectile dysfunction topics IG: students received interactive space education covering benign prostatic hyperplasia and erectile dysfunction	<ul style="list-style-type: none"> <li>CG: 2 x 4 weeks IG: 8 weeks</li> <li>computer with email client and online access</li> </ul>	<p>Knowledge: a 40-item adaptive spaced test and 28-item MCQ</p>

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Kerfoot 2010	RCT	USA	eLearning vs. eLearning	52	Third year	Medicine	CG: students received 2 items daily IG: students received daily emails including evaluative and educational components whereby answers to questions were submitted online	<ul style="list-style-type: none"> <li>8 weeks</li> <li>computer with email client, online access for MyCourses course management system</li> </ul>	Knowledge: orthodontic examination form for each patient
Komolpis 2002	RCT	USA	eLearning vs. traditional learning	99	Second year	Dentistry	CG: students received only hard copy of dental records IG: this group used digital records on computers	<ul style="list-style-type: none"> <li>time N/A</li> <li>computer, online access</li> </ul>	Knowledge: orthodontic examination form for each patient Satisfaction: a survey done at the end of the course for acceptance of the web-based examination
Lee 2010	RCT	China	eLearning vs. traditional learning	52	Fourth year	Medicine	CG: students did not receive the workshop, no illness script-related material during their psychiatry rotation IG: students participated in a web-based workshop on clinical reasoning	<ul style="list-style-type: none"> <li>20 minute lecture plus two 75-minute workshops</li> <li>computer, online access</li> </ul>	Knowledge: clinical reasoning problems (CRP) score and diagnostic thinking inventory (DTI) score Satisfaction: 10-item written questionnaire; each item, students rated the statement using a Likert scale (1 = strongly disagree, 6 = strongly agree)
Leong 2003	RCT	USA	eLearning vs. traditional learning	325	N/A	Medicine	CG: students had to prepare a written exercise on unrelated topics IG I: students completed cases on the computer IG II: two computer cases on low back pain/ kidney stones and pneumonia	<ul style="list-style-type: none"> <li>time N/A</li> <li>computer, online access</li> </ul>	Knowledge: a 100-question clerkship final examination that was given throughout the 3-year study period. 16 questions on pneumonia, low back pain, and kidney stones (CC, computer case-related) were included Skills: time to complete the exercise Satisfaction: anonymous questionnaire – statements on a seven-point scale
Lewis 2011	RCT	Canada	eLearning vs. learning	39	Second year	Medicine	CG: students received a PowerPoint® teaching session and were allowed to use two neuroanatomy textbooks IG: students used an access-to-localization tool exploring cranial nerve lesions	<ul style="list-style-type: none"> <li>75 minutes</li> <li>computer, online access</li> </ul>	Knowledge: a 100-question clerkship final examination Satisfaction: questionnaire and statements on a 7-point scale
Lipman 2001	RCT	USA	eLearning vs. traditional learning	130	Second year	Medicine	CG: students were not assigned a password and could not participate in the web discussions IG: students had access to an Internet component and used the application to discuss a series of four cases involving substantial ethical problems	<ul style="list-style-type: none"> <li>time N/A</li> <li>computer, online access</li> </ul>	Knowledge: final written case analyses Satisfaction: subjective evaluations of the course by both students (using a course-evaluation instrument) and faculty (using an evaluation instrument developed for this study)
Lu 2009	cRCT	Taiwan	eLearning vs. traditional learning	147	Second year	Nursing	CG: students received only classroom lectures and skill demonstration IG: students could use a web-based course and were able to view the content on demand with access to a chatroom, bulletin board, and email	<ul style="list-style-type: none"> <li>time N/A</li> <li>computer, online access and intervention software</li> </ul>	Knowledge: intramuscular injection knowledge assessment scale; 9 quiz questions Skills: intramuscular injection skill performance scale, with possible scores ranging from 0 to 100

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Maag 2004	RCT	USA	eLearning vs. traditional learning	95	N/A	Nursing	CG: students independently read and learned from 3 text-based mathematical modules IG I: students independently read and learned from 3 text-based mathematical modules with images included IG II: students viewed the 3 modules in a multimedia format computer screen in the form of a web page	<ul style="list-style-type: none"> <li>1 hour</li> <li>computer, online access</li> </ul>	Knowledge: 25 MCQ Attitudes: 34-item statement asking respondents to specify their level of confidence on a 10-point scale ranging from no confidence at all to complete confidence Satisfaction: student satisfaction survey; the participants were asked to rate aspects of the learning modules on a scale of 1 to 5 (1 indicating strongly disagree and 5 indicating strongly agree)
Mahnekn 2011	RCT	Germany	eLearning vs. traditional learning	96	Fourth year	Medicine	CG: students looked at imaging procedures and reporting in radiography and radiology without access to the eLearning units IG: students looked at imaging procedures and reporting in radiography and radiology with access to the eLearning units and e-case	<ul style="list-style-type: none"> <li>time N/A</li> <li>computer, online access</li> </ul>	Knowledge: test comprised of 20 items, which were randomly chosen from a pool of 117 test items
Manikam 2013	cRCT	United Kingdom	eLearning vs. eLearning	108	N/A	Medicine	CG: students were given access to a dummy learning package incorporating the outcome measures with no formal learning content IG: students used an online acute breathing difficulty learning package	<ul style="list-style-type: none"> <li>4 weeks</li> <li>computer, online access</li> </ul>	Knowledge: post-intervention MCQ assessment Attitudes: questionnaire
Mattheos 2004	RCT	Sweden	eLearning vs. eLearning	39	Second year	Dentistry	CG: students had access only to the case, and reference materials were available through a static web page IG: students had access to cases, and reference materials were available through interactive software	<ul style="list-style-type: none"> <li>5 weeks</li> <li>computer containing the intervention software and online access</li> </ul>	Knowledge: written essay, written comparison between their answer and that of the expert and oral performance Satisfaction: questionnaire
Nkenke 2012	RCT	Germany	eLearning vs. traditional learning	42	Third year	Dentistry	CG: students received didactic lectures and a PowerPoint® presentation IG: students had access to online modules	<ul style="list-style-type: none"> <li>8 weeks</li> <li>computer with online platform and email client</li> </ul>	Knowledge: MCQ Attitudes: questionnaire with answers chosen between 1 and 6 (1 = totally disagree, 6 = totally agree); attendance at lectures Satisfaction: questionnaire
Nkenke 2012	RCT	Germany	eLearning vs. traditional learning	42	Third year	Dentistry	CG: students received a traditional lecture IG: Students had access to traditional face-to-face lectures, but also received emails containing multiple-choice questions on the content of the lectures	<ul style="list-style-type: none"> <li>8 x 45-minute sessions</li> <li>computer with online platform and email client</li> </ul>	Satisfaction: questionnaire
Ochoa 2008	RCT	USA	eLearning vs. traditional learning	38	Third year	Medicine	CG: students received traditional written material IG: students received a web-based interactive program created to teach seizure disorders, including the basic teaching material using an interactive format	<ul style="list-style-type: none"> <li>2 days</li> <li>computer, online access with audio and video support</li> </ul>	Knowledge: 15 MCQ Attitudes: survey using a Likert scale to assess the students' attitudes to learning, motivation, and feedback perception
Palmer 2008	RCT	Australia	eLearning vs. traditional learning	130	Fourth year	Medicine	CG: students received standard lecture material without any additional learning materials other than those recommended to all students IG I: students received same case studies as CG but in an interactive computer-based format and supplemented with detailed feedback IG II: students received both the standard clinical material plus interactive computer-based case studies	<ul style="list-style-type: none"> <li>9 weeks</li> <li>computer with Medici software installed, online access and CD drive</li> </ul>	Knowledge: a 50-item MCQ and 3-item modified question paper Satisfaction: a questionnaire of their perceptions of the value of these resources

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Peroz 2009	RCT	Germany	eLearning vs. traditional learning	85	First and third preclinical semesters	Dentistry	CG: students received a lecture presenting the same content, including the same photos, with the use of PowerPoint®. It was possible for the students to question or discuss during and after the lecture. IG: students received a module including pictures of clinical situations, MRIs and graphics. It was linked with a test in the virtual test module for self-assessment, with case presentations, and further resources	<ul style="list-style-type: none"> <li>as long as they wanted (average:68 minutes)</li> <li>computer, online access</li> </ul>	Knowledge: 17 MCQ and 3 gap text questions Satisfaction: 7 statements about educational and enjoyment values of the teaching methods were given and the students were asked to express their agreement on a 10-point Likert scale (0 = no agreement, 10 = full agreement)
Phadtare 2009	RCT	USA and Brazil	eLearning vs. traditional learning	48	Second and third years	Medicine, nursing, physiotherapy	CG: students received module incorporating a writing workshop for biomedical sciences offered with face-to-face instruction IG: students used a writing workshop conducted in a virtual environment using virtual tools (VoIP, email ) and templates provided as tools	<ul style="list-style-type: none"> <li>time N/A</li> <li>computer with Voice over the PowerPoint®, Internet protocol (VoIP- SKYPE) installed, Writely (now google docs) access and email support</li> </ul>	Knowledge: tested using a 6-subgroup quality scale Satisfaction: Likert scale, with responses ranging from strongly disagree to strongly agree
Raupach 2009	RCT	Germany	eLearning vs. traditional learning	148	Fourth year	Medicine	CG: students received traditional classroom teaching in group study on case histories IG: students received a web-based collaborative teaching module on the differential diagnosis of dyspnea	<ul style="list-style-type: none"> <li>6 weeks</li> <li>web-based collaborative teaching module. A learning management system (Clix) facilitating live chats, asynchronous group discussions and the exchange of documents was used to create the online module</li> </ul>	Knowledge: 68 MCQ (post-test), problem-solving questions (final test) Satisfaction: questionnaire
Raupach 2010	RCT	Germany	eLearning vs. traditional learning	74	Fourth year	Medicine	CG: no description given IG: students received access to an online module to be completed in addition to the traditionally taught module	<ul style="list-style-type: none"> <li>2 hours expected per week over 6 weeks</li> <li>computer with online access for the web-based learning management system (Clix)</li> </ul>	Knowledge: 68 MCQ Satisfaction: survey completed at the start and at the end of the 6-week course
Ricks 2008	RCT	Canada	eLearning vs. traditional learning	23	Third and fourth year	Medicine	CG: students received no intervention and were tested only IG: students completed multimedia-based computerized procedure tutorials	<ul style="list-style-type: none"> <li>45 minutes</li> <li>computer, online access with support for digital images, short video clips, instructional text, Internet, hospital website</li> </ul>	Knowledge: 20-item multiple-choice examination
Romanov 2006	RCT	Finland	2 elearning vs. elearning	85	Third year	Medicine	CG: students received course material offered through conventional technology and were able to have email discussions with an instructor for non-interactive web-based learning IG: students used WebCT group access to the study materials, discussion forums and message system	<ul style="list-style-type: none"> <li>3 weeks</li> <li>computer, online access for WebCT</li> </ul>	Knowledge: 38-item multiple-choice, matching and short-answer questions Satisfaction: "Impact of ICT" consisted of 11 items, and the "Learning experience" consisted of 8 items on a 5-point Likert scale

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Salas 2013	RCT	USA	eLearning vs. eLearning	86	Second to fourth year	Medicine	CG: students received a PowerPoint® presentation IG: students received an online, self-paced, sleep medicine learning module providing sleep education	<ul style="list-style-type: none"> <li>1 month</li> <li>computer, PowerPoint® installed and online access</li> </ul>	Knowledge: measured with a modified version of the Dartmouth Sleep Knowledge and Attitudes survey
SchitteckJanda 2005	RCT	Sweden	eLearning vs. eLearning	28	First year	Dentistry	CG: students were able to watch a sequential web-based video IG: students had access to the same web-based video but split into 8 different parts	<ul style="list-style-type: none"> <li>1 week</li> <li>computer, online access</li> </ul>	<p>Knowledge: written test with 8 questions</p> <p>Skills: performance was rated on a scale from 1 to 6 (from poor to excellent) for each of 6 different stages of hand-washing</p> <p>Attitude: a questionnaire with 10 questions regarding students' attitudes to video-based instruction 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</p>
Smits 2012	RCT	Netherlands	eLearning vs. traditional learning	128	Second year	Medicine	CG: students received photocopies of pages of an occupational medicine textbook, practice guideline material and a scientific article IG: students elaborated 3 occupational medicine eLearning cases on individual computers	<ul style="list-style-type: none"> <li>half a day</li> <li>computer, online access</li> </ul>	<p>Knowledge: 20 questions, divided in multiple-choice, open-ended and true/false questions</p> <p>Attitude: 15 questions on a 5-point Likert scale were used with anchors ranging from disagree to agree</p> <p>Satisfaction: 9 questions: 1 was a general rating for satisfaction (range 1 – 10), 5 questions about satisfaction with the course content (5-point Likert scale, minimum score 5, maximum 25) and 3 questions about satisfaction with learning (5-point Likert scale, minimum score 3, maximum 15)</p>
Spickard 2002	RCT	USA	eLearning vs. traditional learning	95	Fourth year	Medicine	CG: students received a live lecture and then group discussion work IG: students received an Internet-based PowerPoint® slide presentation from the same lecturer with the option of audio	<ul style="list-style-type: none"> <li>time N/A</li> <li>computer, PowerPoint® installed and online access and audio</li> </ul>	<p>Knowledge: an open book examination that had been used on the course for 1 year</p> <p>Satisfaction: students rated their satisfaction with their lecture on a 5-point Likert scale and provided narrative about their experiences with the live lecture and the online lecture</p>
Spickard 2004	RCT	USA	eLearning vs. eLearning	59	Third and fourth year	Medicine	CG: students received an online lecture consisting of an Internet-based PowerPoint® slide presentation with no audio narration IG: students received an online lecture consisting of an Internet-based PowerPoint® slide presentation with audio narration	<ul style="list-style-type: none"> <li>time N/A</li> <li>technology N/A</li> </ul>	<p>Knowledge: post-test included 4 discussion questions that solicited approaches to 4 hypothetical patients</p> <p>Satisfaction: students rated their satisfaction with their lecture on a 5-point Likert scale and they provided narrative about their experiences</p>

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Stain 2005	RCT	USA	eLearning vs. traditional learning	110	Third year	Medicine	CG: students received lectures on general surgery and surgical specialities IG: students received lectures on general surgery and surgical specialities via videoconference	<ul style="list-style-type: none"> <li>6 hours</li> <li>technology N/A</li> </ul>	Knowledge: quiz questions
Stewart 2013	RCT	Australia	eLearning vs. traditional learning	71	N/A	Medicine	CG: students were based on the standard neonatology teaching programme IG: students had access to the standard neonatal educational programme and additional unlimited online access to the multimedia PENSKE Baby Check Learning Module	<ul style="list-style-type: none"> <li>4 hours</li> <li>technology N/A</li> </ul>	Skills: formative assessment of newborn examination using a standardized checklist Satisfaction: measured using a Likert-like questionnaire
Stolz 2012	RCT	Switzerland	eLearning vs. traditional learning	129	Third year	Medicine	CG: students received a normal lecture including a video demonstration and access to a self-directed web-based learning module on smoking cessation IG I: students received a self-directed web-based learning module on smoking cessation IG II: students used patient-centred counseling through role play in small groups: one medical student acted as a smoker and another acted as the physician following a standardized case description IG III: students supervised interaction with real patients; counselling encounters with real patients who smoke	<ul style="list-style-type: none"> <li>2 hours</li> <li>computer, online access</li> </ul>	Knowledge: 20 MCQ Skills: 12-item OSCE
Subramanian 2012	RCT	USA	eLearning vs. traditional learning	30	Third year	Medicine	CG: students received two PowerPoint® presentations IG: students had access to a web-based learning course	<ul style="list-style-type: none"> <li>1 hour</li> <li>computer, online access and software for the web-based StepStone Interactive Medical Software</li> </ul>	Knowledge: 40-question post-intervention test; long-term retention was tested using a 40-question test 22 days after the first test
Succar 2010	RCT	Australia	eLearning vs. traditional learning	147	N/A	Medicine	CG: students received traditional methods of teaching and no access to the intervention IG: students in this group not only underwent traditional teaching but were also given access to a Virtual Ophthalmology Clinic	<ul style="list-style-type: none"> <li>time N/A</li> <li>computer, online access</li> </ul>	For knowledge and satisfaction, a 20-item multiple-choice ophthalmic knowledge-based pre-test and post-test and student satisfaction questionnaire were administered
Toumas 2009	cRCT	Australia	eLearning vs. traditional learning	236	Second year	Pharmacy	CG: students worked in small group workshops IG: students used an Internet-based tutorial for which they could review any part as many times as they wished	<ul style="list-style-type: none"> <li>15 minutes</li> <li>computer and online access</li> </ul>	Skills: post-test assessing their inhaler technique against a checklist
Truncali 2011	RCT	USA	eLearning vs. traditional learning	94	First 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"> <li>3 days before lecture until 1 day before OSCE</li> <li>computer (Java enabled) and online access</li> </ul>	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' feelings 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 they had to self-learn the topic which also allowed online discussion	<ul style="list-style-type: none"> <li>time N/A</li> <li>computer and online access</li> </ul>	Knowledge: MCQ Satisfaction: questionnaire



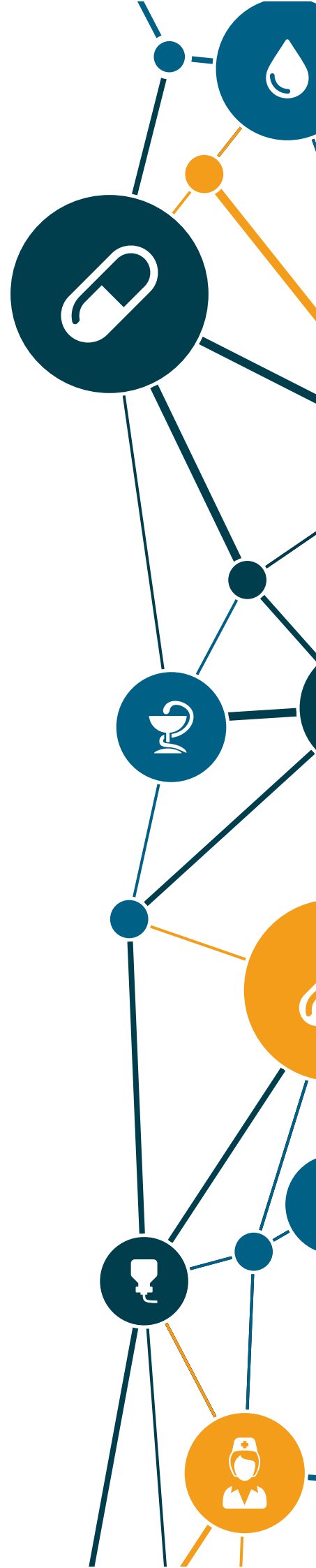
STUDY ID	Methods			Participants			Interventions		
	STUDY DESIGN	LOCATION	COMPARISON	TOTAL NUMBER	YEAR OF STUDY	HEALTH-CARE SPECIALITY	CHARACTERISTICS	TIME AND TECHNOLOGY	TEST/OUTCOMES
Yeung 2012	RCT	United Kingdom	eLearning vs. traditional learning	78	Second year	Medicine	CG: students received a text/image-based document IG: students received an online module with different views and an unlimited time allocation	<ul style="list-style-type: none"> <li>time N/A</li> <li>computer and online access</li> </ul>	Knowledge: MCQ Satisfaction: subjective questionnaire using a 5-point Likert scale

CG = Control group  
IG = Intervention group

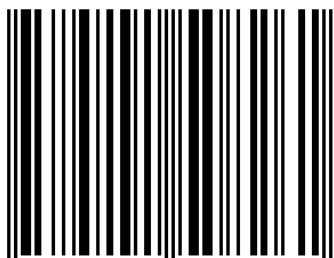
\* Publication contained two studies.







ISBN 978 92 4 1508261



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