Health technology assessment of online eLearning for post-registration health professionals' education

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ABSTRACT

Aim: The overall aim of this thesis was to undertake and report the findings of a health technology assessment (HTA) on the effectiveness, cost-effectiveness and acceptability of online and LAN-based eLearning, and blended learning, among post-registration healthcare professionals.

Methods: This HTA comprised three studies. The first study was a systematic review of 93 randomised controlled trials evaluating the effectiveness of online and LAN-based eLearning on physicians' knowledge, skills, attitude and satisfaction. The second study compared the cost, cost-savings and return on investment between a blended and a face-to-face advanced cardiac life support course for physicians in Singapore. The third study was an online survey that assessed the acceptability of the technology among a sample of optometrists and opticians in Singapore and their scope of practice, primary eye care knowledge, views on extended roles in primary eye care, preferred mode of learning for continuing professional education, and referral behaviour.

Results: The systematic review showed that online and LAN-based eLearning or blended learning compared with self-directed or face-to-face learning resulted in higher post-intervention knowledge scores (21 studies; small to large effect size; very poor quality); higher post-intervention skills scores (seven studies; large effect size; low quality); higher attitude scores (one study; very low quality); higher post-intervention satisfaction (four studies; large effect size; low quality); and higher post-intervention practice or behaviour changes (eight studies; large effect size; low quality) among physicians in the intervention groups. Fourteen studies compared eLearning with other forms of eLearning. Among these, four studies reported higher post-intervention knowledge scores (large effect size; very low quality) for participants in the intervention group. Unintended or adverse effects of the intervention were not reported among the included studies.

Ninety-three studies (N=16,895) were included of which seventy-six studies compared ODE (including blended) vs self-directed/face-to-face learning.

Overall the effect of ODE (including blended) on post-intervention knowledge, skills, attitude, satisfaction, practice or behaviour change and patient outcomes was inconsistent and ranged mostly from no difference between the groups to higher post-intervention score in the intervention group (small to large effect size, very low to low quality evidence).

Twenty-one studies reported higher knowledge score (small to large effect size; very low quality) for the intervention while 20 studies reported no difference in knowledge between the groups. Seven studies reported higher skill score in the intervention (large effect size; low quality) while thirteen studies reported no difference in skill score between the groups. One study reported higher attitude score for the intervention (very low quality), while 4 studies reported no difference in attitude score between the groups. Four studies reported higher post-intervention physician satisfaction with the intervention (large effect size; low quality), while six studies reported no difference in satisfaction between the groups. Eight studies reported higher post-intervention practice or behaviour change for the ODE group (small to moderate effect size; low quality) while five studies reported no difference in practice or behaviour change between the groups. One study reported higher improvement in patient outcome, while three others reported no difference in patient outcome between the groups. None of the included studies reported any unintended/adverse effects, cost-effectiveness of the interventions. Although the review only focused on post-registration medical doctors, the technology could be used for the interprofessional education of post-registration medical doctors and other healthcare professionals. Such an initiative would encourage collaborative learning and facilitate task-shifting, which could address the problem of fragmentation in health care.

Although eLearning and blended learning technology interventions have been implemented, primary studies have not assessed their cost-effectiveness. Hence, to ascertain the technology's cost-saving potential, we used a blended advanced cardiac life support (B-ACLS) course as an exemplar and compared its cost to face-to-face advanced life support (F-ACLS) training. The analysis showed that

the annual cost of F-ACLS training (USD$72,793) was 1.7 times higher than B-ACLS training (USD$43,467). The discounted total cost of training over the life of the course (5-years) was SGD $107,960 for B-ACLS and S$280,162 for F-ACLS. The cost of productivity loss accounted for 52% and 23% of the costs for F-ACLS and B-ACLS, respectively. B-ACLS yielded a 160% return on the money invested, yielding $1.60 for every dollar spent. There would be a 61% saving for course providers if they delivered a B-ACLS instead of F-ACLS course.

The effectiveness component of the HTA showed that online eLearning and blended learning is as effective as traditional learning and has cost-saving potential. We also sought to determine if this technology could be used to train and equip optometrists and opticians in Singapore to take on an extended role in primary care, which would allow some simple primary eye care tasks to be shifted from ophthalmologists to optometrists and ease healthcare access issues at specialist hospital outpatient clinics. The survey of optometrists showed that the current roles of opticians and optometrists in Singapore were limited to diagnostic refraction (92%); colour vision assessment (65%); contact lens fitting and dispensing (62%) amongst others. The average self-rated primary eye care knowledge score was 8.2 ± 1.4; (score range 1-10; 1 = very poor, 10 = excellent). Average self-rated confidence scores for screening for cataract, diabetic retinopathy, chronic glaucoma and age-related macular degeneration were 2.7 ± 1.5; 3.7 ± 1.9; 4.0 ± 1.0 and 2.7 ± 1.5, respectively. Three fourths of the optometrists surveyed felt that they should undertake regular continuing professional education (CPE) to improve their primary eye care knowledge. Blended learning (eLearning and traditional face-to-face lectures) was the most preferred mode (46.8%) for CPE delivery.

Conclusions: Overall, the findings from the HTA provide evidence of effectiveness, cost-saving of online eLearning and blended learning for training medical doctors and the acceptance of the technology in a local context to facilitate its wider adoption for training post-registration healthcare

professionals'. These research outputs would have direct impact on the adoption of online eLearning, blended learning technologies in universities and educational institutes across the region with consequent impacts on post-registration health professionals' education and policy. The results of learning will serve as a guide for policy makers to decide on investment in the learning technology and to learn about the associated factors, which would influence its adoption. This thesis resulted in three papers, of which one has been accepted for publication, the two other papers are under review.

STATEMENT

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LIST OF ABBREVIATIONS

SR – Systematic review

RCT – Randomised controlled trial

PRISMA – Preferred Reporting Items for Systematic Reviews and Meta-Analyses

LAN – Local area network

LMS – Learning management systems

HTA – Health technology assessment

B-ACLS – Blended advanced cardiac life support course

F-ACLS – Face-to-face advanced cardiac life support course

OOB – Optometrists and Opticians Board

CME – Continuing medical education

CPD – Continuing professional development

SFATC – Singapore First Aid Training Centre

Traditional learning – Face-to-face learning or self-directed learning

IPE – Interprofessional education

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OVERVIEW OF THESIS

This thesis is a health technology assessment (HTA) of online and LAN-based eLearning and blended learning conducted among post-registration medical doctors and optometrists. The technology assessment assessed 1) effectiveness of the technology for training medical doctors worldwide 2) cost-saving of a blended advanced cardiac life support course (B-ACLS) among post-registration medical doctors in Singapore and 3) acceptance of this educational technology for training optometrists for role expansion in Singapore. An overview of the three key studies that form the basis of this thesis is presented in Table 1.

Chapter I provide the background to this thesis. It highlights the shortage of healthcare professionals, especially post-registration health professionals, caused by a brain drain of specialists from public to private sector and its impact on healthcare access. ELearning is being used worldwide and in Singapore to train health professionals. However, evidence of its effectiveness, cost-effectiveness and acceptance for training post-registration health professionals is sparse. Third, we propose that eLearning could be used to train post-registration healthcare professionals.

Chapter II assesses the effectiveness aspect of the health technology assessment. It presents the methods and results of a Cochrane systematic review of the effectiveness of online and LAN-based eLearning for medical doctors' education.

Chapter III addresses the cost aspects of the health technology assessment by comparing cost of the blended learning with face-to-face learning using blended advanced cardiac life support (B-ACLS) course as an exemplar.

Chapter IV assesses the applicability and acceptance online eLearning or blended learning to train optometrist for an extended primary care role, to address workforce shortage in Singapore and Chapter V summarises the findings from the HTA and discusses its implications for practice and policy.

Table 1: Overview of studies conducted and included in the thesis

	Chapter II	Chapter III	Chapter IV
Study design	Systematic review of RCTs	Economic evaluation of costs	Cross-sectional survey
Participants	Post-registrations doctors working in academia, hospitals and clinics	Medical doctors participating in ACLS courses	Optometrists and opticians registered with Singapore OOB
Aims	To systematically review the effectiveness and cost-effectiveness of online eLearning interventions for post-registration medical doctors	To appraise the cost, cost-savings and return on investment of a B-ACLS course vs a F-ACLS course	To ascertain the feasibility of eLearning to train optometrists and opticians in primary eye care in Singapore
Methods	A search for RCTs, cRCTs and quasi-randomised studies of eLearning was conducted across nine databases. Studies that compared eLearning with traditional learning, or other forms of eLearning, were included. The outcomes of interest were participants' knowledge, skills, attitude and satisfaction.	B-ACLS and F-ACLS courses are offered in two training institutes in Singapore. Direct and indirect costs of training were obtained from one of the training providers. Major costs included hardware, software, maintenance, installation, training and forfeited income.	A cross-sectional survey of optometrists registered with the OOB in Singapore was conducted using a self-administered questionnaire. The outcomes assessed were primary eye care knowledge and the feasibility of using eLearning for CPE/CPD.
Data collection year	2015 – 2017	2016	2016 - 2017
Data analysis	Mean differences and risk ratios were used to summarise continuous and dichotomous (categorical) outcomes; variance was expressed as 95% CIs. Pooled estimates were computed if studies were homogenous.	The annual and lifetime cost of B-ACLS and F-ACLS was computed. Return on investment was computed using cost-savings over total cost if B-ACLS was used instead of F-ACLS.	Determinants of eLearning use among optometrists/opticians were assessed through between group comparisons using a logistic regression model.

ACLS: advanced cardiac life support; B-ACLS: blended advanced cardiac life support; CPD: continuing professional development; CPE: continuing professional education; F-ACLS: face-to-face advanced cardiac life support; OOB: Optometrists and Opticians Board.

THESIS RATIONALE

Rationale for the topic

There is a worldwide shortage of healthcare professionals.[1] In Singapore, two-thirds of all doctors, and a third of doctors in the public sector, are foreign-educated.[2] Singapore also invites nurses from other countries—an estimated 30% of all nurses working in the country are foreigners.[3] Singapore is also facing a 'brain drain' of skilled specialists who move from public to private hospitals, which results in a shortage of specialists, care fragmentation and lack of timely access to specialist public acute care.[4] Right-siting cases (the provision of healthcare in the appropriate setting) from specialist outpatient clinics to primary care has been suggested as a solution to offload the burden on specialist outpatient clinics, but unfortunately, a lack of training in handling such cases has been cited as a barrier by primary care professionals.[5] ELearning[6] and task-shifting[7] have been proposed as ways to address healthcare professional shortages. Studies worldwide have highlighted the versatility of eLearning in providing a ubiquitous training and learning environment for busy healthcare workers[8-10] and its impact on health care downstream. In Singapore, eLearning is being used widely to train medical professionals. There are several reasons to use online eLearning to train post-registration health professionals. For example, the technology 1) actively engages the learner in the learning process; 2) empowers and transforms the teacher from a subject-matter expert to a facilitator who can encourage students to seek answers online; 3) provides ubiquitous access to content, which encourages the busy post-registration health professional to learn at his or her own pace; 4) increases accessibility to advice, opinion and learning support; 5) accommodates tailor-made content to suit different learning styles (auditory learner, visual learner, kinaesthetic learner); 6) provides online assessments that facilitate transparency in the learning process and help identify learners' strengths and weaknesses, which can then be addressed; 7) allows for efficient archiving of learner's work, task assignments and tracking of their grades; 8) facilitates collaborative work, allowing learners to work in small

groups and participate in problem-solving and project-based learning; and 9) helps teachers to reduce their reliance on didactic lectures, thus freeing their time for patient care.

Rationale for different participants

Interprofessional education (IPE) is as an important strategy for preparing health professionals for present and future practice. The need for IPE stems from the complex, multifaceted nature of healthcare, and the growing body of research that demonstrates effective collaboration among multiple healthcare professionals is essential for the provision of effective and efficient care. Many studies of eLearning worldwide have shown its effectiveness for training nurses,[11] physiotherapists,[12] pharmacists[13] and optometrists.[14] This HTA aims to assess the effectiveness, cost-effectiveness and acceptability of the technology for training post-registration medical doctors. Given the global push towards IPE, it was hypothesised that any technology found to be effective and cost-effective for training medical doctors, could also be applied to train other healthcare professionals including optometrists and opticians.

Rationale for the choice of methods

There has been exponential growth in the use of health technologies worldwide. This rapid diffusion of health technologies has created a challenge for governments worldwide who must find ways to manage and spend finite resources on technologies that provide the best health outcomes for the lowest cost.

HTA is a method that systematically evaluates the effects, cost-effectiveness, safety, organisational implications, and the social, legal and ethical considerations associated with the introduction of a health technology in health policy development.[15] Health technologies include an array of pharmaceutical interventions, diagnostic devices and learning technologies in health. In the past, policymakers only conducted a HTA when a technology was expensive.

However, more recently, technology assessment has become mandatory to ascertain the economic viability of a technology before it is adopted. A lack of long-term impact assessment in a HTA may undermine its importance and value. The global expansion of HTA, its variable implementation has generated greater interest from policy makers and donors about the value and return on investment of the technology.[16] A ROI analysis can serve as an early guide of potential health economic impact of a health technology.

One class of health technology that has been used widely for training healthcare professionals is online eLearning. Although several reviews in the literature have assessed the effectiveness of online eLearning in medical education,[10,17-21] each one has had methodological limitations, e.g. the results from heterogeneous study designs were included, the methodological quality of primary studies was not assessed, or the pooling of results was not explicitly stated.

As such, a HTA of online eLearning to understand the effectiveness, cost and acceptability of the modality for training post-registration healthcare professionals was considered a timely endeavour.

AIMS

The overall aim of this thesis was to undertake and report the findings of a HTA on the effectiveness, cost-effectiveness and acceptability of online and LAN-based eLearning, and blended learning, among post-registration healthcare professionals.

Specifically, this study looked to address the following research aims:

I. A systematic review of the literature to ascertain:
    a. Whether online and LAN-based eLearning is effective, i.e. whether online eLearning interventions compared with traditional

learning lead to an improvement in knowledge, skills, attitudes and satisfaction among post-registration medical doctors.

b. Which pedagogical approaches and delivery modes are used in online and LAN-based eLearning for training post-registration medical doctors?

II. A cost evaluation to ascertain whether:

a. Online and LAN-based eLearning is cost-effective in comparison to traditional learning in improving knowledge, skills, attitudes and satisfaction among post-registration medical doctors.

b. A blended versus a face-to-face ACLS course is cost saving and provides a higher return on investment.

III. A prospective cross-sectional study to assess:

a. Knowledge of primary eye care among post-registration opticians and optometrists in Singapore.

b. The feasibility/acceptability of online eLearning programs (continuing professional education) for training optometrists and opticians in Singapore.

Online eLearning is gaining popularity for training post-registration health professionals'. At this juncture, it is important to assess the effectiveness and cost-effectiveness of this learning mode to inform its usage worldwide. Chapter II describes a systematic review of evidence from randomised controlled trials (RCTs) of online eLearning for medical doctors. The systematic review was developed to address aims Ia, 1b and IIa, Chapter III describes a cost and return on investment study developed to address aims IIb, and Chapter IV describes an online survey, developed to addresses aims IIIa and IIIb.

HEALTH TECHNOLOGY ASSESSMENT METHODS

Definition of health technology assessment

Health Technology Assessment (HTA) systematically evaluates the effects, cost-effectiveness, safety, impacts, organisational implications, and the social, legal and ethical considerations associated with a health technology in a transparent, unbiased and robust manner.[15]

Physical nature of the technology

Health technology encompasses a broad range of technologies including drugs; biologics; devices; equipment and supplies; medical and surgical procedures; public health programs; support systems; and organisational and managerial systems.[22] In this HTA, we evaluated online and LAN-based eLearning and blended learning technologies.

Purpose of the application

Health technologies can be broadly grouped according to their healthcare purpose and into technologies aimed at 1) prevention; 2) screening; 3) diagnosis and treatment; 4) rehabilitation; 5) education; and 6) palliation. Some technologies are a hybrid or include a combination of purposes.[22] This HTA evaluated the use of online and LAN-based eLearning, and blended learning, for post-registration health professionals' education aimed at all the above-mentioned purposes.

Stage of diffusion

A health technology may be at different stages of diffusion and maturity. It could be a future technology that is in a conceptual or early stage of development, an experimental technology undergoing clinical evaluation in humans, an established technology that is already diffused and considered a standard for a particular condition, or an obsolete or abandoned technology that has been found ineffective or harmful.[22] This HTA focuses on an investigational technology.

Purpose of the health technology assessment

This HTA aims to inform universities, government ministries of education and healthcare professional associations on the effectiveness, cost and acceptability of eLearning technology, to aid their decision-making around technology acquisition and management.

Health technology assessment orientation

HTAs have three basic orientations:[22]

1. Technology-oriented assessments, which are intended to determine the characteristics or impacts of particular technologies.
2. Problem-oriented assessments, which focus on solutions or strategies for managing a particular disease, condition, or other problem for which alternative or complementary technologies might be used.
3. Project-oriented assessments, which focus on a local placement or use of a technology in a particular institution, program or other designated project.

This HTA is a technology-oriented assessment that aims to address a problem: the shortage of healthcare professionals and the consequence of this on healthcare access.

Health technology assessment framework

We conducted the HTA using the following steps:

1. identify the topic
2. narrow down to a focused problem
3. develop a search strategy
4. retrieve the evidence
5. appraise the evidence
6. synthesize the evidence

7. contextualize the evidence (with or without economic data)
8. formulate recommendations.

The HTA was conducted as follows:

1. A Cochrane systematic review of evidence from RCTs was conducted as this study design provides the highest level of evidence in the evidence hierarchy. The review focused on post-registration medical doctors. We hypothesised that any technology found to be effective and cost-effective for training medical doctors could be applied to train other healthcare professionals as well.
2. Since the cost-effectiveness of online and LAN-based eLearning was not assessed in the identified RCTs, we compared the cost, cost-savings and return on investment of a B-ACLS course, as cost evaluation of all online eLearning approaches was beyond the scope and time frame of this degree program.
3. To contextualise the use of online eLearning in Singapore and to assess its acceptability among optometrists and opticians for training for an extended primary eye care role, we conducted a cross-sectional online survey.

However, apart from the technical aspects mentioned above, there are two broad reasons why online eLearning needs to be evaluated. First, since online eLearning is used widely in Singapore, a critical review of its strengths and weaknesses is needed, and second, a HTA such as this has the potential to provide robust evidence for policymakers, hospital stakeholders and universities to inform their investment decisions. It is envisaged that the knowledge gained through this HTA will inform the application and development of training solutions for post-registration healthcare professionals in Singapore and elsewhere.

CHAPTER I: BACKGROUND

SHORTAGE OF HEALTHCARE PROFESSIONALS

Healthcare workers are central to any health system: their activities aim to enhance the health of the community, nation or region they serve. However, medical professionals are distributed unevenly across the globe.[1] Two-thirds of doctors in Singapore and a third of doctors in the public sector are foreign-educated.[2] Singapore also invites nurses from other countries—an estimated 30% of all nurses working in the country are foreigners and more than a quarter of the doctors in the public healthcare sector are foreigners.[3] Developed countries such as Singapore are also experiencing a rapid growth in medical tourism within the private sector, which can lead to a 'brain drain' of skilled specialists, who move from public to private hospitals to serve foreign patients, resulting in a shortage of specialists, care fragmentation and lack of timely access to specialist public acute care.[4] Addressing these shortfalls requires a substantial investment in training - it has been proposed that eLearning could help address some of these shortfalls in Singapore.[23]

HEALTHCARE ACCESS

Healthcare systems worldwide and in Singapore are becoming increasingly fragmented and face issues with providing timely access to primary, secondary and tertiary care. This has a negative impact on healthcare utilisation, costs and access to downstream care.[4,24] This problem is discernible in Singapore where specialist outpatient clinics treat a large number of simple cases (dry eyes, early stage cataract, annual eye screening, refraction services), which increases waiting times for appointments at public hospitals. Primary eye care professionals such as optometrists and opticians could manage such cases.[25-27] Right-siting cases (the provision of healthcare in the appropriate setting) from specialist outpatient clinics to primary care has been suggested as a solution to offload the burden from specialist outpatient clinics, but unfortunately, a lack of training in handling such cases has been cited as a barrier by primary care professionals.[5]

Optometrists provide a wide range of primary eye care services including refraction, prescription of optical appliances and the detection of ocular abnormalities through advanced diagnostic techniques, e.g. binocular vision tests, ophthalmoscopy or fundoscopy, retinoscopy, slit-lamp examination, tonometry and visual field testing. They also refer patients to ophthalmologists for further treatment if necessary.[28,29] On the other hand, opticians commonly work together with optometrists. They perform refraction services; interpret prescriptions from medical practitioners and optometrists; supply, prepare and dispense optical lenses (except contact lenses); and perform the fitting and adjustment of optical appliances. Although optometrists and opticians provide high level patient care, the scope of their practice typically depends on their level of training, experience and competence.[28,29] Notwithstanding this, not much is currently known about optometrists' and opticians' knowledge of primary eye care, their confidence in managing minor eye conditions, and their willingness to take on additional training to fulfil an extended primary eye care role, particularly to address Singapore's primary eye care related healthcare access issues.

INTERPROFESSIONAL EDUCATION

Interprofessional education (IPE) is gaining traction as an important strategy for preparing health professionals for present and future practices.[30-32] the need for IPE stems from the complex, multifaceted nature of healthcare[33] and the growing body of research demonstrating that effective collaboration among multiple healthcare providers is essential for the provision of effective and efficient care.[34] IPE is useful in both academic and practice settings[35] for improving professional individuality whilst facilitating communication between healthcare professionals.[36-38]it also allows knowledge and skills sharing between professions and facilitates better understanding of shared values and respect among healthcare professionals.[39]a recent systematic review of IPE showed significant improvements in pre- and post-status scores in knowledge, skills, and attitudes of learners in various disciplines of healthcare.[40] several other reviews have also showed that IPE increases learners' collaborative knowledge and skills.[41,42]

Continuing IPE or post-registration education refers to IPE that occurs after a healthcare professional acquires licensure and is practising in the work place.[43] According to Barr, IPE is 'ongoing learning with, from, and about other professions to improve collaboration and the quality of care'.[44(pg148)] The definition of IPE outlined above stresses the need for explicit interprofessional interaction between participants, as it is argued this interactivity promotes the development of the competencies required for effective collaboration.[34] Learning methods that enable interactivity are therefore a key feature of IPE. ELearning and blended learning are some of the interactive learning methods used in IPE.

ELEARNING

Lifelong learning, upskilling and continuous professional development are more important than ever for medical professionals. Resources and strategies to promote eLearning are often associated with technology and the educational landscape has changed rapidly with technological advancements. As technology has evolved, education has moved from using chalk/blackboards, over-head projectors, televisions, computers and LAN computer-networks to using the Internet. Similarly, educational content, which was earlier delivered through the post, is now being delivered through various other modes such as CD-ROMS, emails and the Internet. Thus eLearning evolved as new technologies have emerged.[45]

ELearning is to be distinguished distinct from 'distance education'. The earliest development of a distance learning course dates back to the 1800s.[45] Distance education refers to learning that takes place at a distance, without an instructor or any technological requirements, whereas eLearning is a form of distance learning where all forms of learning and teaching are conducted using information and communication technologies (ICT).

ELearning definitions

Several definitions of eLearning exist in the literature. The American Society for Training and Development defines eLearning as 'a broad set of applications and processes that include web-based learning, computer-based learning, virtual classrooms, and digital content delivered via the Internet, intranets, audio- and videotape, satellite broadcast, interactive TV, and CD-ROM'.[46(pg xxi)] Sangrà et al. proposed an inclusive 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'.[47(pg 146)]

ELearning can be broadly grouped into two categories: synchronous eLearning and asynchronous eLearning. Synchronous eLearning is real-time learning where both the learners and the teacher are online and interacting with each other at the same time from different locations. Learning resources are delivered and received via mobile, video conference, the Internet or chat. With this type of learning participants can share ideas, interact with each other and receive detailed queries and solutions. In comparison, asynchronous eLearning is a pause-and-resume type of learning where the learner and teacher are not online at the same time. Asynchronous eLearning uses technologies such as email, blogs, discussion forums, eBooks, CDs and DVDs, etc. Students can learn at any time, download documents, and chat with teachers and co-learners.

ELearning components

Creating eLearning material involves several steps including content development, content management and content delivery. Content comprises all instructional materials, which can range in complexity from discrete items to large instructional modules. Examples include tutorials, case-based learning, hypermedia, simulations and game-based learning modules. Content developers

use instructional designs and pedagogical principles to produce learning objects and instructional materials.

Content management involves administrative functions such as storing, indexing, and cataloguing of eLearning content to make it available through portals, repositories, digital libraries, search engines and ePortfolios using learning management systems (LMS). LMS is software that facilitates the delivery and tracking of eLearning. LMS can serve several functions beyond content delivery: it can simplify and automate administrative and supervisory tasks, track learners' achievement of competencies, and operate as a repository for instructional resources 24 hours a day. Content delivery can be either synchronous or asynchronous. Synchronous delivery refers to real-time, instructor-led eLearning, where all learners receive information simultaneously and communicate directly with other learners. Examples include teleconferencing (audio, video, or both), Internet chat forums, and instant messaging. With asynchronous delivery, the transmission and receipt of information does not occur simultaneously; learners are responsible for pacing their own self-instruction and learning. The instructor and learners communicate via email or feedback technologies, but not in real time. A variety of methods can be used for asynchronous delivery, including email, online bulletin boards, listservs, newsgroups and Weblogs.

ELEARNING IN THE EDUCATION OF HEALTHCARE PROFESSIONALS

In the era of the Internet, eLearning is being increasingly used in the education of healthcare professionals. The eLearning approach to teaching and learning uses electronic media and devices as tools for improving access to training, communication and interaction.[48] It not only differs from traditional learning (i.e. face–to–face learning in a classroom environment) in the medium by which learning is delivered,[49] but also in the teaching and learning approaches used. ELearning can be entirely driven by technology (the full eLearning approach), or

can be a mix of traditional and computer–based methodologies (blended learning). It provides many opportunities for universities, including a reduction in delivery costs,[50] increased scalability,[51] improved access and availability to relevant experts and novel curricula through the removal of geographical and temporal barriers.[52] ELearning has been increasingly used in medical and healthcare education in recent times, including in the training of post-registration healthcare professionals. Universities have also started experimenting with eLearning pedagogy.[53]

ELearning use in Singapore health care

Two of the three medical schools in Singapore use eLearning in their undergraduate medical training including team-based learning and the flipped classroom approach (i.e. blended learning). Specifically, the Lee Kong Chian School of Medicine (LKCMedicine) uses technology-enabled team-based learning (TBL),[54] whereas Duke-NUS Graduate Medical School uses TeamLEAD, a learning strategy developed by Duke-NUS educators, which incorporates TBL principles. Lectures, readings and eLearning on a given topic are completed before class; in-class activity focuses on assuring understanding, applying principles, and solving problems within student teams facilitated by the faculty.[55] The Singapore First Aid Training Centre offers ACLS courses for physicians. Poon et al reported that an integrated approach to eLearning enhanced both subjective and objective knowledge of electroencephalograms for doctors and nurses in a neonatal intensive care unit.[56] Zhang et al. evaluated a blended teaching and smartphone application model for psychiatry education and found favourable results for the blended learning group.[57] In a systematic review of online eLearning conducted among undergraduate health professionals, online eLearning was found to be equivalent to traditional learning.[6] Although eLearning and blended learning are used widely, their effectiveness, cost-effectiveness and acceptability among post-registration health professionals in Singapore remains unclear. Moreover, systematic reviews examining the effectiveness of online training and eLearning for medical doctors have included

observational studies with several methodological deficiencies and a high risk of bias, which limits their usefulness.[10,17,19-21,58]

This HTA is a formal response to the system gaps identified in Singapore and the need for evidence to facilitate an effective, informed response to health policy and health system management. The HTA seeks to ascertain:

1. The effectiveness of online and LAN-based eLearning, and blended learning, through a Cochrane systematic review of evidence from RCTs. The review focused on post-registration medical doctors. Given the global push for IPE, and usage of eLearning for training other post-registration healthcare professionals, we hypothesised that any technology found to be effective and cost-effective for training medical doctors could be applied to train other healthcare professionals.

2. The cost-effectiveness of online and LAN-based eLearning, and blended learning. Since there was a lack of available evidence on the cost and cost-effectiveness of the technology, we compared the cost, cost-savings and the return on investment of a B-ACLS course as an exemplar. Cost evaluation of all online eLearning approaches was beyond the scope and time frame of this degree program.

3. The applicability and acceptability of online and LAN-based eLearning, and blended learning. A cross-sectional online survey of optometrists and opticians in Singapore was conducted to contextualise the use of eLearning and blended learning in Singapore and to assess its acceptability for training optometrists and opticians for an extended primary eye care role.

CHAPTER II: SYSTEMATIC REVIEW OF THE EFFECTIVENESS OF ONLINE AND LAN-BASED ELEARNING

CHAPTER OVERVIEW

Chapter I provided the background to this thesis and described the issues surrounding the shortage of healthcare professionals worldwide and in Singapore, and discussed ways the shortage could be addressed through the use of online eLearning. This chapter assesses the effectiveness of online and LAN-based eLearning, and blended learning, through a Cochrane systematic review of evidence from RCTs. The 'Introduction' describes the condition and interventions of interest. The 'Methods' describes the study inclusion and exclusion criteria, the type of interventions, participants, outcomes and data analysis. The 'Results' presents a narrative description of the risk of bias among the included studies and the effects of the interventions. The final section of the chapter provides a summary of the main results of the review, its overall completeness, applicability and quality. It also compares the findings with other studies and discusses their implications for practice and research.

INTRODUCTION

A direct correlation exists between healthcare worker availability, coverage of health services and population health outcomes.[59,60] Currently, there is a shortage of healthcare professionals worldwide, especially in low and middle income countries (LMICs).[61,62] The poorest communities of Africa, Asia and Latin America have less than 10% of the world's trained healthcare workers while they face 80% of the global burden of disease and death. The shortage of healthcare workers coupled with the added burden of 'brain drain' (defined as the emigration of highly trained or qualified people from a particular country), is aggravated by the inadequacy of many training programs.[63] Addressing these shortfalls through the adequate training of the healthcare workforce, especially

post-registration medical doctors, requires innovative cost- and time-effective methods.

ELearning (i.e. the use of technology and electronic media to disseminate information for the purpose of education) may be one such innovation. ELearning encompasses a variety of interventions characterised by their tools, content, learning objectives, pedagogical approaches and delivery settings. ELearning can include, but is not limited to, online (LAN-based) and offline computer-based eLearning, Massive Open Online Courses (MOOCs)[64], virtual reality environments (VREs),[65] simulation,[66] mobile learning (mLearning)[67] and digital game-based learning (DGBL).[68]

Medical education has undergone rapid change in the last decade primarily due to the expansion of the Internet, advances in the diagnosis and management of diseases, and improvements in healthcare delivery.[69-72] The traditional model of medical education has evolved into a dynamic system, moving from an instructor/student focused presentation session, to a student-centred process, where students can learn at their own pace. Furthermore, the student's role has changed, moving from a receiver of knowledge and content, to being a continuous learner. Similarly, the instructor's role has evolved to that of a mentor, guiding students to acquire knowledge and improve their learning skills.[73]

Lifelong learning is a concept adopted by governments and educational institutions worldwide that acknowledges the need for continuous learning irrespective of one's profession. Lifelong learning has always been formally considered an ethical obligation for medical doctors[74] - it is critical doctors keep up-to-date with medical advances to ensure the delivery of high quality health care.[75]

The traditional 'lecture and test' method of teaching provides learners with plenty of information but not the skills to update and replace this knowledge as needed.[76] Consequently, the content, structure and delivery mode of these training programs often fails to equip healthcare professionals with the necessary skills and knowledge required to keep pace with the changing health needs of the populations they serve.[77] ELearning has the advantage of providing easy access and time flexibility. Research shows learning is influenced more by the content and instructional strategy than by the type of technology used to deliver the content;[78] in other words, the design of the course determines its effectiveness on learning.[79] There are many learning theories. According to behaviourists, it is the observable behaviour, and not what is going on in a learner's head, that indicates whether or not something has been learned.[80] In contrast, some educators argue that not all learning is observable and that there is more to learning than a change in behaviour.[80] Such views led to a shift away from behaviourist to cognitive learning theories.[80] According to cognitive psychologists, learning involves the use of memory, motivation, and thinking, and reflection plays an important part in learning. Learning is an internal process; the amount learned depends on the processing capacity of the learner, the amount of effort expended during the learning process, the depth of the processing and the learner's existing knowledge structure.[78,80] In the early 1990s, instructional design in education moved to a constructivist perspective. Constructivist theorists claim that learners interpret information and the world according to their personal reality, and that they learn by observation, processing and interpretation, information which they then internalise into personal knowledge.[81,82] Learners learn best when they can contextualise what they have learned for immediate application and personal meaning.[78,80] In 2004, theorist George Siemens advanced a learning theory for the digital age, which he called connectivism. The theory addresses the role technology plays in the learning process. Within connectivism, learning happens in many different ways. Learning is a process of connecting specialised nodes or information sources, such as courses, email, communities, conversations, web searches, email lists, reading blogs etc. Courses are no longer the primary conduit

for learning. Learners can exponentially improve their learning by plugging into an existing network. Currency (accurate, up-to-date knowledge) is the intent of all connectivist learning.[83]

When the schools of thought from behaviourism, cognitivism, and constructivism are analysed closely, many overlapping ideas and principles become apparent. For example, behaviourism focuses on how learning behaviour is shaped through positive or negative reinforcement; constructivism focuses on communication between the learner and the teacher; cognitivism focuses on comprehension, abstraction, analysis, synthesis, generalisation, evaluation, decision-making and creative thinking; and lastly, connectivism focuses on learning through specialised information sources and staying up-to-date. Therefore, the design of online learning materials can draw upon principles from all four theories.

Description of the intervention

ICT has transformed the way information is exchanged and shared around the world. ICT-based learning interventions allow medical doctors to learn anywhere and at any time, and provide unique opportunities for interactive communication and networking. In addition to its increased use in undergraduate medical and health professional education,[6] online eLearning is gaining popularity in post-registration medical education (i.e. continuing education), evidenced by the growing number of studies conducted in recent years. There is no sharp division between continuing medical education (CME) and continuing professional development (CPD), as during the past decade, CME has moved beyond solely traditional clinical medical subjects[84] to include managerial, social and personal skills training.

ELearning can be defined as '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 to improve access to training, communication and interaction and that facilitates the adoption of new ways of understanding and learning'.[85(pg2)] ELearning differs from traditional learning in the approach and

medium through which content is delivered.[49] ELearning can use a full electronic approach, which is entirely driven by technology, or use a mix of traditional and computer–based methodologies (i.e. blended learning). Blended learning may be more suitable for healthcare training, which commonly needs to combine hands–on skill–based training at a practical level and self–directed learning.[86-88]

Internet (online) and LAN-based eLearning represents a further evolution of computer–assisted or computer-based eLearning and is an important tool that has the potential to transform post-registration medical education.[6,89] In recent years, nearly all medical schools in the USA and Canada moved to providing some form of online course material as part of their CME for physicians.[90] Online eLearning approaches vary widely in their configuration (e.g. tutorial, asynchronous discussion, live conferencing, etc.), instructional methods (e.g. practice exercises, cognitive interactivity) and presentation.[90]

For the purpose of this review, we defined online and LAN-based eLearning interventions as those that used the Internet or an intranet as a standard for participants' learning activities. These can also be referred to as 'online', 'web-based' or 'networked' interventions. In the absence of a network connection, a loss of both functionality and usability would occur to such an extent that the original intended purpose would no longer be provided and the user interaction would end. In this review we referred to both 'online' and 'LAN-based eLearning' as eLearning for ease of reading.

How the intervention works

In contrast to didactic lectures, students using eLearning can access a network-based eLearning tutorial at any time of the day. Students are also provided with constant content updates, individualised learning,[71,72] novel instructional methods[91] and automated assessment and documentation.[72] These interventions present numerous opportunities for universities that include reduced costs associated with the delivery of educational content;[92] improved scalability of educational developments;[93] and the ability to provide educational content,

relevant experts and novel curricula to learners in regions that have traditionally been difficult to access.[94]

ELearning, especially Internet-based delivery, can be interactive, and allows for immediate feedback to facilitate learning, improve cognitive skills and study habits. In addition, eLearning allows for the transfer of a greater amount of multimedia than non-networked methods, partially due to the increased availability of wireless connections and enabled linked devices. It may be particularly effective in eLearning, due to the vast amount of personal and group interaction, wider potential access and reduced physical materials required (e.g. CD-ROMs).[6,95]

Online eLearning is associated with a number of limitations. First, access to appropriate technology can be a problem for learners in LMIC countries. Second, learners can find it difficult to access graphics, images and video clips because of poor equipment and network connectivity. Third, the necessary infrastructure may not be available or affordable to all. A lack of adequate peer support and interaction between learners and the tutor can also pose a problem.[96] If online eLearning developers could address these issues, eLearning has the potential to play a major role in providing up-to-date educational content to medical doctors globally.

Why this review is important

Past reviews that focused on assessing the effectiveness of eLearning have been conducted among a heterogeneous group of healthcare professionals, e.g. surgical education among medical and dental students, surgeons, oral health specialists;[97] medical students, nurses, physicians;[98] and GPs.[99] These reviews included non-RCT study designs,[97] interrupted time series and before-after studies,[99] and compared heterogeneous eLearning technologies e.g. CD-ROM or computer-based simulation, virtual reality and web-based as a whole.[98] There was significant methodological, educational and clinical heterogeneity amongst the studies, which highlighted the need for a review on online eLearning that

focused specifically on the education of medical doctors with homogenous eLearning technologies. The a priori protocol reported here has also been published in the Cochrane library.[100] See Appendix IA.

The present review attempts to address the gaps in the existing literature by:

- Updating the rapidly growing body of evidence on the topic of online and LAN-based interventions;
- focusing on online and LAN-based interventions among doctors from various medical specialties;
- Evaluating the impact of such interventions on the knowledge, skills, attitudes and behaviours of medical doctors; and
- Including evidence from both developed and developing countries, where available.

OBJECTIVES

The primary objective of this review was to evaluate the effectiveness of online (Internet) and LAN-based eLearning in the ongoing training of medical doctors, specifically looking at the impact on their knowledge, skills, attitude, satisfaction and unintended/adverse effects on patients and physicians. The secondary objectives were to assess (i) changes in clinical practices or behaviours in response to these interventions; (ii) patient outcomes; and (iii) the costs and cost-effectiveness of the intervention.

METHODS

Inclusion criteria

Types of studies

Randomised, cluster-randomised (cRCTs) and quasi-randomised controlled trials were eligible for inclusion in this review. Cross-over trials were excluded due to the high likelihood of carry-over effects. Similarly, studies that used qualitative or semi-structured quantitative interview methods (mixed-methods) were excluded as these studies typically have inherent problems with how information

is reported, particularly the role and sequence of different data collection methods and how the analysis and findings are integrated.[101-103]

Types of participants

We included studies involving medical doctors enrolled in a post-registration medical educational program defined as any type of study offered after professional qualification, which is recognised by the relevant governmental or professional body that grants entry into or continues membership in the health workforce, in a more independent or senior role. CME and CPD programs that used online eLearning interventions such as webinars, online lectures and online journals were also included.

CME was defined as 'all educational activities which serve to maintain, develop, or increase the knowledge, skills, and professional performance and relationships that a physician used to provide services for patients, the public, or the profession',[104(pg1)] and CPD as 'a range of learning activities through which medical professionals maintained and developed throughout their career to ensure that they retain their capacity to practice safely, effectively and legally within their evolving scope of practice'.[105(pg4)] Participants were not excluded on the basis of age, gender or any other socio-demographic variables.

Types of interventions

Online eLearning interventions used to deliver course-learning content in physicians' education, either as the sole or partial mode (i.e. blended learning) of delivery for the purpose of teaching, learning, training or a combination, were included. The following describes the inclusion criteria in further detail.

We included studies that evaluated:

- Online eLearning interventions (computer-based, computer-assisted) where the learning content was delivered using the Internet or LAN[106] with or without a learning management system (LMS);

- interventions such as web-based tutorials (the online equivalent of classroom-based lectures), discussion boards, email, and Internet-mediated videoconferencing;[106]
- educational interventions that required Internet connectivity throughout the duration of the intervention and CMEs that required occasional Internet connections for online discussion and evaluation; and
- educational interventions targeted at 'physician activation'.

We included studies that made the following intervention comparisons:

- Online and LAN-based interventions versus traditional learning;
- online and LAN-based interventions versus other online eLearning interventions;
- online and LAN-based interventions (where online and LAN were used as the sole mode of intervention) versus blended interventions (where online and LAN were used together with other forms of intervention); and
- blended interventions where online and LAN-based eLearning was used together with other forms of intervention versus traditional learning.

Traditional learning in post-registration medical doctors' education includes formal and informal training (self-study), thus traditional learning refers to both formal and no training (self-directed training).

The following studies were excluded:

- Studies with mixed participant groups (doctors, nurses, pharmacists), as well as pre- and post-registration healthcare professionals, in which results were not presented separately for each professional group. However, if the studies presented results for doctors separately we included them.
- studies of educational interventions targeted at 'patient activation' alone;
- studies of interventions that only required an Internet connection for the downloading of software, slides or other educational content;

- studies investigating telemedicine, telehealth-based learning interventions and video conferencing, delivered through an analogue or digital telephone network or using satellite connectivity;
- studies investigating computer-based educational interventions (e.g., CD-ROMs), unless these interventions used the Internet to disseminate information;[106]
- studies in which the online eLearning intervention was accessed using mobile phones or tablets, as these interventions are covered in a separate review;[107]
- studies investigating offline and computer-based eLearning interventions in the education of medical students, as these interventions are covered in a separate review;[108]
- studies investigating virtual patient simulations in the education of health professionals, as these interventions are covered in a separate review;[109]
- studies investigating virtual reality environments in the education of health professionals, as these interventions are covered in a separate review;[110]
- studies investigating serious gaming and gamification interventions in the education of health professionals;[111] and
- studies investigating offline and computer-based eLearning interventions in the education of medical doctors, as these interventions are covered in a separate review.[112]

Types of outcomes

This review investigated different types of online eLearning content and a range of outcomes that included physician's knowledge comprehension, intellectual skills and their applications, attitudes (cognitive and affective domains)[113] and patient outcomes. Studies of online eLearning that assessed motor skills and skills-based learning (psychomotor domain) were excluded, as they will be analysed in a separate review. However, studies were included that assessed intellectually-based skills (e.g. reading instructions, solving problems) and other

tasks that involve the recall and processing of information.[114] Studies were included that reported at least one of the following primary or secondary outcomes:

Primary outcomes

The impact of online and LAN-based eLearning interventions on the following primary outcomes was assessed:

- Physicians' post-intervention knowledge, defined as the evaluation of learners' factual or conceptual understanding, measured using any validated or non-validated instrument to measure differences in pre- and post-test scores, or post-test scores only if no pre-test scores were reported. If several post-test results were available, we used the difference between the pre-test and the first post-test;
- physicians' post-intervention cognitive skills, defined as a learners' ability to demonstrate a procedure or technique in an educational setting, measured with any validated or non-validated instrument (e.g. pre- and post-test scores, time taken to perform a procedure, number of errors made while performing a procedure);
- physicians' post-intervention attitudes, defined as a learners' stance towards the intervention, patients and/or new clinical knowledge or skills, measured using any validated or non-validated instrument;
- physicians' post-intervention satisfaction defined as the level of approval of the online and LAN-based eLearning intervention and its perceived performance compared with their expectations of the intervention, measured using validated or non-validated instrument; and
- the adverse or unintended effects of online and LAN-based intervention (e.g. patient mortality, patient morbidity, medical errors, etc.)

Secondary outcomes

The secondary outcomes considered for inclusion were:

- Changes in practice or behaviour (e.g. reduced antibiotics prescribing, improved diagnosis, improved quality of care, etc.);
- patient outcomes (e.g. anxiety, depression, quality of life, etc.); and
- the cost and cost-effectiveness of the intervention.

We took into account outcomes measured at all available time points.

Search strategy

A search strategy was developed in accordance with the Cochrane Handbook of Systematic Reviews of Interventions.[115] We defined and used a common search strategy for all of our Cochrane reviews[100,107,110] examining eLearning interventions (see the 'Types of interventions' section above) in health professional education (Appendix IB). All included studies were in English; no studies were excluded on the basis of language.

Electronic searches

The keywords and MEDLINE search strategy presented in Appendix IB was adapted and used to search the following databases:

• The Cochrane Central Register of Controlled Trials (CENTRAL; The Cochrane Library, current issue)

• MEDLINE (Ovid)

• Embase (Elsevier)

• PsycINFO (Ovid)

• Educational Resource Information Centre (ERIC; Ovid)

• Cumulative Index to Nursing and Allied Health Literature (CINAHL; Ebsco)

• Web of Science Core Collection (Thomson Reuters)

Databases were searched from 1 January 1990 to 9 March 2017. We selected 1990 as the starting year for our search because prior to this the use of computers and the Internet for eLearning was limited.

Searching other resources

We searched the reference lists of all included studies and any relevant systematic reviews and meta-analysis identified through the electronic searches and trials registries (clinical trial.gov and the World Health Organization International Clinical Trials Registry Platform).

Data collection and analysis

Study selection

All references identified by the searches were imported into reference manager software and duplicates removed. Three reviewers, Pradeep Paul George (PPG), Olena Zhabenko (OZ) and Monika Semwal (MS), independently screened the titles and abstracts to identify studies that met the inclusion criteria. We retrieved the full-text of articles that appeared to meet the criteria or for which we were unsure. Two authors independently assessed the full-text of the retrieved articles for compliance with the inclusion criteria. Disagreements were resolved through discussion. If no agreement was reached, a third review author, Bhone Myint Kyaw (BMK), was consulted. Studies that appeared to be relevant but were excluded at this stage are listed in Appendix VI, where the reasons for exclusion are noted. Two review authors verified the final list of included studies.

Data extraction

Three reviewers (PPG, OZ and MS) independently extracted and managed the data for each of the included studies using a structured data recording form. The data extraction form was piloted and amended according to the feedback received prior to use. In addition to extracting standard information such as the study design and participants' demographics, we extracted data on the participants, the intervention and control, and outcome measures, as well as the mode of the eLearning intervention. We contacted study authors in cases where the information reported was missing or unclear. A fourth review author (BMK) acted as an arbiter in cases of disagreement.

Risk of bias assessment

Two reviewers independently assessed the risk of bias for RCTs using the Cochrane Collaborations' 'risk of bias' tool.[116] The risk of bias assessments were piloted to investigate the level of agreement between reviewers. Study authors were contacted in cases where the information reported was missing or unclear. RCTs were assessed for risk of bias using the following criteria: random sequence generation; allocation concealment; blinding of outcome assessors; completeness of outcome data; selective outcome reporting (e.g. the presence or absence of a published protocol); and other sources of bias (e.g. baseline imbalance; the inappropriate administration of an intervention). Judgements concerning the risk of bias for each study were classified as 'low', 'high', or 'unclear', Figure 2 and Figure 3. We incorporated the results of the risk of bias assessment into the review using risk of bias tables, Summary of Findings tables, a graph, and a narrative summary. Studies were not judged on the basis of participant blinding as the nature of the intervention precluded this type of blinding. For cRCTs, we assessed for additional biases: recruitment bias;[117] baseline imbalance; loss of clusters; incorrect analysis; and comparability with individually randomised trials,[116] (Appendix V) as these biases are inherent in cRCT'S.

Measures of treatment effect

Mean differences (MD) and risk ratios (RR) were used to summarise continuous and dichotomous (categorical) outcomes, respectively, and their variance expressed as 95% confidence intervals (CI). Where studies measured the same outcome using different scales, the standardised mean difference (SMD) was estimated by dividing the study mean difference between the groups by the standard deviation of outcomes among participants. In studies that reported outcomes as change scores and post-test scores, only change scores were presented. If studies only reported post-test scores, the data was presented as is. The clinically meaningful interpretation of effect sizes could not be identified in the eLearning intervention literature. Therefore, we presented outcomes using the

post-intervention SMD and interpreted the effect size using Cohen's rule of thumb (i.e. 0.2 reflects a small effect; 0.5 a moderate effect; and 0.8 a large effect),[116,118] in line with other studies in the field.[118] If studies used multiple arms, the intervention arm was compared to the least active control arm and the difference in post-intervention outcomes was assessed. In papers that reported the median and range for an outcome, this was converted to the mean and standard deviation (SD) via the method explained by Wan.[119] The standard way to convert the results was used as recommended by the Cochrane guidelines.[116]

Unit of analysis issues

For cRCTs, we attempted to obtain data at the student or learner level. In cases where the statistical analysis of the cRCTs had already been adjusted for the clustering of data, we extracted the reported effect estimates and used them directly in our analysis. In cases where individual data were not reported in the study, the trial author(s) were contacted with a request for the data; however, no reply was received. We planned to meta-analyse all available data using the generic inverse-variance method in Review Manager 5.3,[120] however, due to substantial heterogeneity, meta-analysis was not possible. When access to student-level data was not possible, a summary effect measurement was extracted for each cluster.

Handling missing data

The original study investigators were contacted to clarify or request missing information. If this could not be obtained, data from the published studies was unused and the risk of bias assessed using the criterion 'incomplete outcome data'. We did not impute any missing data.

Assessment of heterogeneity

Clinical heterogeneity was assessed to check if the included studies were similar in terms of their population, intervention characteristics and reported outcomes, and to ascertain the possibility of pooling the measures of effect.[116] We found

significant heterogeneity (clinical and statistical) among the included studies; hence meta-analysis was not appropriate. However, a subgroup analysis of learners' outcomes was conducted by 1) LMICs; 2) time spent on the intervention; and 3) the effects of the intervention by specialty.

Assessment of reporting biases

Reporting bias was assessed using a funnel plot, which compared at least 10 studies (Figure 7), to maintain sufficient power for distinguishing chance from real asymmetry[121-123] and qualitatively, based on the characteristics of the included studies.

Data synthesis

Data was extracted and entered into tables and grouped by study design and intervention type to create a descriptive synthesis in Review Manager.[120] The results from individual RCTs were reported as the SMD for continuous variables and RR for dichotomous variables. Where studies reported more than one measure for each outcome, the primary measure, as defined by the study authors, was used in the analysis. If studies had multiple arms, we compared the intervention arm to the least active control arm and assessed the difference in post-intervention outcomes. Similarly, when multiple domains of the same outcome were measured, only the primary measures identified and agreed upon by the review authors were reported. Meta-analyses were not possible as there was significant clinical and methodological heterogeneity across the included studies.

Subgroup analysis and investigation of heterogeneity

We performed the following subgroup analyses by splitting data into the following subgroups to make comparisons to investigate heterogeneity:

- The effects of low-, middle-, and high-income countries;
- the type of online- and LAN-based intervention used;

- the type of post-registration medical professional education according to the sub-specialties listed in the International Standard Classification of Occupations (ISCO-08);
- the duration of the intervention and the time of assessment; and
- the effects of eLearning by training method and focus.

We calculated and presented the measure of adherence or time spent on the intervention, and the time comparison between the intervention and the control. It is acknowledged that many other subgroup analyses could have been performed, for example, by comparing interventions according to pedagogical aspects or interactivity; however, this was not within the scope of the current review. Future reviews could explore this.

Sensitivity analysis

Due to substantial methodological and clinical heterogeneity among the included studies, pooled results were not presented, and consequently no sensitivity analysis was conducted.

Summary of Findings

Summary of Findings tables (Tables 2.1, 2.2 and 2.3) were prepared based on the methods described in Chapter 11 of the Cochrane Handbook for Systematic Reviews of Interventions.[115] Two review authors independently used the GRADE criteria to rank the quality of the evidence using the GRADE profiler (GRADEpro) software.[124] As the pooling of results in a meta-analysis was not appropriate in this review, the results are presented in a narrative Summary of Findings table.[125,126] Additionally, a comparison between the various learning types and direction of effects for the outcomes are presented in Appendices II A-F and III.

Table 2.1: Summary of Findings for online eLearning vs self-directed learning

Patient or population: Post-registration medical doctors; **Setting:** Universities, hospitals and primary care; **Intervention:** Online and local area network (LAN) based digital education (ODE); **Comparison:** Self-directed learning			
Outcomes	**No. of participants (No. of studies)**	**Quality of evidence (GRADE)**	**Direction of effects**
Knowledge assessed with multiple choice questions. Follow-up ranged from post-test to 1-year.	3067 participants (29 RCTs)	⊕⊖⊖⊖ VERY LOW[1,2,3]	Seventeen studies [127-144] reported that ODE was significantly effective compared to self-directed learning (very low quality). Three studies [145-147] reported mixed results (very low quality). Nine studies [148-156] reported that ODE was equally as effective as self-directed learning (very low quality).
Skills assessed with OSCE, diagnostic assessment, examination, questionnaires and surveys. Follow-up ranged from post-test to 4-years.	829 participants (8 RCTs)	⊕⊕⊖⊖ LOW[1,2,]	Five studies [151,157-160] reported that ODE was significantly more effective than self-directed learning (low quality). Two studies [161,162] reported that ODE was equally as effective as self-directed learning (low quality). One study [131] reported self-directed learning was more effective than ODE (low quality).
Attitude assessed with questionnaires. Follow-up ranged from post-test to 136-days.	392 participants (4 RCTs)	⊕⊕⊖⊖ LOW[1,2]	One study [136] reported that ODE was significantly effective than self-directed learning (low quality). Another [154] reported that ODE was equally as effective as self-directed learning (low quality). Two studies [132,141] reported mixed results (low quality).
Satisfaction assessed with questionnaires. Follow-up ranged from post-test to 6-months.	934 participants (6 RCTs)	⊕⊕⊖⊖ LOW[1,2]	Two studies [148,163] reported that ODE was significantly more effective (low quality). Three studies [131,141,164] reported that ODE was equally as effective as self-directed learning (low quality). One study[145] reported mixed results (low quality).
ODE: Online digital education; OSCE: objective structured clinical examination; RCT: randomised controlled trial.			
Low quality: Our confidence in the effect estimate is limited: The true effect may be substantially different from the estimate of the effect; **Very low quality:** We have very little confidence in the effect estimate: The true effect is likely to be substantially different from the estimate of effect.			

[1]Rated down by one level for study limitations: most studies were considered to be at an unclear or high risk of bias. Overall, the risk of bias for most studies was unclear due to a lack of information reported; [2] Rated down by one level for inconsistency: there was variation in effect size (i.e. very large and very small effects were observed), [3]Rated down by one level for publication bias: the effect estimates were asymmetrical suggesting possible publication bias.

Table 2.2: Summary of Findings for online eLearning vs face-to-face learning

Patient or population: Post-registration medical doctors; **Setting:** Universities, hospitals and primary care; **Intervention:** Online and local area network (LAN) based digital education (ODE); **Comparison:** Face-to-face learning			
Outcomes	**No. of Participants (No. of studies)**	**Quality of evidence (GRADE)**	**Direction of effects**
Knowledge assessed with multiple choice questions. Follow-up ranged from post-test to 18-months.	1202 participants (9 RCTs)	⊕⊖⊖⊖ VERY LOW[1,2,3]	Two studies [8,165] reported that ODE was significantly more effective in improving physicians' knowledge scores than face-to-face learning (very low quality). Six studies [166-171] found that ODE was equally as effective as face-to-face learning in improving physicians' knowledge scores (very low quality). One study [172] reported that face-to-face learning was significantly more effective in improving physicians' knowledge scores than ODE.
Skills assessed with OSCE, diagnostic assessment, examination, questionnaires and surveys. Follow-up ranged from post-test to 12-months.	291 participants (7 RCTs)	⊕⊕⊖⊖ LOW[1,2,]	Six studies [166,168,173-176] reported ODE was equally effective as face-to-face learning in improving physicians' skills (low quality). In one study [177] data was missing.
Attitude assessed with questionnaires. Follow-up ranged from post-test to 18 months.	220 participants (2 RCTs)	⊕⊕⊖⊖ LOW[1,2]	Two studies [165,178] reported that ODE was equally as effective as face-to-face learning in improving physicians' attitude (low quality).
Satisfaction assessed with questionnaires. Follow-up ranged from post-test to 12-weeks.	260 participants (4 RCTs)	⊕⊕⊖⊖ LOW[1,2]	Two studies [166,170] reported that ODE was significantly more effective than face-to-face learning for improving physicians' satisfaction (low quality). Two studies [8,168] reported that ODE was equally as effective as face-to-face learning in improving physicians' satisfaction (low quality).
ODE: Online digital education; OSCE: objective structured clinical examination; RCT: randomised controlled trial.			
Low quality: Our confidence in the effect estimate is limited: The true effect may be substantially different from the estimate of the effect; **Very low quality:** We have very little confidence in the effect estimate: The true effect is likely to be substantially different from the estimate of effect.			

[1]Rated down by one level for study limitations: most studies were considered to be at an unclear or high risk of bias. Overall, the risk of bias for most studies was unclear due to a lack of information reported; [2] Rated down by one level for inconsistency: there was variation in effect size (i.e. very large and very small effects were observed), [3]Rated down by one level for publication bias: the effect estimates were asymmetrical suggesting possible publication bias.

Table 2.3: Summary of Findings for blended learning vs self-directed/face-to-face learning

Patient or population: Post-registration medical doctors; **Setting:** Universities, hospitals and primary care; **Intervention:** Blended learning **Comparison:** Self-directed/face-to-face learning			
Outcomes	**No. of participants (No. of studies)**	**Quality of evidence (GRADE)**	**Direction of effects**
Knowledge assessed with multiple choice questions. Follow-up ranged from post-test to 26-months.	4413 participants (7 RCTs)	⊕⊖⊖⊖ VERY LOW[1,2,3]	Two studies [179,180] reported that blended learning was significantly more effective in improving physicians' knowledge than as self-directed/face-to-face learning (very low quality). Five studies assessed together [179,181-184] reported that blended learning was equally as effective as self-directed/face-to-face learning (very low quality).
Skills assessed with OSCE, diagnostic assessment, examination, questionnaires and surveys. Follow-up ranged from post-test to 26-months.	4131 participants (6 RCTs)	⊕⊕⊖⊖ LOW[1,2]	Two studies [179,185] reported blended learning may significantly improve physicians' skills and four studies [181,182,186,187] reported blended learning may be as effective as face-to-face learning in improving skills (low quality).
Attitude assessed with a questionnaire. Follow-up was assessed post-test.	61 participants (1 cRCT)	⊕⊕⊖⊖ LOW[1,2]	Kulier et al.[188] compared an blended learning course on EBM vs a face-to-face EBM course and reported that the intervention may be equally as effective as the controls for improving physicians' attitude.
Satisfaction assessed with questionnaires, Likert scale. Follow-up ranged from post-test to 6 months.	166 participants (3 RCTs)	⊕⊕⊖⊖ LOW[1,2]	Ali et al.[181] compared ATLS delivered through blended learning to a standard ATLS course and reported no difference in satisfaction between the groups, (low quality). Kronick et al.[189] compared 3-hours of online training vs no training (self-directed training), and found that the intervention slightly improved satisfaction, (low quality). Platz et al.[183] compared basic ultrasound principles and extended focused assessment with sonography for trauma using blended learning vs face-to-face training and reported mixed results, (low quality).
ATLS: Advanced Trauma Life Support; EBM: evidence-based medicine, RCT: randomised controlled trial.			

[1]Rated down by one level for study limitations: most studies were considered to be at an unclear or high risk of bias. Overall, the risk of bias for most studies was unclear due to a lack of information reported; [2] Rated down by one level for inconsistency: there was variation in effect size (i.e. very large and very small effects were observed), [3]Rated down by one level for publication bias: the effect estimates were asymmetrical suggesting possible publication bias.

RESULTS

Search results

Our search strategy retrieved 27,488 unique references. After scanning the titles and abstracts, we retrieved the full-texts of 162 potentially eligible studies. Of these, 45 studies were excluded as they did not meet the inclusion criteria and 24 studies await classification subject to further information. The authors of these studies were contacted to obtain the missing information, but no reply was received. The flow of studies through the systematic review selection process is shown in Figure 2.1.

Included studies

We included 93 studies involving a total of 16,895 participants, of these, 24 studies had a maximum of 50 participants.

Types of studies

Of the included studies, 74 were RCTs involving 12,537 participants and 19 were cRCTs involving 1262 clusters, 3727 physicians' and 7690 patients. No quasi-randomised trials were found. Fifty-seven studies were published between 2010 and 2015 and the remaining 29 studies were published between 1999 and 2009. Eight studies were published between 2016 and 2017, Figure 2.2.

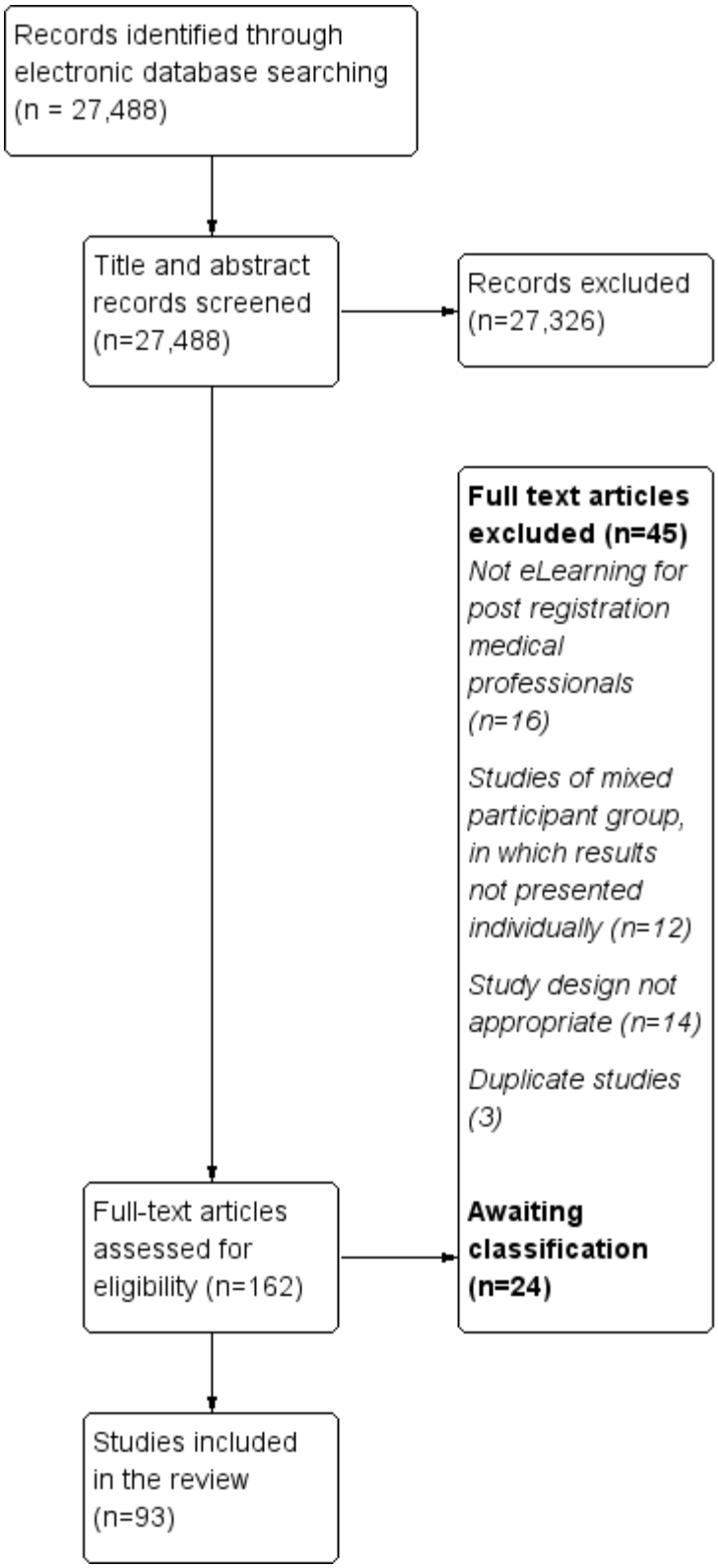


Figure 2.1: Modified PRISMA flow chart of the search results and study selection process

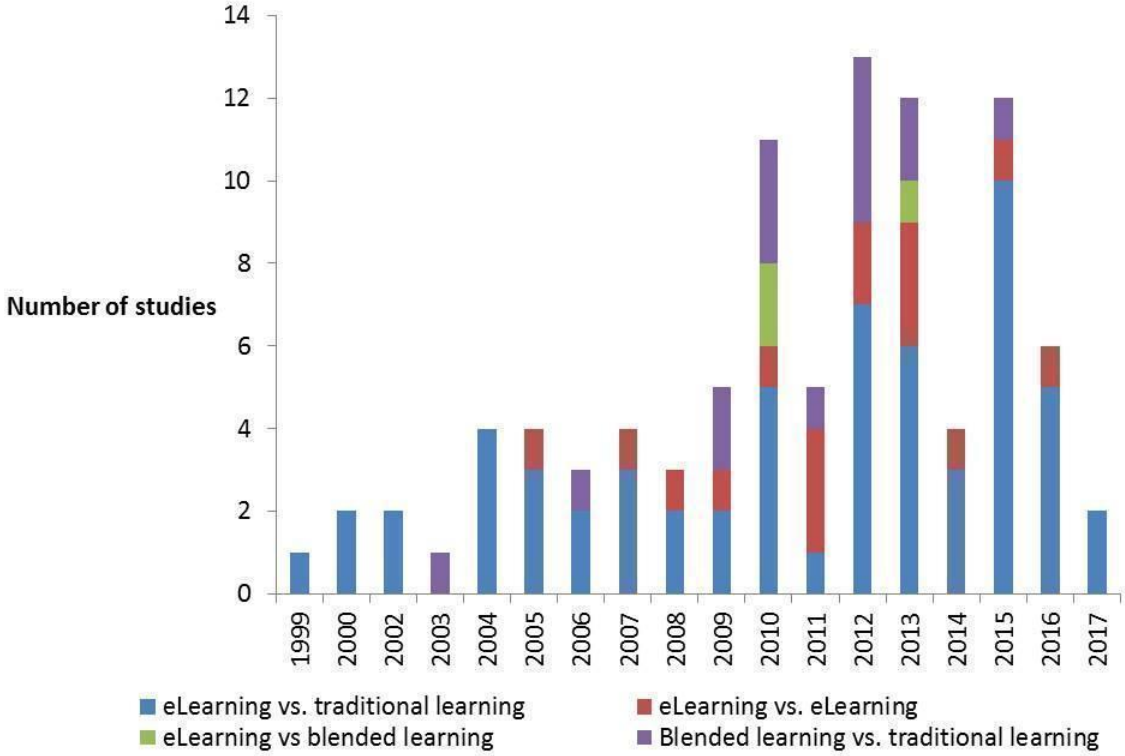


Figure 2.2: Number of online/LAN-based eLearning studies by type of learning and year of publication

Types of participants and settings

Twenty-nine studies included primary care practitioners (general practitioners, family medicine practitioners/residents, and occupational physicians); 12 studies included surgeons; 11 studies included general and internal medicine practitioners; eight studies included paediatricians; 11 studies included practitioners from multiple specialties; four studies include emergency medicine physicians; Schroter et al.[190] included multidisciplinary practitioners (doctors, nurses and physician assistants; results presented separately for doctors); two studies included anaesthesiologists and anaesthesiology residents (results presented separately for anaesthesiologist); two studies included obstetricians and gynaecologists; and three studies included radiologists and radiation oncologists. Figure 2.3 shows the studies by specialty and type of learning.

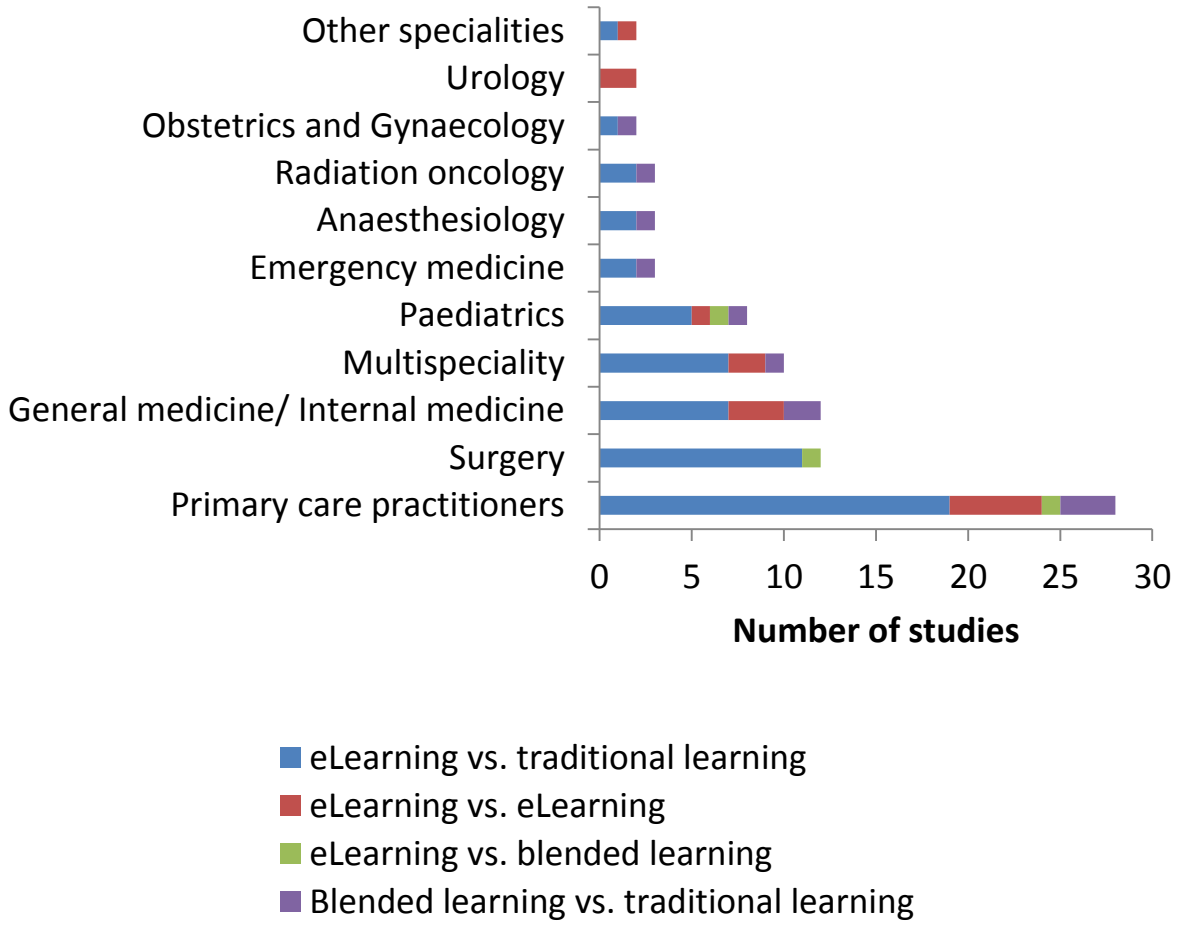


Figure 2.3: Number of online eLearning studies by specialty and type of learning

Only two[170,179] of the 93 studies were conducted in LMIC countries (Iran, and a multi-centre study conducted in Argentina, Brazil, the Democratic Republic of the Congo, India, the Philippines, South Africa and Thailand); all other studies were conducted in high-income countries.

Fifty studies were conducted in the USA; 10 studies were conducted in Canada; five studies were conducted in Germany; five studies were conducted in the UK; five studies were conducted in Australia; three studies were conducted in Italy; three studies were conducted in the Netherlands; two studies were conducted in France; and one study each in Spain, Iran and Ireland; see Figure 2.4.

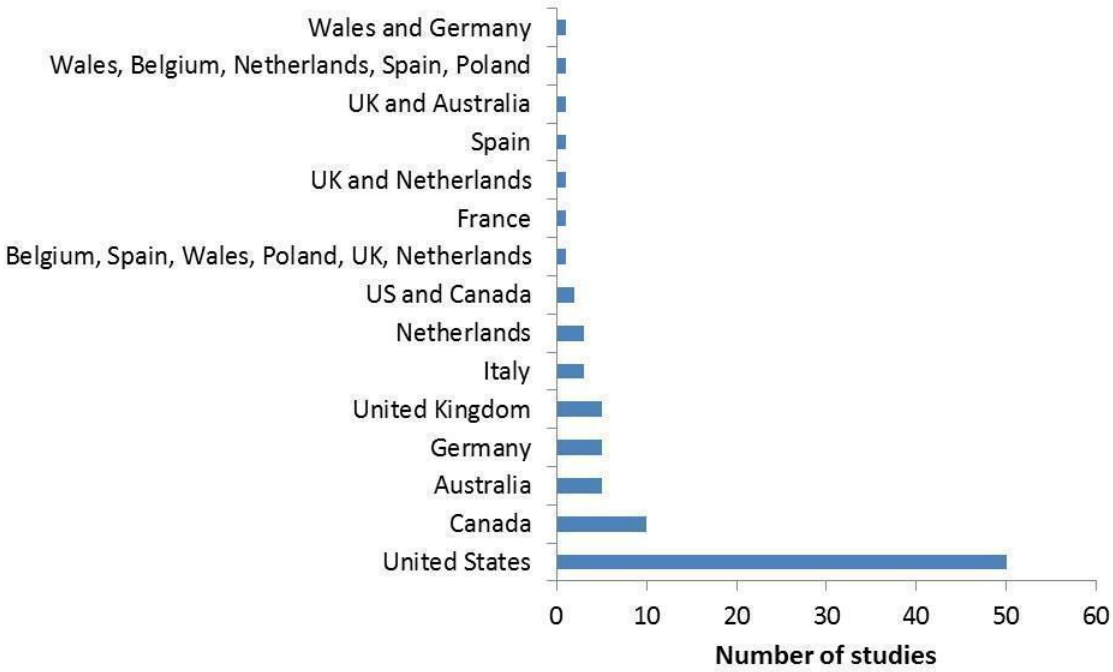


Figure 2.4: Number of online/LAN-based eLearning studies by country of publication

Fifty studies were carried out in hospital settings; 31 studies were conducted in universities; one study was conducted in both a hospital and university setting; and 11 studies were conducted in primary care settings.

ELearning pedagogy, theory, learning management and funding

Individual learning was the eLearning pedagogical approach used in 72 studies. In individual learning (self-learning), the learners had access to online lectures and self-instructional materials. Fourteen studies evaluated 'facilitated eLearning' interventions, i.e. learning was facilitated by a faculty member or tutor and learners had access to online lectures and self-instructional materials. Seven studies assessed 'collaborative eLearning' in which learning took place in a team environment and the learners were exposed to discussion forums, problem-based learning and online learning.

Interventions in 25 studies were based on a learning theory, (cognitive and constructivist learning theories) and learning content was validated in 19 studies. Among the studies that validated the learning content, McLeod et al.[172] and Macrae et al.[160] assessed face, construct and content validity; Stewart et al.[146] assessed discriminant validity; and the remaining studies assessed the content validity of the intervention.

The eLearning intervention was piloted before the study in 20 studies. Fifty studies included interactivity in the eLearning intervention. Interactivity was deemed present if it was mentioned or explicitly stated in the description of the intervention, or if the intervention had clickable animated graphics with audio or video, or complex simulations where learner entered data into fields and the system responded to the learners' input. Twenty-seven studies reported using learning analytics and feedback.

Eight studies reported using a LMS, i.e. web-based software applications that facilitate content delivery to learners, manage its delivery, monitor learner participation, assess performance and archive course documentation. These systems offer learners and teachers the ability to interact with video conferencing, threaded discussions and forums.

Thirty-one studies were supported by public sponsorship; eight studies were sponsored by the pharmaceutical industry or insurance companies; 12 studies were funded by international organisations, associations or societies; three studies were jointly sponsored by the pharmaceutical industry and public sponsorship; seven studies were sponsored by universities; and 31 studies omitted details about funding.

Types of interventions and comparisons

The interventions in the included studies were heterogeneous. Sixty-one studies compared eLearning vs self-directed/face-to-face learning; 14 studies compared eLearning vs eLearning; three studies compared eLearning vs blended learning;

and 15 studies compared blended learning vs self-directed/face-to-face learning. Among the included studies, 81 made two comparisons and 12 studies made three or more comparisons, (Appendices IIIA - IIIF).

Two studies used synchronous learning technology (video-conferencing systems) for training: Daetwyler et al.[191] used online modules and a video conferencing system to enhance physician-patient communication skills, while Girgis et al.[192] used video conferences as part of a consultation skills training (CST) program.

Thirty-nine studies used asynchronous learning technologies such as web-based libraries/repositories of video modules, CD-ROMs, emails and online discussion groups, to deliver the intervention. Twenty-five studies used a web-based delivery mode as the intervention; seven studies used emails to deliver the interventions; 10 studies used online video-based modules to deliver the interventions; and four studies used CD-ROM-based eLearning modules with or without the Internet. Butzlaff et al.[149] used CD-ROM-based guidelines; Gold et al.[145] used a CD-ROM thoracic surgery eLearning system for surgical training; Hymowitz et al.[157] used a hybrid website/CD-ROM training program on tobacco; Le et al.[154] used web- or CD-ROM–based multimedia learning modules on asthma; three studies used online discussions forums for their training; Bello et al.[166] used a discussion forum for airway management training; McLeod et al.[172] used an online moderated journal club discussion group for teaching critical appraisal skills; and Midmer et al.[186] used case discussions for improving physicians' opioid- and benzodiazepine-prescribing skills.

Types of outcomes

The included studies reported on the following outcomes: knowledge, skills, attitude, satisfaction, practice or behaviour change, patient outcomes and the cost of the interventions. No studies reported on the adverse or unintended effects of online and LAN-based eLearning interventions.

Knowledge

Fifty-four studies assessed knowledge: 20 studies used questionnaires (open-ended); 28 studies used multiple choice questions (MCQs); and six studies did not specify the type of instrument used to measure knowledge.

Skills

Twenty-six studies assessed participants' skills: five studies used an objective structured clinical examination (OSCE); six studies used different types of checklists; Ali et al.[181] used evaluation by an instructor; Claxton et al.[131] used a Likert scale; Ngamruengphong et al.[187] used a chart audit; Ruf et al.[193] used diagnostic assessment; Szmuilowicz et al.[185] used a behavioural checklist; Talib et al.[194] used an observation test; Bello et al.[166] implemented a practical test using a manikin; Conroy et al.[161] assessed the correct classification of adverse drug reaction skills using the Liverpool Causality Assessment Tool (LCAT); four studies[161,162,174,186,195] used questionnaires; Bernstein et al.[196] used structured clinical observations; Pape-Koehler et al.[197] used a modified objective structured assessment of technical skills (OSATS; tool for assessing practical skills); Perkins et al.[198] used a technical skills assessment template (patient assessment, defibrillation, cardiopulmonary resuscitation [CPR], cardiopulmonary and airway management); Koppe et al.[158] used the Psychological Medicine Inventory (PMI), a professional isolation scale (PIS), and the heterogeneous Work-related Affect Scale (WWAS); and Sangvai et al.[199] evaluated videotaped encounters to assess physicians' skills before and after the intervention.

Attitude

Eight studies assessed participants' attitude: six studies used questionnaires while both Kulier et al.[188] and Le et al.[154] used Likert scales.

Satisfaction

Sixteen studies assessed participants' satisfaction: 10 used questionnaires and six used Likert scales.

Practice or behaviour change

Twenty-five studies assessed practice or behaviour change: eight studies used questionnaires; eight studies used chart audits or case note reviews; Farah et al.[134] used a MCQ; Le et al.[154] used a Likert scale; Weston et al.[200] used clinical vignettes; in the study by Xiao et al.[201] surgeons independently reviewed the video recordings of central venous catheter insertions; Short et al.[155] used the Intimate Partner Violence Survey (PREMIS) scale; Dayton et al.[202] used a scenario-based decision support system; and Daetwyler et al.[191] used a behavioural checklist. Gerbert et al.[203] and Meeker et al.[204] did not state the assessment tools used to measure practice or behaviour change.

Patient outcomes

Five studies assessed the effects of online and LAN-based eLearning on patient outcomes: Butler et al.[205] assessed hospital admissions and re-consultation rates among patients using hospital chart audits; Estrada et al.[206] assessed markers of diabetes care (haemoglobin A1c, blood pressure, low density lipoprotein); Girgis[192] used the European Organisation for Research and Treatment of Cancer Quality of Life Questionnaire-C30, a hospital anxiety and depression scale, and a supportive care needs survey questionnaire; Dolan et al.[151] used chart audits; and Franchi et al.[207] assessed the prevalence of inappropriate medication (PIM) and drug-drug interactions (DDI) at discharge using 'Beers criteria'.

Cost

Three studies assessed the cost of the interventions: Braido et al.[129] performed inter- or intra-group comparisons and a cost-minimisation analysis; Butler et al.[205] presented cost information for the Stemming the Tide of Antibiotic

Resistance educational program; and Perkins et al.[182] presented the cost of the Advanced Life Support training program.

No studies reported on the adverse or unintended effects of the online eLearning interventions.

Excluded studies

Forty-five studies were excluded from the review (Appendix IV): 12 studies did not evaluate an eLearning intervention that sought to educate post-registration medical doctors; 12 studies involved a mixed sample and the results were not presented separately for the different groups; 16 studies had an ineligible study design or inappropriate comparator; and five studies were duplicates.

Risk of bias in the included studies

The groups compared in the included studies were similar in all respects except in their use of the eLearning technology (mode of information delivery). However, as presented in the risk of bias summary (Appendix ID) and in the risk of bias graph (Figure 2.5), it was often difficult to assess the risk of bias in the included studies due to the under-reporting of relevant information. Six studies were rated as having a high risk of bias for random sequence generation; one study was rated as having a high risk of bias for allocation concealment; 31 studies had a high risk of attrition bias; three studies were at high risk of reporting bias; and 25 studies were rated as having a high risk of other potential sources of bias.

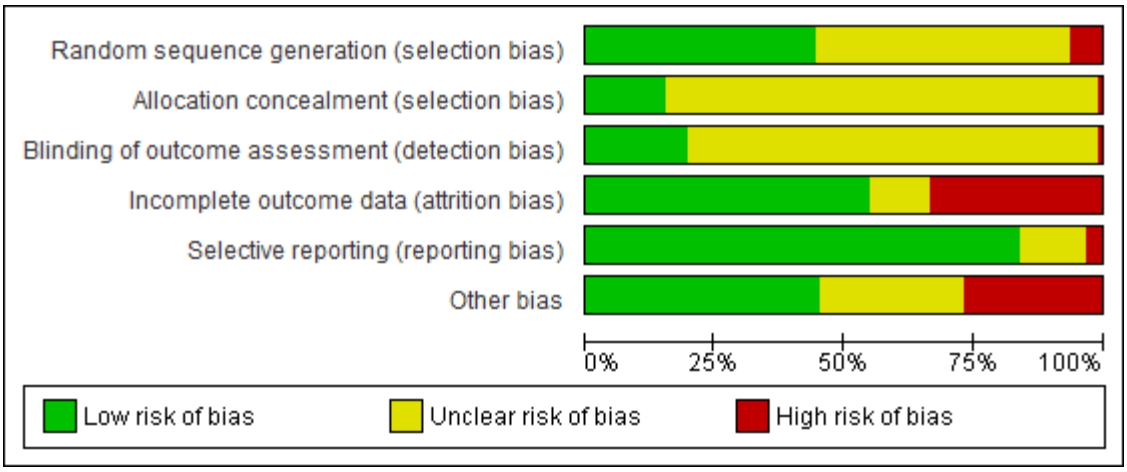


Figure 2.5: Risk of bias item results presented as percentages across all included studies

Allocation (selection bias)

Random sequence generation

Six studies were rated as having a high risk of selection bias. Allison et al.,[208] Fordis et al.[8] and Houwink et al.[138] used a pseudo-random number generator to randomise participants; in Platz et al.[183] participants were randomised alphabetically by surname; in Le et al.[154] matched pairs were assigned to the intervention and control groups; and in Xiao et al.[201] participants were randomised based on the month of their rotation starting time.

Forty-six studies were rated as having an unclear risk of bias as insufficient information was reported to permit judgement, and 41 studies were rated as having a low risk of bias for random sequence generation, as these studies explicitly stated the methods used for randomisation (e.g. coin toss, computer-generated random sequence, random number table, random permuted blocks).

Allocation concealment

Platz et al.[183] was rated as having a high risk of bias for allocation concealment: the allocation protocol was predictable by the personnel responsible for determining the eligibility of participants and group assignment. Seventy-eight studies were rated as having an unclear risk of allocation concealment as

insufficient information was reported to permit judgement. The risk of bias for allocation concealment was low in 14 studies as these studies explicitly stated the methods used for allocation concealment, e.g. centralised randomisation, the use of sealed opaque envelopes to conceal the randomisation sequence.

Blinding (performance and detection bias)

It was not expected that participants would be blinded to intervention allocation given the nature of the interventions precludes this type of blinding. However, efforts were made to blind outcome assessors in 18 of the included studies, which were assessed as having a low risk of detection bias. Epstein et al.[209] had a high risk of detection bias as the chart reviewers were not blinded to the treatment condition. The remaining 74 studies were judged as having an unclear risk of bias for the blinding of outcome assessment.

Incomplete outcome data (attrition bias)

Thirty-one studies were rated as having a high risk of attrition bias due to a high drop-out rate. Ten studies had an unclear risk of attrition bias as they reported insufficient information to permit judgement, and fifty two studies were rated as having a low risk of attrition bias for incomplete outcome data, as they had no missing outcome data.

Selective reporting (reporting bias)

Three studies had a high risk of reporting bias: secondary outcomes were not reported in Estrada et al.;[206] Ngamruengphong et al.[187] did not report control data for post-test comparisons; and Daetwyler et al.[191] did not report data on learners' understanding of the module. Twelve studies had an unclear risk of bias as insufficient information was reported to permit judgement and 78 studies were rated as having a low risk of bias for selective reporting as they reported on all prespecified outcomes of interest.

Other potential sources of bias

Other biases were assessed by examining whether significant baseline differences existed between participants in the intervention and control groups. Inconsistency was assessed by comparison of point estimates, confidence intervals, statistical test of heterogeneity and I^2 values. Twenty-five studies were judged as being at high risk of 'other biases' as a result. Effect estimates were highly inconsistent among the included studies. Similarly for most of the included studies, it was difficult to assess whether the inappropriate administration of an intervention had occurred, and hence these studies were judged to have an unclear risk of ‘other bias’.

Risk of bias in included cRCTs

Evidence for risk of bias in 19 cRCTs is presented in Appendix V. Twelve studies were rated as having a high risk of bias for baseline imbalance; eight studies were rated as having a high risk of bias for loss of clusters; and three studies were at high risk of bias for incorrect analyses.

Recruitment bias

Seven studies were rated as having an unclear risk of bias on the recruitment bias criterion as these studies reported insufficient information to permit judgement. Ten studies were rated as having a low risk of bias as no evidence of recruitment bias (recruitment rate differences between the groups) was found in these studies.

Baseline imbalance

Twelve studies were rated as having a high risk of bias for baseline imbalance as baseline differences were compared between intervention groups but not clusters. Five studies were rated as having a low risk of bias as no baseline imbalance between the clusters was found in these studies.

Loss of clusters

Eight studies were rated as having a high risk of bias on the loss of clusters criterion because there was a high drop-out rate among clusters and statistical adjustments to counter for the losses were not reported by the authors. Three studies were rated as having an unclear risk of bias on loss of clusters as they reported insufficient information to permit judgement. Six studies were rated as having a low risk of bias as there was no loss of clusters in these studies.

Incorrect analysis

Three studies had a high risk of bias for incorrect analysis as they did not take clustering into account in the data analysis. Three studies were rated as having an unclear risk of bias as they reported insufficient information on the statistical analyses used. Twelve studies were rated as having a low risk of bias as these studies used appropriate statistical analyses (accounting for intracluster correlation), which took into account the effects of clustering.

Comparability with individual trials

All studies were rated as having an unclear risk of bias as the comparison of cluster with individual trials was not possible due to clinical heterogeneity.

Effects of interventions

The characteristics of included studies by participants' specialty, outcomes, comparisons and intervention types are presented in Appendices IIA – IIF.

Knowledge

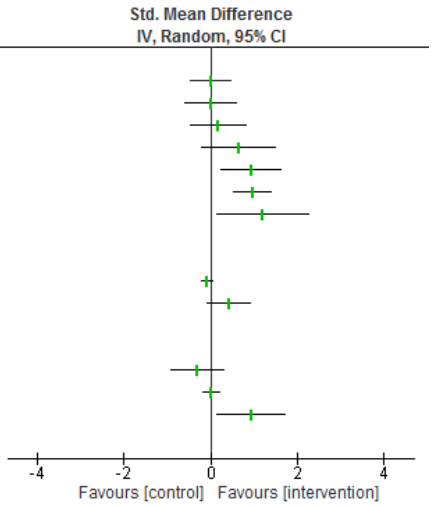
We defined knowledge as a gain in new facts and information obtained through the intervention and assessed using any validated or non-validated instrument.

ELearning vs self-directed learning

The effects of online and LAN-based eLearning vs self-directed learning on medical doctors' knowledge are presented in Figures 2.6, 2.7 and 2.8.

Twenty-nine studies compared eLearning with self-directed learning, which included no intervention or text-based learning. These studies assessed knowledge among learners from 12 specialties: emergency medicine; eye, nose and throat (ENT); gastroenterology; general or internal medicine; orthopaedics; paediatrics; primary care; public health; rheumatology; radiation oncology; radiology; and surgery. Six studies included participants from multiple specialties. The educational content was heterogeneous among the included studies, see Characteristics of included studies assessing knowledge, Appendix IIA.

Study or Subgroup	Intervention Mean	Intervention SD	Intervention Total	Control Mean	Control SD	Control Total	Std. Mean Difference IV, Random, 95% CI
1.1.1 eLearning vs self-directed learning							
Butzlaff 2004 (1)	0	0.3	38	0	0.3	34	0.00 [-0.46, 0.46]
Wang 2013 (2)	2.5	1.6	22	2.5	1.6	22	0.00 [-0.59, 0.59]
Cabrera-Muffly 2015 (3)	7	11.5	18	4	19.3	19	0.18 [-0.46, 0.83]
Le 2010 (4)	4.7	3.2	15	2.8	2	9	0.65 [-0.20, 1.50]
Alfieri 2012 (5)	17	14.8	19	5	9.8	17	0.92 [0.23, 1.62]
Westmoreland 2010	27.6	18.1	48	9	20	48	0.97 [0.54, 1.39]
Satterwhite 2012	20	17.8	9	1	10.7	8	1.21 [0.15, 2.27]
1.1.2 eLearning vs eLearning							
Schroter 2011	18.1	17	499	19.4	15.9	498	-0.08 [-0.20, 0.05]
Grover 2010 (6)	11.9	19.88	36	5	9.68	28	0.42 [-0.08, 0.92]
1.1.3 Blended learning vs self-directed/face-to-face learning							
Platz 2010	14.7	10.4	23	18	11.4	19	-0.30 [-0.91, 0.31]
Vollmar 2010	3.67	4.51	228	3.6	4.51	161	0.02 [-0.19, 0.22]
Sharma 2013 (7)	30	13.28	14	16	15.39	14	0.95 [0.16, 1.73]



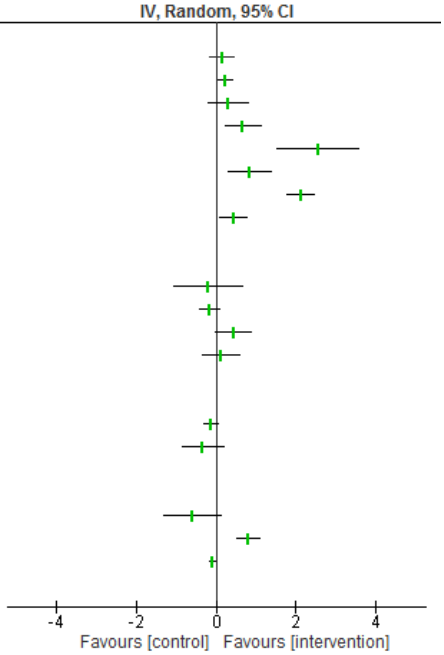
Footnotes
(1) Mean and SD calculated from median and range.
(2) The study reported three difference in test scores, we reported only the immediate posttest-pretest scores.
(3) The study assesses residents skills in 9 domains, of which we have presented the results for otology.
(4) The study reported guidelines score, guideline recommendations and questionnaire test score, we have reported overall guidelines score.
(5) SDs computed from pvalues of difference.
(6) Intervention group belong to AL test, control group to CVL test.
(7) Mean difference and 95% CI was computed from means and SD for the intervention and control groups. SD was computed using Revman...

Figure 2.6: Comparison of change in knowledge scores (pre-post intervention)

Of these studies, only 18 studies reported numerical data in a format that could be used in Figures 2.6, 2.7 and 2.8. Seven of these studies assessed a change in mean knowledge scores,[128,140,143,147,149,154,156] three[128,140,143] of which (n=149) reported higher knowledge scores in the online and LAN-based eLearning group (large effect size) compared to the self-directed learning group, Figure 2.6. Nine studies[130,131,133,137,141,142,146,148,150] assessed knowledge post-test. Of these, six

studies reported higher knowledge scores in the online and LAN-based eLearning group (n=672; small to large effect size) compared to the self-directed learning group, Figure 2.7.

Study or Subgroup	Intervention Mean	Intervention SD	Intervention Total	Control Mean	Control SD	Control Total	Std. Mean Difference IV, Random, 95% CI
1.2.1 eLearning vs self-directed learning							
Bell 2000	15	4.6	83	14.5	2.2	79	0.14 [-0.17, 0.45]
Chang 2014 (1)	21.8	10.96	225	19.7	6.58	233	0.23 [0.05, 0.42]
Chung 2004	48	10	31	45	10	32	0.30 [-0.20, 0.79]
Claxton 2011 (2)	15.7	1.84	41	14.2	2.53	41	0.67 [0.23, 1.12]
Hearty 2013	90.9	6.8	14	73.5	6.4	14	2.56 [1.52, 3.59]
Stewart 2005 (3)	63.8	17.6	27	50.5	13.8	31	0.84 [0.30, 1.38]
Sullivan 2010	8.4	0.8	109	6.1	1.3	104	2.13 [1.80, 2.47]
Viguier 2015 (4)	21.7	2.1	71	20.8	2.1	70	0.43 [0.09, 0.76]
1.2.2 eLearning vs face-to-face learning							
Chenkin 2008	78.8	7.3	11	80.3	6.6	10	-0.21 [-1.07, 0.65]
Hadley 2010	27	7.5	122	28.2	6	115	-0.18 [-0.43, 0.08]
Hemmati 2013 (5)	85.5	5.16	40	83.1	5.84	40	0.43 [-0.01, 0.87]
Hugenholtz 2008 (6)	64.9	9.2	37	63.8	7.3	35	0.13 [-0.33, 0.59]
1.2.3 eLearning vs eLearning							
Kerfoot 2007 (7)	53.2	29.5	264	56.8	27.6	273	-0.13 [-0.30, 0.04]
Sangvai 2012	87.9	6.8	29	90.3	7.3	29	-0.34 [-0.85, 0.18]
1.2.4 Blended learning vs self-directed/face-to-face learning							
Ali 2013	85.8	7.24	16	89.6	5.16	16	-0.59 [-1.30, 0.12]
Kulier 2012	43.1	6.16	123	38.1	6.33	81	0.80 [0.51, 1.09]
Perkins 2012	88.9	7.2	1843	89.5	7.2	1889	-0.08 [-0.15, -0.02]



Footnotes
(1) The study post-test presented results by speciality, we have presented for emergency medicine residents.
(2) Mean and SD estimated from Median and range
(3) Intervention: Two email evidence based cases, control: Delayed intervention. The study reported knowledge on prevention and diabetes...
(4) The study reported four topics, here we report only MCQ scores.
(5) Intervention: Group 2 (Internet based learning), Control: Group 1 (Traditional classroom learning)
(6) The study presented the mean and SD for baseline and post-test data, we have presented post-test data for Test Y..
(7) Kerfoot 2007, intervention: cohort 1, control:cohort 2

Figure 2.7: Comparison of post-intervention knowledge scores

Online and LAN-based eLearning improved physicians' knowledge compared with self-directed learning in 17 studies (small to large effect size; very low quality). Individual eLearning pedagogy was used in all 17 studies.[128-132,134-142,144] Nine studies[128,130,132,137-141,143] included an interactivity component in their intervention and five studies[128,137-139,143] used learning analytics and feedback.

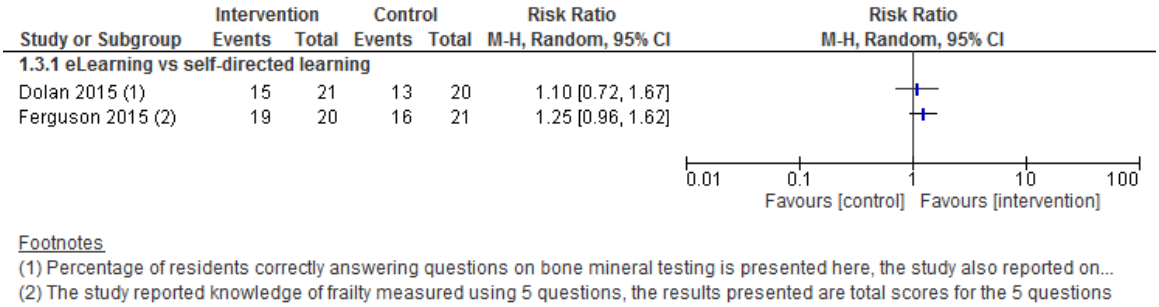


Figure 2.8: Comparison of post-intervention knowledge scores (dichotomous)

Two studies,[151,153] assessed knowledge as a dichotomous outcome and found no difference in knowledge scores between the groups, Figure 2.8. Eleven studies[129,132,134-136,138,139,144,145,152,155] presented incomplete data (missing means, SDs or confidence intervals), which could not be included in the data analysis.

Nine studies reported that online and LAN-based eLearning was equally as effective as self-directed learning for improving mean knowledge scores.[148-156] Of these seven studies used individual eLearning pedagogy[148-153,155] and five studies included an interactivity component in their intervention.[151,152,154-156] Three studies reported mixed results,[145-147] i.e. some outcomes from the same domain showed improvement while others did not.

Overall, empirical evidence from 17 of the 29 studies (n=2107) suggests that online eLearning may be effective compared to self-directed eLearning (small to large effect size; very low quality). Twelve of these studies had a high risk of bias in one or more of the risk of bias domains. Evidence from nine of the 29 studies (n=793) suggests that online eLearning may be as effective as self-directed learning in improving physicians' knowledge; three of these studies had a high risk of bias in one or more of the risk of bias domains.

ELearning vs face-to-face learning

The effect of online and LAN-based eLearning vs face-to-face learning on medical doctors' knowledge is presented in Figure 2.7.

Nine studies compared eLearning with face-to-face learning (classroom didactic lecture-based learning). These studies assessed knowledge among learners from four specialties: anaesthesiology, emergency medicine, primary care and surgery, see Characteristics of included studies assessing knowledge, Appendix IIA. The educational content was heterogeneous among the included studies. Of these, only four studies[168-171] reported numerical data in a useable format; no difference was found in post-test knowledge scores between online and LAN-based eLearning and face-to-face learning, Figure 2.7. Five studies[8,165-167,172] presented incomplete data (missing means, SDs or confidence intervals), which could not be included in the data analysis.

Online and LAN-based eLearning improved physicians' knowledge compared with face-to-face learning in studies by Fordis et al.[8] and Pelayo-Alvarez et al.[165] Fordis et al.[8] used facilitated eLearning pedagogy and the intervention included interactivity and learning analytics/feedback. Pelayo-Alvarez et al.[165] used individual eLearning pedagogy without interactivity or learning analytics/feedback. Six studies[166-171] reported that online and LAN-based eLearning may be equally as effective as face-to-face learning for improving knowledge scores (n=489). All studies used individual eLearning pedagogy. Only Bell et al.,[148] Chenkin et al.[168] and Hemmati et al.[170] used interactivity, and only Bell et al.[148] and Hemmati et al.[170] used learning analytics/feedback in the eLearning interventions. The study by McLeod et al.[172] used facilitated eLearning pedagogy and an interactive intervention component, and reported that knowledge scores were higher with face-to-face learning compared to online and LAN-based eLearning.

Overall, empirical evidence from six of the nine studies suggests that online eLearning may be as effective as face-to-face learning. One study[167] had a high risk of bias in one of the risk of bias domains. Evidence from two of the nine studies suggest that online eLearning may be more effective than face-to-face learning in improving physicians' knowledge (moderate effect size; low quality); both[8,165] these studies had a high risk of bias in one of the risk of bias domains.

ELearning vs eLearning

The effect of eLearning vs other types of online eLearning on physicians' knowledge is presented in Figures 2.6, 2.7 and 2.8.

Learners' knowledge was reported in eight studies[190,196,199,210-214] that compared online and LAN-based eLearning with other forms of online eLearning. These studies assessed knowledge among learners from four specialties (general medicine or internal medicine, urology, primary care practice, paediatrics), see Characteristics of included studies assessing knowledge, Appendix IIA. Shaw et al.[214] included participants from multiple specialties while Schroter et al.[190] included participants from multiple disciplines. The educational content was heterogeneous among the included studies. The interventions included the Bright Futures Oral Health online curriculum (vs eLearning on a different topic);[196] a web-based curriculum for central venous and arterial line procedures used in combination, or alone (vs no procedure);[210] an online educational program (a bolus educational program vs a spaced education program) for urology residents;[211] a web-based intervention designed to improve and sustain knowledge and screening for amblyopia in primary care settings (vs blood pressure screening and chlamydia screening);[212] an interactive vs non-interactive web-based module on injury prevention for paediatric residents;[199] hyperlink-embedded journal articles vs journal articles with no hyperlinks;[213] an online interactive diabetes needs assessment tool (DNAT) vs online self-directed learning for doctors;[190] and online spaced education vs an online slide show followed by a quiz to improve patient-safety behaviours in interns;[214] see

Characteristics of included studies, Appendix IIA. Of the nine studies that assessed knowledge, two studies reported a change in mean knowledge scores, [190,210] [190,210] [190,210] [190,210] [190,210] [190,210] [190,210] [190,210] [190,210] [190,210] [189,210] [190,211] [190,211] [190,211] [190,211] [190,211] [189,210] [189,210] [189,210] [188,209] [188,209] [188,209] [188,209] [188,209] [188,209] [188,209] [188,209] [188,209] [188,209] [188,209] [188,209] [188,209] [187,208] [187,208] [187,208] [187,208] [187,208] [186,207] [185,206] [185,206] [185,206] [184,205] [183,204] [182,203] [182,203] [181,202] [180,201] [179,200] [178,199] [177,198] [176,197] [175,196] [174,195] [173,194] [172,193] [171,192] [170,191] [169,190] [169,190] [169,190] [169,190] [168,189] [168,189] [168,189] [168,189] [168,189] [168,189] [168,189] [168,189] [168,189] [167,188] [167,188] [166,187] [166,187] [166,187] [166,187] [166,187] [168,189] [168,189] [168,189] [168,189] [168,189] [168,189] [168,189] [168,189] [167,188] [167,188] [167,188] [167,188][167,198] Figure 2.6. Two studies[199,211] compared post-test scores between the intervention groups, Figure 2.7. Four studies[196,212-214] presented incomplete data (missing means, SDs or confidence intervals), which could not be included in the data analysis.

Two studies[196,212] reported an improvement in physicians' knowledge with online and LAN-based eLearning compared with other forms of eLearning (n=270; very low quality); these studies used individual eLearning pedagogy. In Marsh-Tootle et al.[212] the eLearning intervention was based on a learning theory and the intervention contained an interactivity component and learning analytics/feedback. In the study by Bernstein et al.,[196] participants with access to the Bright Futures Oral Health online curriculum had higher knowledge scores compared to those who used the 1-hour online curriculum. In Marsh-Tootle,[212] participants in the web-based strabismus and amblyopia modules had higher knowledge scores than those in the web-based blood pressure and chlamydia modules. Six studies reported than online and LAN-based eLearning may be equally as effective as the other evaluated online eLearning interventions for improving physicians' knowledge scores. Three of these studies[199,211,214] had a high risk of bias in one of the risk of bias domains.

ELearning vs blended learning

Of the three studies that compared blended learning to eLearning[193,194,197] only Talib et al.[194] reported a change in knowledge scores for the whole group and hence could not be included in the data analysis. The study compared web-based training on oral health (eLearning) vs hands-on training and web-based training (blended learning) on oral health counselling for paediatric residents (see Characteristics of included studies assessing knowledge, Appendix IIA) and reported that online and LAN-based eLearning intervention may improve physicians' knowledge compared with blended learning. The study used individual eLearning pedagogy with an interactive eLearning component and was judged as having a high risk of bias on one of the risk of bias domains.

Blended learning vs self-directed/face-to-face learning

The effects of blended learning vs self-directed/face-to-face learning on learners' knowledge are presented in Figures 2.6 and 2.7.

Seven studies assessed learners' knowledge among participants from anaesthesiology, emergency medicine, obstetrics and gynaecology, and primary care. Perkins et al.[182] included participants from multiple specialties. The educational content was heterogeneous among the included studies, see Characteristics of included studies assessing knowledge, Appendix IIA. The interventions included an telemedicine-based advanced trauma life support (ATLS) course to teach trauma resuscitation skills vs a face-to-face ATLS course;[181] evidence-based medicine (EBM) reproductive health training vs face-to-face learning;[188] EBM reproductive health training vs self-directed learning;[179] physicians' opioid- and benzodiazepine-prescribing skills training vs a 3-hour interactive presentation;[186] advanced life support training vs conventional instructor led face-to-face training;[182] web-based training in basic ultrasonographic and extended focused assessment with sonography for trauma (EFAST) vs no training or face-to-face training;[183] Internet and simulation-based

training in transoesophageal echocardiography vs self-directed guideline training for anaesthetic trainees;[180] a blended learning approach using online modules, quality circles (QCs) and QCs alone on dementia management vs lectures and structured discussion vs reading materials.[184] All seven studies that assessed knowledge reported numerical data in a useable format, which was included in Figures 2.6 and 2.7. Of these studies, three[180,183,184] assessed a change in mean knowledge scores, and three[179,181,182] compared post-test knowledge scores between the intervention groups, Figure 2.7.

Two studies[179,180] reported higher post-intervention knowledge scores (n=232; large effect size) for physicians in the blended learning group compared with the comparator group, Figures 2.6 and 2.7. Both studies had a high risk of attrition bias. Kulier et al.[179] used collaborative eLearning pedagogy and learning analytics/feedback in the intervention; while Sharma et al.[180] used individual eLearning pedagogy and an interactivity component in the intervention. Perkins et al.[182] reported higher knowledge scores for the face-to-face learning group.

Five studies[181-184,188] reported that blended learning may be as effective as self-directed/face-to-face learning for improving physicians' knowledge scores. Platz et al.[183] had a high risk of bias on random sequence generation, allocation concealment, incomplete outcome data and other biases; Vollmar et al.[184] had a high risk of bias for incomplete outcome data. These studies used collaborative eLearning pedagogy,[181,184,188] facilitated eLearning pedagogy[182] and individual eLearning pedagogy.[183] Four of these studies[181-184,188] used an interactive eLearning intervention.

Overall, empirical evidence from two of the seven studies suggests that blended learning may be as effective as self-directed/face-to-face learning for improving physicians' knowledge (large effect size; very low quality), however, both studies[179,180] were at high risk of attrition bias. Evidence from five of the seven studies suggests that blended learning may be as effective as self-directed/face-

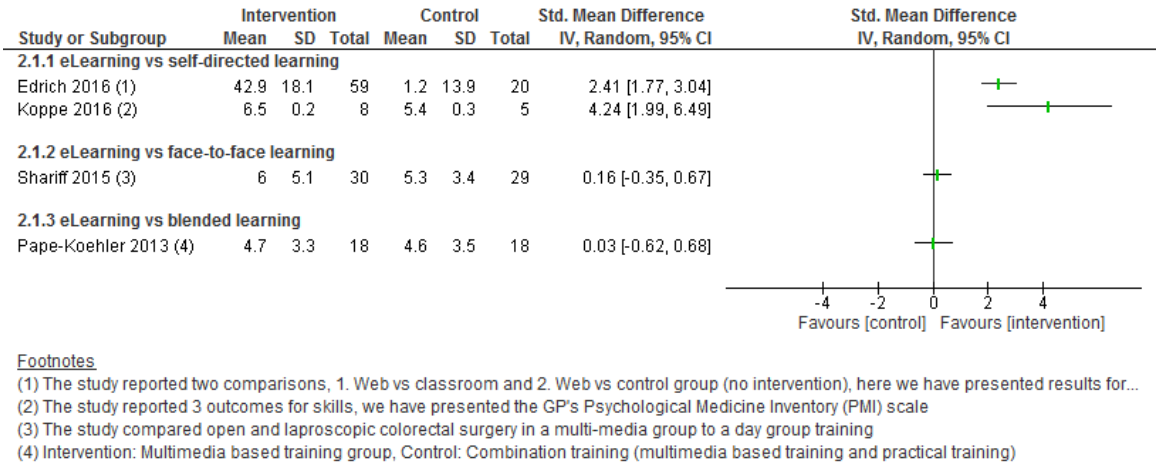
to-face learning in improving physicians' knowledge; however, two of these studies[183,184] had a high risk of bias on one or more of the risk of bias domains.

Skills

We defined skills as the ability and capacity to smoothly and adaptively carry out complex activities (technical, cognitive or interpersonal tasks) as a result of the intervention. We included studies that assessed physicians' skills using any validated or non-validated instrument.

ELearning vs self-directed learning

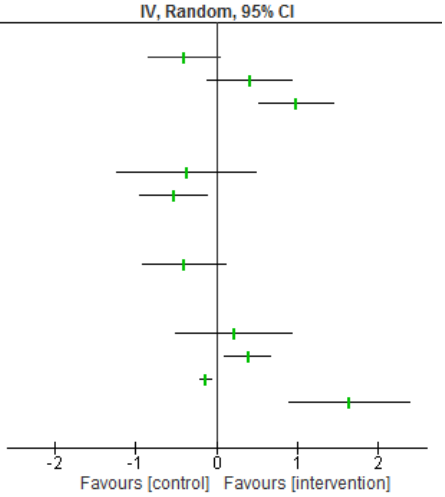
The effects of online and LAN-based eLearning vs self-directed learning on medical doctors' skills are presented in Figures 2.9, 2.10 and 2.11.



Footnotes
(1) The study reported two comparisons, 1. Web vs classroom and 2. Web vs control group (no intervention), here we have presented results for...
(2) The study reported 3 outcomes for skills, we have presented the GP's Psychological Medicine Inventory (PMI) scale
(3) The study compared open and laproscopic colorectal surgery in a multi-media group to a day group training
(4) Intervention: Multimedia based training group, Control: Combination training (multimedia based training and practical training)

Figure 2.9: Comparison of **c**hange in skills scores (pre-post intervention)

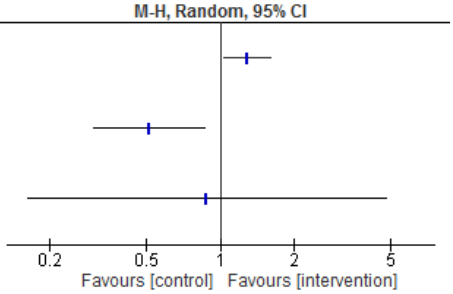
Study or Subgroup	Intervention Mean	Intervention SD	Intervention Total	Control Mean	Control SD	Control Total	Std. Mean Difference IV, Random, 95% CI
2.2.1 eLearning vs self-directed learning							
Claxton 2011 (1)	36.6	6.3	41	39.5	8	41	-0.40 [-0.84, 0.04]
Conroy 2015 (2)	9.2	3.3	29	7.9	2.9	28	0.41 [-0.11, 0.94]
Macrae 2004	58	8	45	50	8	38	0.99 [0.53, 1.45]
2.2.2 eLearning vs face-to-face learning							
Chenkin 2008	75	9.3	11	77.8	3.6	10	-0.37 [-1.24, 0.49]
Houwink 2015 (3)	7.7	0.8	42	8.1	0.7	50	-0.53 [-0.95, -0.11]
2.2.3 eLearning vs eLearning							
Sangvai 2012 (4)	0.5	0.7	29	0.9	1.2	29	-0.40 [-0.92, 0.12]
2.2.4 Blended learning vs self-directed/face-to-face learning							
Ali 2013	3.1	0.5	14	3	0.4	16	0.22 [-0.50, 0.94]
Kulier 2012 (5)	9.1	2.2	123	8.3	1.8	81	0.39 [0.11, 0.67]
Perkins 2012	74.5	42.2	1843	80.2	42.2	1889	-0.14 [-0.20, -0.07]
Szmuilowicz 2012 (6)	75.1	8.9	19	53.2	16.2	19	1.64 [0.89, 2.39]



Footnotes
(1) Palliative care preparedness
(2) Correct classification score
(3) The study compares 3 interventions, results presented here are for genetics elearning CPD module about oncogenetics vs live genetic CPD...
(4) Experimental: Web-based interactive modules, Control: Non-interactive web-based modules
(5) Post-course OSCE scores
(6) Intervention, Blended learning: Multi-modality communication skills training, control group: clinical rotation

Figure 2.10: Comparison of post-intervention skills scores

Study or Subgroup	Intervention Events	Intervention Total	Control Events	Control Total	Risk Ratio M-H, Random, 95% CI
2.4.1 eLearning vs self-directed learning					
Dolan 2015 (1)	57	75	47	80	1.29 [1.03, 1.62]
2.4.2 eLearning vs blended learning					
Ruf 2010 (2)	10	27	31	43	0.51 [0.30, 0.87]
2.4.3 Blended learning vs self-directed/face-to-face learning					
Ngamruengphong 2015 (3)	3	29	2	17	0.88 [0.16, 4.75]



Footnotes
(1) The study reported treatment rates for high risk fragility fractures among the groups.
(2) Intervention: eLearning, Control: online system and a training programme for the general practitioners (GPs), Outcome: Correct diagnosis
(3) The study reported documentation skills of HBV vaccination status at 6 months after the intervention

Figure 2.11: Comparison of post-intervention skills scores (dichotomous)

Eight studies[131,151,157-162] compared eLearning with self-directed learning, which included no intervention or text-based learning. These studies assessed skills among six specialties (anaesthesiology, general or internal medicine, primary care practice, paediatrics, public health and surgery), see Characteristics of included studies assessing skills, Appendix IIB. The educational content in these studies included Fast Facts and Concept (FFAC) emails for palliative care

training;[131] the Liverpool Adverse Drug Reaction Causality Assessment eLearning tool to improve causality assessment among paediatric trainees;[161] an online curriculum in bone health;[151] web-based training in lung ultrasounds to exclude pneumothorax for anaesthesia physicians;[162] solutions for smoking - a teaching tool on tobacco related problems for paediatric residents;[157] a Web 2.0 Balint group to improve psychological medicine skills and work-related affect for primary care practitioners;[158] cross-cultural communication skills for family medicine clerkship students;[159] and critical appraisal skills training for surgeons.[160] Of these, only six studies[131,151,158,160-162] reported numerical data that could be used in Figures 2.9, 2.10 and 2.11. Two of these studies assessed a change in mean skills scores;[158,162] Figure 2.9; three studies[131,132,160] assessed skills post-test, Figure 2.10; and Dolan et al.[151] assessed skills as a dichotomous outcome, Figure 2.11. Four of these studies[151,158,160,162] reported an improvement in physicians' skills (large effect size; low quality). Two studies[157,159] presented incomplete data (missing means, SDs or confidence intervals), which could not be included in the data analysis.

Overall, empirical evidence from six studies[151,157-160,162] indicated that online and LAN-based eLearning interventions can improve physicians' skills compared with self-directed learning. These studies used individual eLearning pedagogy[131,151,158,159,162] and facilitated learning pedagogy.[157,160] The eLearning content was validated in three studies[131,158,160] and three studies used an interactive eLearning intervention.[151,157,160] Four of the studies[151,158,159,162] had a high risk of bias on one of the risk of bias domains. Similarly, evidence from two[131,161] of the eight studies, which used individual eLearning pedagogy, indicated that online and LAN-based eLearning may be as effective as self-directed learning for improving physicians' skills scores. One[162] of the two studies had a high risk of ‘other bias’.

ELearning vs face-to-face learning

The effects of online and LAN-based eLearning vs self-directed learning on medical doctors' skills are presented in Figures 2.9, 2.10 and 2.11.

Seven studies[166,168,173-177] compared eLearning with face-to-face learning (class room didactic lecture-based learning). These studies assessed skills among five specialties (anaesthesiology, emergency medicine, general or internal medicine, primary care practice and surgery), see Characteristics of included studies assessing skills, Appendix IIB. The educational content in these studies included an advanced training course on the principles and practice of airway management;[166] a web-based training on ECG interpretation;[173] a web-based tutorial for ultrasound-guided vascular access training;[168] a genetics eLearning CPD module on oncogenetics for primary care practitioners;[174] multimedia educational tools for cognitive surgical skill acquisition in open and laparoscopic colorectal surgery;[175] an online course on "mastering difficult family conversations in surgical care" for surgical residents in the general and orthopaedic program;[177] and technology-driven simulation-based cardiac ultrasonography training for internal medicine residents.[176]

Five of these studies reported numerical data in a useable format and were included in Figures 2.9, 2.10 and 2.11. Barthelemy et al.[173] and Shariff et al.[175] assessed a change in mean skills scores, Figure 2.9; Chenkin et al.[168] and Houwink et al.[174] assessed skills post-test, Figure 2.10; and Wilkinson et al.[176] assessed skills as a dichotomous outcome. Bello et al.[166] and Schmitz et al.[177] presented incomplete data (missing means, SDs or confidence intervals), which could not be included in the data analysis.

Six studies[166,168,173-176] reported that eLearning may be as effective as face-to-face learning for improving physicians' skills scores. These studies used individual eLearning pedagogy,[166,168,174,175] facilitated eLearning pedagogy[176] and an interactive learning component in the intervention.[166,168,176] Houwink et al.[174]

reported an improvement in physicians' skills scores in the face-to-face learning group (n=92; moderate effect size), Figure 2.10.

Overall, empirical evidence from six studies suggests that online eLearning may be as effective as face-to-face learning in improving physicians' skills, while evidence from one study[138] suggests that face-to-face learning may be effective in improving physicians' skills compared to online eLearning; however, the study had a high risk of bias on one of the risk of bias domains (moderate effect size; very low quality).

ELearning vs eLearning

Bernstein et al.[196] and Sangvai et al.[199] assessed skills among paediatric residents. The intervention in the studies included an interactive web-based module vs a non-interactive module on clinical practice in injury prevention for paediatric residents;[199] and the Bright Futures Oral Health online curriculum (vs eLearning on a different topic).[196] The studies reported that online and LAN-based eLearning intervention may improve physicians' skills compared to the other eLearning intervention evaluated. Sangvai et al.[199] reported that online eLearning may be as effective as other types of online eLearning for improving physicians' skills, Figure 2.10.

ELearning vs blended learning

The effects of online and LAN-based eLearning vs blended learning on learners' skills are presented in Figures 2.9, 2.10 and 2.11.

Three studies assessed skills[193,194,197] among surgeons, primary care practitioners, and paediatric residents, see Characteristics of included studies assessing skills, Appendix IIB. The educational content in these studies included multimedia-based training on Internet platforms to improve surgeon's performance in completing a laparoscopic cholecystectomy using a Pelvic-Trainer, which simulates an abdomen so that surgery can be reproduced in a realistic manner;[197] an online quality improvement program for alcohol-related disorders;[193] and

web-based training in oral health.[194] Among the studies, individual eLearning pedagogy was used in studies by Pape-Koehler et al.[197] and Talib et al.[194] Studies were based on learning theory in studies by Pape-Koehler et al.[197] and Ruf et al.[193] The intervention was interactive in studies by Pape-Koehler et al.[197] and Talib et al.,[194] while learning analytics and feedback was only presented in the study by Pape-Koehler et al.[197] Two studies[193,197] reported numerical data in a useable format, which was included in Figures 2.9, 2.10 and 2.11. Pape-Koehler et al.[197] assessed a change in skills scores and Ruf et al.[193] reported skills as a post-test dichotomous outcome, M-H RR (random) was calculated using RevMan; RR was 0.50 (95% CI 0.28 to 0.91), Figure 2.11.

Pape-Koehler et al.[197] reported that online and LAN-based eLearning may be as effective as blended learning (combination training) for improving physicians' skills. Ruf et al.[193] and Talib et al.[194] reported that blended learning may improve physicians' skills compared to online and LAN-based eLearning (large effect size; low quality). Overall, empirical evidence from two of the three studies suggests that blended learning may be effective, or as effective, as online eLearning in improving physicians' skills.

Blended learning vs self-directed/face-to-face learning

The effect of blended learning vs self-directed/face-to-face learning on learners' skills is presented in Figure 2.10.

Six studies assessed skills[179,181,182,185-187] among four specialties (surgery, primary care practice, obstetrics and gynaecology, general or internal medicine), Perkins[182] included participants from multiple specialties, see Characteristics of included studies assessing skills, Appendix IIB. The educational content in these studies included ATLS face-to-face trauma resuscitation skills training;[181] a clinically integrated self-directed eLearning course in EBM for reproductive health vs self-directed training;[179] a distance learning program on opioid and benzodiazepine prescribing skills vs face-to-face learning for physicians;[186] a multifaceted blended learning program vs self-directed learning on hepatitis B

virus immunisation;[187] Advanced Life support training (ALS) compared to conventional instructor-led ALS training;[182] and an Internet based multimodality communication skills (code status discussions) intervention vs clinical rotation.[185] Four studies reported numerical data at post-test,[179,181,182,185] Figure 2.9, while Ngamruengphong[187] reported skills as a post-test dichotomous outcome, Figure 2.11.

Kulier et al.[179] and Szmuilowicz et al.[185] reported that blended learning may improve physicians' skills compared with self-directed/face-to-face learning, Figure 2.9. Both studies used collaborative eLearning pedagogy and included learning analytics and feedback in the eLearning intervention. Ali et al.,[181] Midmer et al.,[186] Ngamruengphong et al.[187] and Perkins et al.[182] reported that blended learning may be equally as effective as self-directed/face-to-face learning for improving physicians' skills. These studies used facilitated eLearning,[182,186] collaborative eLearning,[181] and individual eLearning pedagogies.[187] Three of the studies included an interactive eLearning component[181,182,186] and two studies[186,187] included learning analytics and feedback.

Overall, empirical evidence from two of the six studies suggests that blended learning may be as effective as self-directed/face-to-face learning in improving physicians' skills (moderate to large effect size; very low quality); however, both studies[179,185] had a high risk of bias on one of the risk of bias domains. Evidence from four of the six studies suggests that blended learning may be as effective as self-directed/face-to-face learning in improving physicians' skills; however, two[186,187] of the six studies had a high risk of attrition and reporting bias.

Attitude

We defined attitude as the tendency to respond positively or negatively towards new knowledge or skills acquired as a result of the intervention. We included studies that assessed attitude using any validated or non-validated instrument.

ELearning vs self-directed learning

The effects of online and LAN-based eLearning vs self-directed learning on physicians' attitude are presented in Figures 2.12 and 2.13. Four studies[132,136,141,154] compared eLearning with self-directed learning, which included no intervention or text-based learning. These studies were from general or internal medicine[141] and paediatrics.[132,154] Harris et al.[136] included participants from multiple specialties, see Characteristics of included studies assessing attitude, Appendix IIC. The educational content in these studies included a digital resource vs self-directed learning on normal child development for paediatric trainees;[132] a case-based domestic violence education program vs no training for physicians caring for domestic violence patients;[136] a distance learning program vs no training on paediatric asthma for paediatricians;[154] and web-based training on shared decision-making for chronic opioid therapy vs opioid guidelines for medical residents.[141] The studies used individual eLearning pedagogy[132,136,141] or facilitated eLearning pedagogy.[154] Three studies[105,114,127] included interactivity in their interventions[132,141,154] and two studies used learning analytics and feedback.[136,154] Of these, only two studies[141,154] reported numerical data in a useable format, which were included in Figures 2.12 and 2.13. Le et al.[154] assessed a change in mean attitude scores, Figure 2.12; and Sullivan et al.[141] assessed attitude post-test, Figure 2.13. Two studies[136,138] reported incomplete data (omitted the mean, SD or confidence intervals), which could not be included in the data analysis.

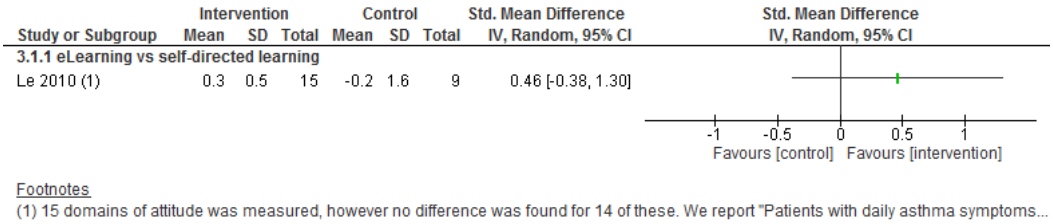
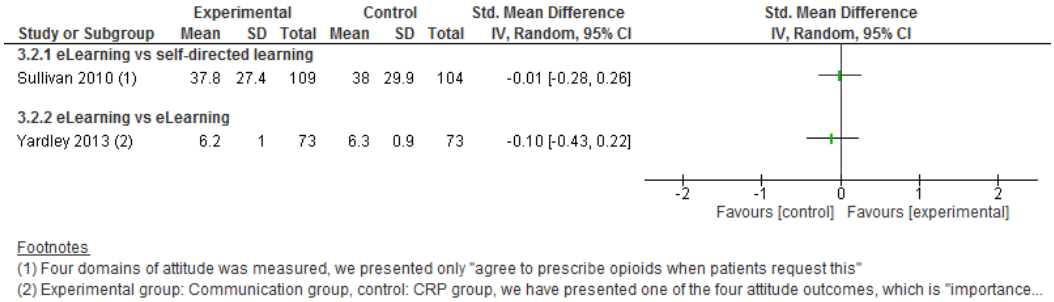


Figure 2.12: Comparison of change in attitude scores (pre-post intervention)



Footnotes
(1) Four domains of attitude was measured, we presented only "agree to prescribe opioids when patients request this"
(2) Experimental group: Communication group, control: CRP group, we have presented one of the four attitude outcomes, which is "importance...

Figure 2.13: Change in post-intervention attitude scores (dichotomous)

Harris et al.[136] reported that online and LAN-based eLearning interventions may improve physicians' attitude compared to self-directed learning; the study had a high risk of bias on one of the risk of bias domains. Le et al.[154] reported that online and LAN-based eLearning may be equally as effective as self-directed learning for improving physicians' attitude; however, the study had a high risk of selection, attrition and 'other bias'. Connolly et al.[132] and Sullivan et al.[141] reported mixed results. Overall, empirical evidence from the studies suggest that online eLearning may be effective, or as effective, as self-directed learning in improving physicians' attitude.

ELearning vs face-to-face learning

The effect of online and LAN-based eLearning vs face-to-face learning on physicians' attitude is presented in Figure 2.13.

Two studies[165,178] compared eLearning with face-to-face learning (classroom didactic lecture-based learning) in primary care and surgery, see Characteristics of included studies assessing attitude, Appendix IIC. The educational content in these studies included online palliative care education for primary care physicians (PCPs) vs face-to-face learning;[165] and an online curriculum on patient safety for surgical residents.[178] Both studies used individual eLearning pedagogy. Only Putnam et al.[178] reported a change in learners' attitude as a dichotomous outcome, Figure 2.14. Empirical evidence from both studies suggests that online and LAN-based eLearning may be as effective as face-to-

face learning in improving physicians' attitude; however, both studies had a high risk of attrition bias.

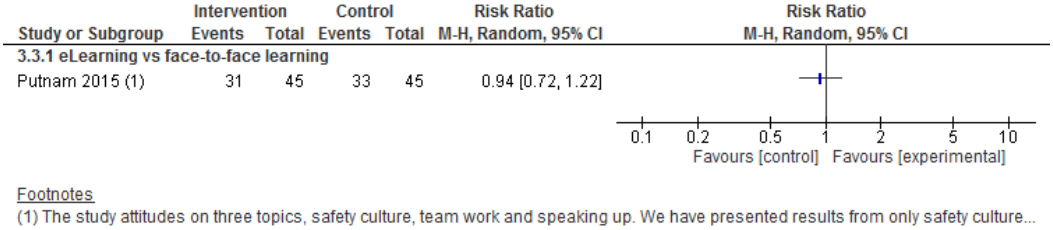


Figure 2.14: Comparison of post-intervention attitude scores (dichotomous)

ELearning vs eLearning

The effects of online and LAN-based eLearning vs other forms of online eLearning on learners' attitude is presented in Figure 2.13. Yardley et al.[215] assessed attitude among primary care practitioners in a cRCT, see Characteristics of included studies assessing attitude, Appendix IIC. PCPs were randomised into one of three intervention groups or a control group. The intervention groups received web-based training in C-reactive protein (CRP) testing, communication skills and using a patient booklet (usual care group), or training in both (combined group). The study assessed post-test attitude scores, with mixed results observed between the intervention groups, Figure 2.13.

Blended learning vs self-directed/face-to-face learning

The effects of blended learning vs self-directed/face-to-face learning on learners' attitude are presented in Figure 2.15. Kulier et al.[188] compared an integrated eLearning course vs face-to-face training on EBM among obstetrics and gynaecology residents; another study by Kulier et al.[179] compared an integrated eLearning course vs a self-directed course on EBM, and assessed attitude scores at baseline only. Kulier et al.[188] reported blended learning may be equally as effective as face-to-face training for improving physicians' attitude, Figure 2.15.

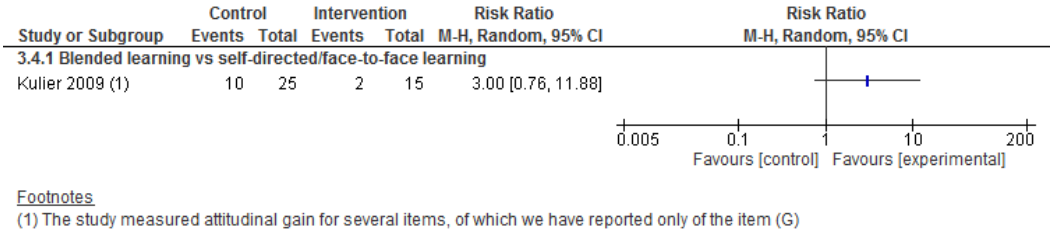


Figure 2.15: Comparison of post-intervention attitude scores (dichotomous)

Satisfaction

We defined satisfaction as the learner's level of approval of the intervention and its perceived performance compared with the learner's expectations of the intervention. We included studies that assessed satisfaction using any validated or non-validated instrument.

ELearning vs self-directed learning

The effects of online and LAN-based eLearning vs self-directed learning on physicians' satisfaction are presented in Figures 2.16 and 2.17.

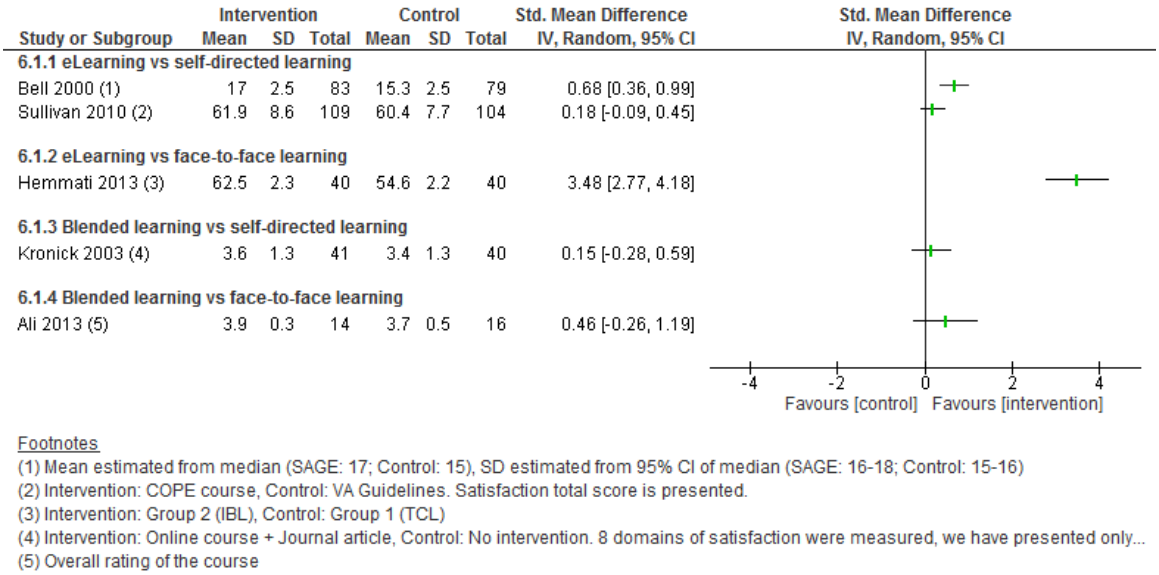
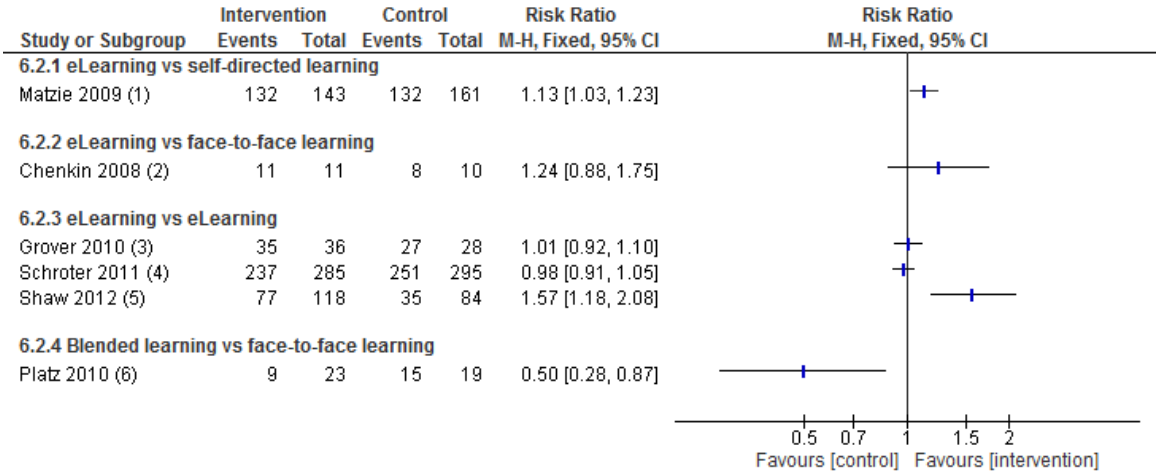


Figure 2.16: Comparison of post-intervention satisfaction scores

Six studies[131,141,145,148,163,164] compared eLearning with self-directed learning, which included no intervention or text-based learning. These studies assessed satisfaction among three specialties (primary care, general or internal medicine, paediatrics), see Characteristics of included studies assessing satisfaction, Appendix IID. The educational content was heterogeneous and included the web-based Self-study Acceleration with Graphic Evidence (SAGE) guidelines vs printed self-study materials on care after acute myocardial infarction for family medicine and internal medicine residents;[148] FFAC emails vs self-directed learning for palliative care training;[131] Internet-based CME for lipid management, Internet CD-ROM thoracic surgery, and prerequisite surgery curriculum vs curriculum outline;[145] spaced education vs no spaced education emails on blood pressure and chlamydia screening for surgical residents;[163] spaced education vs no emails for faculty training in a surgery department;[164] web-based training vs opioid guidelines on shared decision-making for opioid therapy.[141] Of these, only three studies[141,148,163] reported numerical data in a useable format, which was included in Figures 2.16 and 2.17. Two studies[141,148] assessed mean satisfaction scores post-test, Figure 2.16; and Matzie et al.[163] assessed students' satisfaction post-test scores as a dichotomous outcome, Figure 2.17. Three studies[131,145,164] presented incomplete data (missing means, SDs or confidence intervals), which could not be included in the data analysis.



Footnotes
(1) Frequency and quality of feedback was measured, only "usefulness and helpfulness" of the feedback is presented here.
(2) The study reported 4 outcomes for satisfaction, we have presented "found the teaching format to be effective"
(3) Satisfaction was measured for a number of domains, here we have presented " their rating of online curricula for AL...
(4) 15 measures of satisfaction was reported. We have included only " the learning materials have improved my overall...
(5) Intervention: Spaced education (SE), Control: Online slide show followed by a quiz. Several domains of satisfaction was...
(6) Intervention: Webgroup, Control: Classroom (Didactic). Participant satisfaction was measured using a 4 point rating scale, we...

Figure 2.17: Comparison of post-intervention satisfaction scores (dichotomous)

Matzie et al.[163] reported students' satisfaction across a range of domains such as frequent feedback, usefulness of feedback, frequency or quality of feedback from residents, frequent feedback and high quality feedback received from residents - both frequency and quality of feedback were included in Figure 2.17. The study reported higher satisfaction in four of the five domains. Similarly, Bell at al reported higher satisfaction for the intergroup group.[148]

Overall, empirical evidence from two studies [148,163] suggests that online and LAN-based eLearning may be as effective as self-directed learning on physicians' satisfaction (moderate to large effect size; low quality); the risk of bias was unclear across three domains. Both studies used individual eLearning pedagogy. Similarly, evidence from three[131,141,163,164] of the six studies suggests that online and LAN-based eLearning may be as effective as self-directed learning in improving physicians' satisfaction; however, the risk of bias was high in the study by Claxton et al.[131] All three studies used individual eLearning pedagogy and the eLearning intervention was interactive in studies by Matzie et al.[163] and Sullivan et al.[141] Gold et al.[145] reported mixed results.

eLearning vs face-to-face learning

The effects of online and LAN-based eLearning vs face-to-face learning on physicians' satisfaction are presented in Figures 2.16 and 2.17.

Four studies[8,166,168,170] compared eLearning with face-to-face learning (classroom didactic lecture-based learning). These studies assessed satisfaction among three specialties (anaesthesiology, emergency medicine, primary care), see Characteristics of included studies assessing satisfaction, Appendix IID. The educational content was heterogeneous among the included studies. The education interventions included an Internet-based course vs face-to-face learning on difficult airway management for anaesthesiology residents;[166] ultrasound-guided vascular access training vs didactic learning for emergency physicians and residents;[168] Internet-based CME on cholesterol management for primary care practitioners;[8] and Internet-based learning vs face-to-face room lectures on cardiopulmonary resuscitation for general physician trainees.[170] Two studies[168,170] reported numerical data in a useable format, which was included in Figures 2.16 and 2.17. Hemmati et al.[170] assessed satisfaction scores post-test, Figure 2.16; whereas Chenkin et al.[168] assessed satisfaction as a dichotomous outcome, Figure 2.17.

Overall, empirical evidence from two[166,170] of the four studies suggests that online and LAN-based learning may be effective compared with face-to-face learning in improving physicians' satisfaction (large effect size; low quality); the risk of bias was low or unclear for both studies. Both studies used individual eLearning pedagogy and the interventions contained interactivity and learning analytics/feedback. Similarly, evidence from two[8,168] of the four studies suggests that online and LAN-based learning may be as effective as face-to-face learning in improving physicians' satisfaction; however, the risk of selection bias was high in the study by Fordis et al.,[8] Figure 2.5. The studies used individual learning[168] and facilitated learning pedagogy.[8] The interventions in both studies

contained an interactive component, however learning analytics and feedback was only included in the study by Fordis et al.[8]

ELearning vs eLearning

The effect of online and LAN-based eLearning vs other forms of online and LAN-based eLearning on physicians' satisfaction is presented in Figure 2.17.

Four studies[190,210,214,215] assessed satisfaction within general or internal medicine and primary care practice; one study included learners from multiple specialties[214] and another included learners from multiple disciplines,[190] see Characteristics of included studies assessing satisfaction, Appendix IID. The educational content was heterogeneous among the included studies. Interventions assessed in the studies included web-based curriculum for central venous vs arterial live procedures;[210] an online interactive DNAT vs online self-directed learning for medical doctors;[190] a cluster randomised trial of web-based training for using CRP tests, communication skills and a patient booklet (usual care group), or training in both (combined group) among GPs;[215] online spaced education vs an online slide show followed by a quiz to improve patient-safety behaviours in interns.[214] Individual eLearning pedagogy and interventions were used in studies by Schroter et al.[190] and Yardley et al.[215] who also used interactivity. Of the four studies that assessed satisfaction, only three studies[190,210,214] reported numerical data (post-test, dichotomous outcomes) between the intervention groups, Figure 2.17. Yardley et al.[215] presented incomplete data (missing means, SDs or confidence intervals), which could not be used in the data analysis.

Yardley et al.[215] reported that online and LAN-based eLearning (communications group, combined groups) may be effective in improving physicians' satisfaction compared to the other forms of online and LAN-based eLearning evaluated (CRP and usual care group); however, the study was at high risk of bias for baseline imbalance. The study by Shaw et al.[214] reported mixed results for the interventions compared and had a high risk of attrition bias. Schroter et al.[190]

reported online and LAN-based eLearning (i.e. DNAT) may be as effective as the other form of eLearning (a diabetes learning module) in improving physicians' satisfaction; the study had a low or unclear risk of bias, Figure 2.5.

Blended learning vs self-directed/face-to-face learning

The effect of blended learning vs self-directed/face-to-face learning on physicians' satisfaction is presented in Figure 2.17.

Three studies[181,183,189] assessed satisfaction among general or internal medicine and emergency medicine physicians. The educational content was heterogeneous among the included studies, see Characteristics of included studies assessing satisfaction, Appendix IID. The education interventions included a standard 2-day ATLS course (control group) vs a telemedicine teaching course (telemedicine group);[181] an individualised 3-hour training session for rural physicians on using the World Wide Web to research patient-related questions vs self-directed learning;[189] and web- vs classroom-based basic ultrasonographic and EFAST vs face-to-face training.[183] Kronick et al.[189] used facilitated eLearning pedagogy and Platz et al.[183] used individual eLearning pedagogy. All three studies reported numerical data in a useable format, which was included in Figures 16 and 17. Kronick et al.[189] and Ali et al.[181] assessed post-test satisfaction scores and Platz et al.[183] reported satisfaction as a dichotomous outcome. Two studies[181,189] reported blended learning may be equally as effective as self-directed/face-to-face learning for improving physicians' satisfaction. Platz et al.[183] found higher satisfaction with face-to-face learning compared to web-based training (moderate effect size; very low quality). The studies had a high risk of attrition bias,[183,189] selection bias and baseline imbalance.[183] Overall, empirical evidence from three[181,183,189] studies suggests that blended learning may, or may not be, effective compared to self-directed/face-to-face learning in improving physicians’ satisfaction (moderate effect size; very low quality). The risk of bias for the studies was high on one or more of the risk of bias domains, Figure 2.5.

Secondary Outcomes

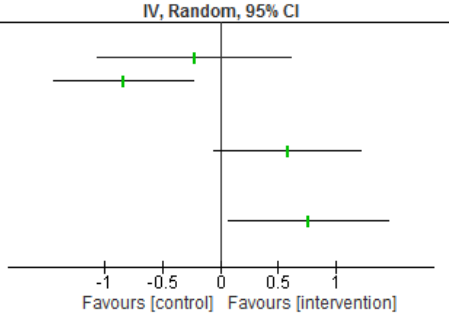
Practice or behaviour change

We defined practice or behaviour change as any change in the way a physician practices or changes in physicians' behaviour in diagnosing, prescribing and counselling after the intervention. We included studies that assessed practice or behaviour change using any validated or non-validated instrument.

ELearning vs self-directed learning

The effects of online and LAN-based eLearning vs self-directed/face-to-face learning on physicians' practice or behaviour change are presented in Figures 2.18, 2.19 and 2.20.

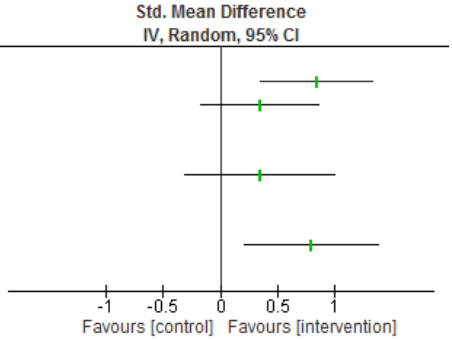
Study or Subgroup	Intervention Mean	Intervention SD	Intervention Total	Control Mean	Control SD	Control Total	Std. Mean Difference IV, Random, 95% CI
5.1.1 eLearning vs self-directed learning							
Le 2010 (1)	6.9	15.3	15	10.5	15.7	9	-0.23 [-1.05, 0.60]
Meeker 2016 (2)	19.2	4.8	20	24	6.2	27	-0.84 [-1.44, -0.23]
5.1.2 eLearning vs face-to-face learning							
Fordis 2005 (3)	-0.1	5.5	20	-3.3	5.4	20	0.58 [-0.06, 1.21]
5.1.3 Blended learning vs self-directed learning							
Daetwyler 2010 (4)	27	21	16	8	27	19	0.76 [0.07, 1.45]



Footnotes
(1) This study presents 2 behavioural outcomes, we report one of these "considering the total number of your patients with persistent asthma,...
(2) Intervention: Peer comparison; Control: Self-directed learning
(3) The study reported appropriateness of screening / treatment for Dyslipidemia, we report screening for dyslipidaemia between online CME...
(4) Number correct behaviours scored by SPs between "Doc.com+Web OSCE group" and "Control group"

Figure 2.18: Comparison of practice or behaviour change scores (pre-post intervention)

Study or Subgroup	Intervention Mean	Intervention SD	Intervention Total	Control Mean	Control SD	Control Total	Std. Mean Difference IV, Random, 95% CI
5.2.1 eLearning vs self-directed learning							
Gerbert 2002 (1)	71	8	39	62	13	32	0.84 [0.36, 1.33]
Stewart 2005 (2)	52.2	11.7	27	47.7	13.8	31	0.35 [-0.18, 0.87]
5.2.2 eLearning vs face-to-face learning							
Fordis 2005 (3)	94.3	5.2	17	92	7.5	19	0.34 [-0.31, 1.00]
5.2.3 Blended learning vs self-directed learning							
Epstein 2011 (4)	42	25.9	27	18.1	33.1	22	0.80 [0.21, 1.39]

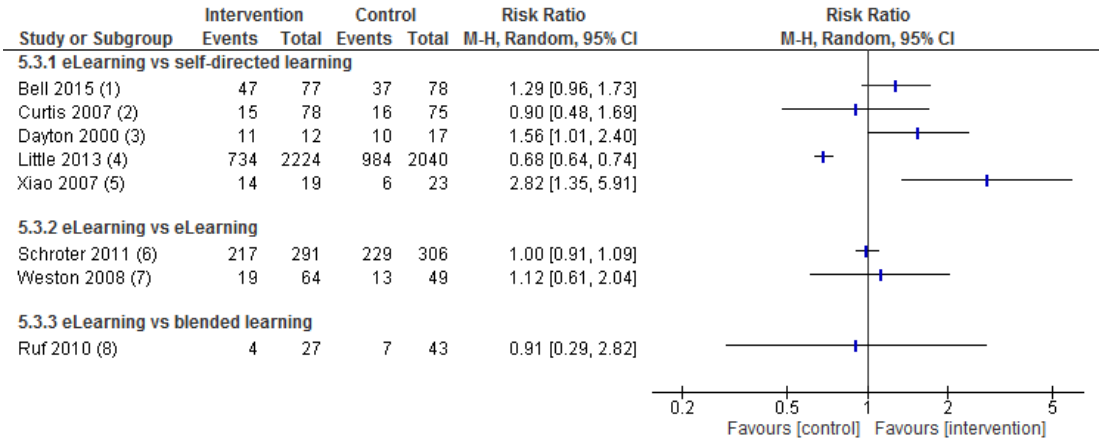


Footnotes
(1) The study reported several behavior change outcomes on diagnosis and evaluation planning, we report overall mean changes in...
(2) Intervention: Two email evidence based cases, control: Delayed intervention. The study reported knowledge on prevention and diabetes...
(3) Outcome: Patients appropriately screened for dyslipidemia. Intervention: Online CME, control: Live CME
(4) Several behavioral change outcomes were reported, we report only "use of parent rating of ADHD during assessment at 6 months", the...

Figure 2.19: Comparison of post-intervention practice or behaviour change scores

Fourteen studies[129,134,146,154,155,201-205,216-219] compared eLearning with self-directed learning, which included no intervention or text-based learning, among three specialties (primary care, paediatrics, general or internal medicine), see Characteristics of included studies assessing practice or behaviour change, Appendix IIE. Three studies[155,201,218] included learners from multiple specialties. The educational content among the included studies was heterogeneous and included an interactive web-based genetics curriculum for PCPs with standardised patients' that assessed clinicians' behaviour with transcripts;[216] web-based CME or CPD on asthma guidelines and compliance;[129] a multifaceted educational program for reducing antibiotic dispensing;[205] a web-based glucocorticoid-induced osteoporosis (GIOP) program for osteoporosis care;[217] an Internet-based decision support system for applying the American Thoracic Society (ATS) or Centers for Disease Control (CDC) guidelines for tuberculosis preventive therapy;[202] an information aid for prostate cancer screening;[134] an interactive web-based prostate cancer screening module for physicians;[218] a skin cancer triage tutorial;[203] web-based multimedia learning modules on paediatric asthma;[154] Internet-based training on antibiotic prescribing for acute respiratory tract infections;[219] behavioural interventions (peer-comparison and an email-based intervention) on inappropriate antibiotic prescribing for primary care

practitioners;[204] online intimate partner violence (IPV) CME;[155] case-based online learning (CBOLL);[146] and an online training course on central venous catheter insertion.[201]



Footnotes
(1) Several domains of behavioural change was measured, we report "benefits of genetic counselling"
(2) BMD testing rate, 19% of 78 (intervention), 21% of 75 (control)
(3) Intervention: Group A (Computer DSS group), Control: Guideline card. Outcome reported here is concordance with ATS...
(4) Intervention: CRP training, Control: No CRP training, we report the antibiotic prescription rates among patients between CRP...
(5) Intervention: Video based online training course, Control: Paper . Compliance for sterile practice is reported.
(6) Intervention: DNAT plus learning modules, Control group: Diabetes learning modules alone. We report awareness of change in...
(7) Intervention: online CME Diabetes, Control: Online CME Systolic Heart Faliure. The study reported intentions to change patient...
(8) The study reported behavior changes in patient documentation at follow-up between GP group (Blended learning, Intervention) vs...

Figure 2.20: Comparison of post-intervention practice or behaviour change scores (dichotomous)

Of these, only nine studies[146,154,201-204,216,217,219] reported numerical data in a useable format, which was included in Figures 2.18, 2.19 and 2.20, Two studies[154,204] assessed a change in mean practice or behaviour scores, Figure 2.18; and two studies[146,203] assessed practice or behaviour scores at post-test, Figure 2.19. Five studies[201,202,216,217,219] assessed practice or behaviour as a dichotomous outcome. Five studies[129,134,155,205,218] presented incomplete data (missing means, SDs or confidence intervals), which could not be included in the data analysis.

Overall, empirical evidence from three[201-203] of the 14 studies suggests that online and LAN-based eLearning may be effective compared to self-directed learning in improving physicians' practice or behaviour change (moderate to large effect size; very low quality); the studies had a high risk of selection bias

and baseline imbalance. The studies used individual eLearning pedagogy, with the exception of Butler et al.[205] who used facilitated eLearning pedagogy. The eLearning intervention was interactive in four studies.[201,205,218,219] Evidence from four[146,154,216,217] of the 14 studies suggests that online and LAN-based eLearning may be as effective as self-directed learning in improving physicians' practice or behaviour change. Two[146,154] of the four studies had a high risk of selection bias, attrition bias and baseline imbalance, Figure 2.5. The studies used individual eLearning pedagogy[146,217] and facilitated eLearning pedagogy.[154] All three studies used an interactive eLearning intervention and two studies[154,217] also included learning analytics and feedback. Three studies[155,203,216] reported mixed results.

ELearning vs face-to-face learning

The effect of online and LAN-based eLearning vs face-to-face learning on physicians' practice or behaviour change is presented in Figures 2.18 and 2.19.

Fordis et al.[8] compared an online CME on cholesterol management with face-to-face learning for physicians. The study reported that online and LAN-based eLearning (online CME) may be as effective as face-to-face learning (live CME) for improving physicians' practice or behaviour change (appropriately screening patients for dyslipidemia), Figures 2.18 and 2.19.

ELearning vs eLearning

The effect of online and LAN-based eLearning vs other forms of online eLearning on physicians' practice or behaviour change is presented in Figure 2.20. Four studies[190,200,208,214] assessed practice or behaviour change. Two studies included primary care practitioners;[200,208] Shaw et al.[214] included learners from multiple specialties; and Schroter et al.[190] included learners from multiple disciplines, see Characteristics of included studies assessing practice or behaviour change, Appendix IIE. The educational content was heterogeneous among the studies and included multi-component Internet CME (mCME) to promote chlamydial screening;[208] an online interactive DNAT tool vs online self-

directed learning for doctors;[190] online spaced education vs an online slideshow followed by a quiz to improve patient-safety behaviours in interns;[214] an online seminar on type 2 diabetes vs an online seminar on systolic heart failure to improve clinical practice among PCPs.[200] Of the five studies that assessed physicians' practice or behaviour change, only two[190,200] reported numerical data as a dichotomous outcome in a format that could be used in Figure 2.20. Two studies[208,214] presented incomplete data (missing means, SDs or confidence intervals), which could not be included in the data analysis. Overall, empirical evidence from one[208] of the four studies suggests that online and LAN-based eLearning may be effective compared to other forms of online and LAN-based eLearning (Internet-based CME) in improving physicians' practice or behaviour change. Two studies[190,206] suggest that online and LAN-based eLearning may be as effective as the other form of eLearning evaluated for improving practice or behaviour change. Two studies[200,214] reported mixed results.

Blended eLearning vs eLearning

The effect of online and LAN-based eLearning vs blended learning on medical doctors' practice or behaviour change is presented in Figure 2.20. Ruf et al.[193] evaluated an online quality improvement program for alcohol-related disorders for general practitioners. The study assessed practice or behaviour change among primary care practitioners following the interventions (see Characteristics of included studies assessing practice or behaviour change, Appendix IIE), which included an online program and GP training (intervention 1: blended learning) vs access to the online system without any training (control: eLearning). The study reported mixed results on practice or behaviour change (patient documentation), Figure 2.20.

Blended learning vs self-directed/face-to-face learning

The effect of blended learning vs self-directed/face-to-face learning on physicians' practice or behaviour change is presented in Figure 2.19.

Three studies[186,191,209] assessed practice or behaviour change among interns or consultants from three specialties (primary care, paediatrics, general or internal medicine), see Characteristics of included studies assessing practice or behaviour change, Appendix IIE; one study included learners from multiple specialties. The educational topics were heterogeneous and included a 'doc.com' and 'WebEncounter' eLearning module to enhance physician-patient communication in bad news delivery compared to self-directed learning[191] and opioid- and benzodiazepine-prescribing skills (workshops+ email case discussions) for primary care practitioners compared to didactic face-to-face discussion[186] and internet-based portals to improve community-based paediatric attention-deficit or hyperactivity disorder (ADHD) care training.[209] The studies used facilitated eLearning pedagogy[186,209] and individual eLearning.[191] The eLearning intervention was interactive in the studies by Epstein et al.[209] and Midmer et al.[186] and included learning analytics/feedback in the studies by Daetwyler et al.[191] and Midmer et al.[186] Of the three studies that assessed practice or behaviour change, only two studies[191,209] reported numerical data that could be used in Figures 2.18 and 2.19.

Overall, empirical evidence from two[191,209] of the three studies suggests that blended learning may be significantly effective (large effect size; very low quality) than self-directed learning in improving physicians' practice or behaviour change. The study by Daetwyler et al.[191] was at high risk of attrition and reporting bias and the study by Epstein et al.[209] had a high risk of detection bias. Similarly, one[186] of the three studies suggests that blended learning may be as effective as self-directed/face-to-face learning in improving physicians' practice or behaviour change; however, the study had a high risk of attrition bias and baseline imbalance.

Patient outcomes

A patient outcome is defined as any benefit derived from the intervention by patients. The effects of online and LAN-based eLearning or blended learning vs

self-directed/face-to-face learning on patient outcomes are presented in Figures 2.21 and 2.22.

Seven studies reported patient outcomes among 2809 patients,[151,192,205-207,220,221] these studies used hospital chart audits or questionnaires to assess patient outcome. Of these, four studies[151,192,205,221] compared online and LAN-based eLearning or blended learning with self-directed/face-to-face learning, see Characteristics of included studies assessing patient outcomes, Appendix IIF. Butler[205] compared a multifaceted educational program to reduce antibiotic dispensing in primary care and assessed hospital admissions and re-consultation rates among patients. The study reported that online and LAN-based eLearning may be equally as effective as self-directed learning for improving patient outcomes. Estrada et al.[206] compared an interactive multi-component web-based CME program with a web-based intervention on diabetes practice guidelines for PCPs, and found that both eLearning interventions were equally effective in improving patient diabetes care as assessed by haemoglobin A1c, blood pressure and LDL control. Dolan et al.[151] compared an online curriculum in bone health with self-directed learning and reported online and LAN-based eLearning may be effective compared with self-directed learning for improving patient outcomes (inappropriate screening for osteoporosis) between the groups, Figure 2.22. Girgis et al.[192] compared blended learning with face-to-face learning. The study assessed patient outcomes such as emotional functioning, anxiety, depression, psychological needs, health system and information needs, and patient care and support needs among radiation oncologists at post-test. Findings from the study revealed that blended learning may be equally as effective as face-to-face learning for improving patient outcomes; the mean difference (random) between the intervention and the control group was 0.00 (95% CI -0.84 to 0.84), Figure 2.21. Legare et al.[221] assessed shared decision-making to reduce the overuse of antibiotics in acute respiratory infections. The study assessed post-test dichotomous patient outcome data and found that blended learning may be equally as effective as self-directed learning for improving patient outcomes. The

study reported five preferred roles in decision making among patients of which one (patient decides) was included at the physician level in Figure 2.22.

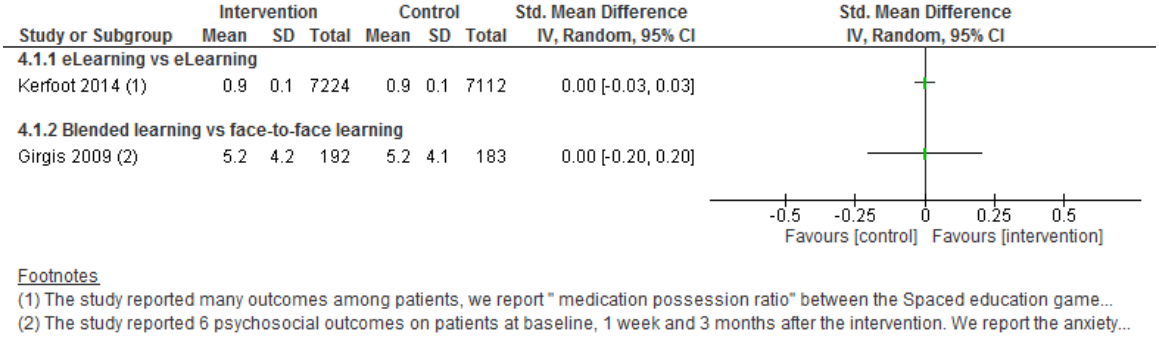


Figure 2.21: Comparison of post-intervention patient outcomes

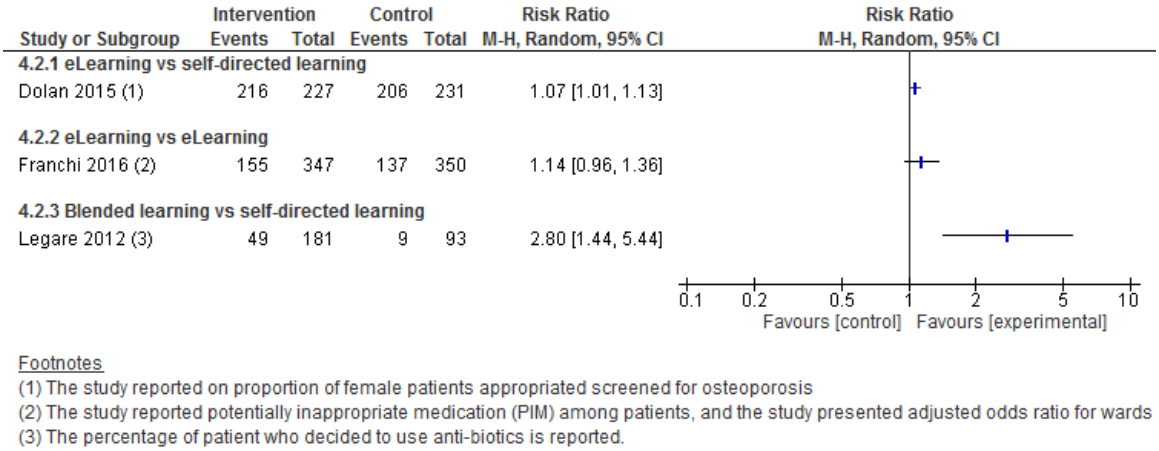


Figure 2.22: Comparison of post-intervention patient outcomes (dichotomous)

Franchi et al.[207] compared interactive online eLearning to improve drug prescribing (module A, B, C, D, E) with another form of eLearning (a refresher course on the basic notions of geriatric pharmacology [module B]), and found that online and LAN-based eLearning may be equally as effective as the other eLearning intervention evaluated for reducing inappropriate medication and drug-drug interactions, Figure 2.22. Kerfoot et al.[220] compared an online space education game with identical online educational content on hypertension management for primary care clinicians, and its effects on patient medication possession ratios. The study found that online and LAN-based eLearning may be

equally as effective as the other eLearning intervention for improving patient outcomes, Figure 2.21.

Overall, empirical evidence from the three studies[151,192,205] suggests that blended learning may be as effective as self-directed/face-to-face learning in improving patient outcomes; however, the study by Girgis et al.[192] was at high risk of baseline imbalance. Similarly, three[206,207,220] of the five studies suggest that online and LAN-based may be as effective as the other eLearning interventions evaluated in improving patient outcomes; however, the study by Estrada et al.[206] had a high risk of reporting bias and the Franchi et al.[207] study had a high risk of baseline imbalance.

Cost

Three studies reported the cost of the eLearning interventions evaluated.[129,182,205] Braido et al.[129] compared the respiratory Global Initiative for Asthma (GINA) and the Allergic Rhinitis and its Impact on Asthma (ARIA) guidelines with self-directed learning (no training), and found that the pharmaceutical cost containment was +122.21 euros per GP in the training-group compared with +3595.04 euros per GP in the control group. Also, GPs in the training group increased spending on diagnostic investigations by 13.4% (+108.85 euros per GP) while GPs in the control group reduced costs by 24.4% (-164.14 euros per GP). Butler et al.[205] compared an antibiotic resistance educational program with self-directed learning (no training), and found that the mean annual cost of antibiotic dispensing fell in both groups between baseline and follow-up, but the fall in the intervention was greater (intervention £120.76; control £2.21 per 1000 patients). The mean antibiotic cost for the follow-up year in the intervention group decreased by 5.5% (−0.4% to 11.4%; p=0.07) compared with the control group. Perkins et al.[182] compared a blended learning intervention (electronic ALS training) with face-to-face learning and reported that faculty, catering and facility costs were $438 per participant for electronic ALS training and $935 for conventional ALS training. Overall, there was no definitive evidence of the cost-

savings or cost-effectiveness of online and LAN-based eLearning or blended learning for physicians.

No studies reported on the **adverse** or **unintended effects** of online eLearning interventions.

Assessment of reporting bias

A funnel plot was produced using 11 studies (Figure 2.23) to establish whether any evidence of publication bias existed on the knowledge outcome stratified by comparison type. Studies comparing online eLearning with other types of learning appear to be asymmetrical on the funnel plot suggesting a potential reporting bias.

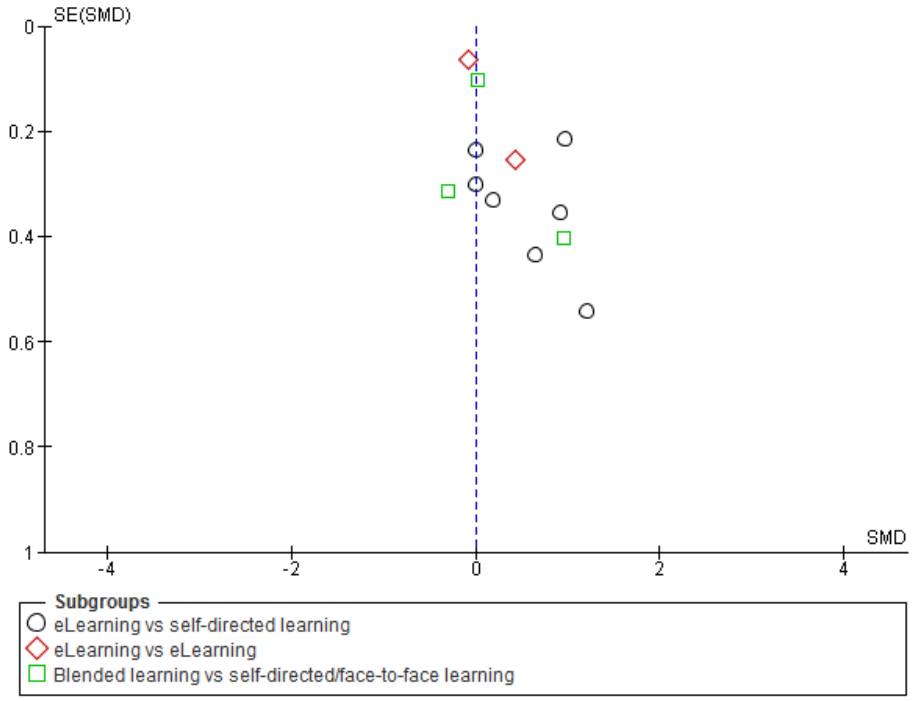


Figure 2.23: Funnel plot comparing studies assessing learners' knowledge (change scores)

Subgroup analysis

Effects of online eLearning from low-, middle- and high-income countries

Of the 93 included studies, two[170,179] were from LMICs. Hemmati et al.[170] compared the effects of Internet-based cardiopulmonary resuscitation training vs face-to-face training on the knowledge and satisfaction of learners from the Kermanshah University of Medical Sciences and Health Services in Iran. Kulier[179] included learners from seven LMICs (Argentina, Brazil, the Democratic Republic of the Congo, India, the Philippines, South Africa and Thailand) and compared the effects of a clinically integrated eLearning course (blended learning) that incorporated the WHO reproductive health library for teaching basic EBM, vs self-directed learning on postgraduates' knowledge, skills and attitudes. Hemmati et al.[170] found that online and LAN-based eLearning may be as effective as face-to-face learning in improving medical doctors' knowledge and may improve learners' satisfaction post-intervention. Kulier et al.[179] reported that blended learning may improve physicians' post-intervention knowledge and skills compared with self-directed learning (see Appendices IIIA - IIIC).

From the 91 studies conducted in high income countries, 50 were conducted in the USA; 10 in Canada; five each in Australia, Germany and the UK; three each in Italy and the Netherlands; and two in France, see Figure 2.4.

The learning content in these studies was heterogeneous. Among the studies from high income countries, 27 were conducted among PCPs; 12 each among surgeons, and general or internal medicine physicians; eight each among paediatricians or residents; three among emergency medicine physicians; three each among anaesthesiologists and radiation oncologists; two among urologists; and one each from gastroenterology, obstetrics and gynaecology, orthopaedics, public health, and rheumatology. Ten studies included learners from multiple specialties; one study included learners from multiple disciplines; and two studies did not specify learners' professional specialties. The effectiveness of the

interventions from these studies is shown in Appendices IIIA – IIIF, and is described by learning type in the 'Effects of intervention' section.

Time spent on the intervention and time of assessment

The time spent on the interventions ranged from 12 minutes[202] to 52 weeks,[220] Table 7. The assessment time for studies varied from post-test to long-term follow-up (at 26 months), Appendix III. Two studies[140,148,220] reported that online and LAN-based eLearning may take less time than self-directed learning in terms of time spent on the intervention. Ruf et al.[193] and Shaw et al.[214] reported that the time spent on the intervention was similar between the intervention and control groups.

Effects of interventions by specialty

Thirty-one studies were conducted among primary care practitioners; twelve studies among surgeons; eleven studies among general medicine or internal medicine physicians; eight among paediatricians; three studies each among emergency medicine practitioners and anaesthesiologists; two studies each among radiation oncologists, obstetricians/gynaecologists, and urologists; one each among gastroenterologists, orthopaedicians, rheumatologists, public health physicians and radiologists. Ten studies included learners from multi specialties, one study included learners from multiple disciplines and two studies did not specify learners' specialties.

Primary care

Thirty-one studies were conducted among PCPs. Twelve of these studies were conducted in the USA; four in Canada; three in Germany; three in the Netherlands; and one each in Iran, Spain and the UK. Two of these were multi-centre studies.[215,219] The learning content used in these studies was heterogeneous. Five studies used online CME or CPD for training in chlamydial screening,[208] cholesterol management,[8] prostate cancer screening,[218] oncogenetics,[138,174] and diabetes and systolic heart failure.[200] Two studies focused

on eLearning for cardiovascular conditions, specifically, acute myocardial infarction[148] and hypertension management.[220] Four studies focused on eLearning for antibiotic reduction;[215,219,221,222] three studies focused on Internet-based guidelines;[146,149,170] and five studies focused on mental health interventions and depression among the elderly,[167] mental health issues,[171] alcohol related disorders,[193] dementia management[184] and opioid and benzodiazepine prescribing.[186] Ali et al.[181] focused on training learners in ATLS; Kutob et al.[139] focused on cultural competence surrounding type 2 diabetes; Lee et al.[159] focused on online cultural competence and problem-affect-concern-treatment training (PACT); Braido et al.[129] focused on using online CME to improve knowledge of allergic rhinitis and its impact on ARIA and GINA guidelines; and Pelayo-Alvarez et al.[165] focused on palliative care. The remaining six studies[158,187,204,212,216,217] focused on different domains of learning, Appendix III.

The eLearning content for 27 of the 30 studies was self-developed. The source of eLearning was unknown in two studies[149,205] and Feng et al. [218] used open source eLearning content. The interventions in 10 of the 30 studies[146,174,184,193,204,205,212,215,217,220] were based on a learning theory and the learning content was validated in five studies.[146,158,187,215,220] Twenty-four studies used individual eLearning pedagogy where the learning content was self-instructional.[129,138,139,146,148,149,158,159,165,167,170,171,174,187,200,204,208,212,215-220] In five studies, the learners were involved in facilitated eLearning pedagogy where a faculty member or tutor facilitated during lectures or presentations or after the reading of text books or self-instructional material. In Ali et al.[181] and Vollmar et al.[184] collaborative eLearning pedagogy was used where learners were involved in regular meetings and discussion forums. Three studies[8,129,148] used web-based LMS for content and learning management. Fifteen studies included an interactive component in the eLearning intervention,[8,138,139,146,170,174,184,186,200,205,212,215-219] and seven studies provided learning analytics or feedback to learners.[8,138,139,170,174,186,212,217]

Six studies[8,129,138,139,165,212] reported that online and LAN-based eLearning may be more effective than self-directed/face-to-face learning in improving physicians' knowledge, Figures 2.6 and 2.7. Two studies[154,158] reported that online and LAN-based eLearning may be more effective than self-directed/face-to-face learning for improving physicians' skills. Ruf et al.[193] reported that blended learning may be more effective than online and LAN-based eLearning for improving physicians' skills, Figure 2.11. Four studies[8,148,170,215] reported that online and LAN-based eLearning may be effective, or as effective, as self-directed/face-to-face learning or the other eLearning groups evaluated, for improving physicians' satisfaction, Figures 2.16 and 2.17. Six studies[8,204,205,208,218,219] reported that online and LAN-based eLearning may be effective, or as effective, as self-directed/face-to-face learning or the other eLearning groups evaluated for improving physicians' practice or behaviour change, Figures 2.18, 2.19 and 2.20. Braido et al.[129] reported online and LAN-based eLearning resulted in pharmaceutical cost containment compared with the control group.

The results from the majority of studies among PCPs (n=19) suggest that online and LAN-based eLearning or blended learning may be as effective as self-directed/face-to-face learning or other eLearning groups evaluated for improving physicians' knowledge (n=6; low quality), skills (n=2; large effect size; very low quality), satisfaction (n=4; moderate effect size; low quality), patient outcomes (n=1; large effect size) and practice or behavioural change (n=6), in areas such as cholesterol management, oncogenetics, ATLS training, cultural competence in managing type 2 diabetes, palliative care, CPR curriculum training, SAGE guidelines training, depression, opioid and benzodiazepine prescribing skills training, dementia, case-based online learning, antibiotic resistance training, a GIOP course, CRP training and amblyopia screening.

Surgery

Eleven studies[140,145,153,160,163,164,172,175,177,178,197] were conducted among surgeons or surgical residents. Seven of these studies were conducted in the USA; three in

Canada; one in Germany and one in the UK. The learning content used in these studies was heterogeneous. In four studies, learners were trained in surgical skills: thoracic surgery;[145] laparoscopic cholecystectomy;[197] laparoscopic colorectal surgery;[175] and microsurgery.[140] In two studies, learners were trained in surgical teaching skills[163,164] and in another two studies, learners were trained in EBM skills.[160,172] Ferguson et al.[153] provided online frailty education to surgical residents to improve their estimates of lobectomy risk. Putnam et al.[178] focused on patient safety education in the operating room for surgical residents. Schmitz et al.[177] delivered communication skills training for end-of-life and error disclosure at family care conferences, Appendix III. The eLearning content for all the studies was self-developed. The interventions in five of the twelve studies[160,163,164,172,197] were based on a learning theory and the learning content was validated in six studies.[160,163,164,172,175,197] Nine studies used individual eLearning pedagogy, where the learning content was self-instructional.[140,145,153,163,164,175,177,178,197] In two studies[160,172] learners were involved in facilitated eLearning pedagogy sessions where a faculty member or tutor facilitated during lectures or presentations, or after the reading of text books or self-instructional materials. In Ali et al.[181] collaborative eLearning pedagogy was used, where learners were involved in regular meetings and discussion forums. LMS was not used in any of the studies. Six studies included an interactive component in the eLearning intervention,[140,160,163,172,181,197] and two studies reported that learning analytics or feedback was provided to learners.[164,197]

Two studies[140,153] reported that online and LAN-based eLearning may be effective, or as effective, as self-directed/face-to-face learning for improving physicians' knowledge. Macrae et al.[160] reported that online and LAN-based eLearning may be effective compared with self-directed learning for improving physicians' post-intervention skill scores, Figure 2.10 (large effect size; low quality). Putnam et al.[178] reported that online and LAN-based eLearning may be as effective as face-to-face learning in improving physicians' attitude, Figure

2.14. Matzie et al.[163] reported that online and LAN-based eLearning may be effective in improving physicians' post-intervention satisfaction compared with self-directed learning, (M-H RR 1.13, 95% CI 1.03 to 1.23; low quality), Figure 2.17. Pernar et al.[164] reported that online and LAN-based eLearning may be as effective as self-directed learning for improving physicians' post-intervention satisfaction. The majority of studies conducted with surgeons or surgical residents found that online and LAN-based eLearning may be effective, or as effective, as self-directed/face-to-face learning or blended learning, for improving physicians' post-intervention knowledge, skills, attitude and satisfaction scores in a range of areas (e.g. colorectal surgery, improving teaching skills in a surgery department, micro-surgery, general surgery, blood pressure and chlamydia screening, and laparoscopic cholecystectomy using Pelvic-Trainers).

Paediatrics

Eight studies[132,154,157,161,194,196,199,209] were conducted among paediatricians or paediatric residents/trainees. Six of these studies were conducted in the USA, and one each in Italy, Australia and the UK. The learning content used in these studies was heterogeneous, see Appendices IIIA - IIIF. Two studies[194,196] focused on oral health; Conroy et al.[161] focused on an LCAT tool to improve causality assessment among paediatric medical trainees; Connolly et al.[132] focused on normal child development; one study focused on ADHD care;[209] and one study focused on solutions for smoking.[157] Le et al.[154] focused on the Distributed Asthma Learning Initiative (DALI) program; and Sangvai et al.[199] focused on injury prevention, Appendix III. The eLearning content in six of the eight studies was self-developed;[129,132,157,196,199,209] the source of eLearning was not mentioned in the study by Le et al.;[154] and Talib et al.[194] used open source learning materials. The intervention in one[199] of the eight studies was based on a learning theory and the learning content was validated in the study by Sangvai et al.[199] Five studies[132,161,194,196,199] used individual eLearning pedagogy, where the learning content was self-instructional, and in three studies[154,157,209] learners were

involved in facilitated eLearning pedagogy where facilitation was undertaken by a faculty member or tutor during lectures or presentations, or after the reading of text books or self-instructional materials. Six studies included an interactive component in the eLearning intervention[132,154,157,194,199,209] and two studies reported providing learning analytics or feedback to learners.[154,199]

Four studies[132,194,196,199] reported that online and LAN-based eLearning may be effective compared to self-directed learning, blended learning or other forms of eLearning, for improving physicians' knowledge. Two studies[157,196] reported that online and LAN-based eLearning may be effective, or as effective, as self-directed learning for improving physicians' skills. Le et al.[154] reported that online and LAN-based eLearning may be as effective as self-directed learning in improving physicians' attitude, Figure 2.12. Le et al.[154] reported online and LAN-based eLearning may be effective, or as effective, as self-directed learning for physicians' practice or behaviour change. Conroy et al.[161] reported that online and LAN-based eLearning may be equally as effective as self-directed learning for improving physicians' skills, Figure 2.10.

The majority of studies among paediatricians or paediatric residents found that online and LAN-based eLearning may be effective, or as effective, as self-directed learning, blended learning or other forms of learning, for improving knowledge, skills, attitudes, behavioural change and cost in areas such as child development, guidelines training, solutions for smoking, injury prevention, oral health training and paediatric asthma.

General or internal medicine

Twelve studies[131,134,141,151,176,185,191,202,203,207,210,213] were conducted among general or internal medicine physicians or residents; nine of these studies were conducted in the USA and one each in Australia, Canada and Italy. The learning content used in these studies was heterogeneous: two studies focused on palliative care training;[131,191] Dayton et al.[202] focused on an Internet-based decision support system for the application of ATS or CDC guidelines for tuberculosis preventive

therapy; Dolan et al.[151] delivered an online curriculum in bone health; Farah et al.[134] focused on prostate specific screening and testing; Franchi et al.[207] provided interactive online eLearning to improve drug prescription; Gerbert et al.[203] focused on skin cancer; Grover et al.[210] focused on arterial and central live placement; Sullivan et al.[141] focused on opioid therapy for chronic non-cancer pain; Szmuilowicz et al.[185] focused on multimodality communication skills; and Wilkinson et al.[176] focused on technology-driven simulation-based cardiac ultrasonography teaching, Appendix III.

The eLearning content for eleven of the twelve studies was self-developed;[141,151,176,185,191,202,203,207,210,213] the source of eLearning was not reported in the study by Claxton et al.[131] The intervention in one[185] of the twelve studies was based on a learning theory, and two studies validated their learning content.[131,210] Ten studies used individual eLearning pedagogy, where the learning content was self-instructional. Szmuilowicz et al.[185] used a collaborative eLearning pedagogy, where learners were involved in regular meetings and discussion forums, and Wilkinson et al.[176] used a facilitated eLearning pedagogy, where a faculty member or tutor facilitated during lectures or presentations, or after the reading of text books or self-instructional materials. LMS was not used for content management in any of the studies. Five studies included an interactive component in the eLearning intervention[141,151,176,185,207] and four studies reported providing learning analytics and feedback to learners.[185,191,203,207] Five studies[131,134,141,151,210] reported that online and LAN-based eLearning may be effective, or as effective, as self-directed learning in improving physicians' knowledge, Figures 2.6, 2.7 and 2.8.

Szmuilowicz et al.[185] reported that blended learning may be as effective as face-to-face learning (clinical rotations) in improving physicians' skills, (SMD 1.64, 95% CI 0.89 to 2.39; low quality), Figure 2.10. Dolan et al.[151] reported that online and LAN-based eLearning may be effective in improving physicians' skills. Wilkinson et al.[176] reported that online and LAN-based eLearning may be as effective as face-to-face learning in improving physicians' skills. Claxton et

al.[131] and Sullivan et al.[141] reported that online and LAN-based eLearning may be as effective as self-directed learning for physicians' satisfaction, Figure 2.10. Two studies[191,202] reported that online and LAN-based eLearning or blended learning may be effective, or as effective, as practice or behaviour change compared to self-directed learning, Figures 2.19 and 2.20. The majority of studies conducted among general or internal medicine physicians or residents reported that online and LAN-based eLearning or blended learning may be effective, or as effective, as self-directed/face-to-face learning in improving physicians' knowledge, skills, satisfaction and behavioural change, in areas such as prostate cancer screening, opioid therapy for chronic non-cancer pain, spaced education, arterial or central venous line placement, and bad news delivery.

Emergency medicine

Four studies[150,168,173,183] were conducted among emergency medicine physicians or residents, one each in the USA, Canada, France and Germany. The learning content used in these studies was heterogeneous, Appendices IIIA - IIIF. Barthelemy[173] 2017 focused on web-based ECG training. Chenkin et al.[168] and Platz et al.[183] delivered ultrasound training and Chung et al.[150] taught physicians about bio-terrorism. The eLearning content for three of the four studies was self-developed[150,173,183] while the source of eLearning was unknown in the study by Chenkin et al.[168] Interventions in all three studies were not based on a learning theory, however learning content was validated in the studies by Barthelemy[173] and Platz et al[183] All four studies used individual eLearning pedagogy, where the learning content was delivered using self-instructional materials. Barthelemy et al.[173] used LMS for content management and Chenkin et al.[168] included an interactive component in the eLearning intervention. None of the four studies reported on the use of learning analytics or feedback.

All four studies reported that online and LAN-based eLearning or blended learning may be as effective as self-directed/face-to-face learning for improving physicians' knowledge scores, Figures 2.6 and 2.7. Barthelemy et al.[173] reported

that online and LAN-based eLearning may be effective compared to face-to-face learning for improving physician's skills, Figure 2.9. Chenkin et al.[168] reported that online and LAN-based eLearning may be as effective, as face-to-face learning, for physicians' skills, Figure 2.10, and satisfaction, Figure 2.17. Platz et al.[183] compared blended learning with face-to-face learning among emergency medicine physicians or residents, and found that blended learning may be as effective as face-to-face learning for improving physicians' knowledge scores, Figure 2.6. The study reported mixed results for physician satisfaction. Studies conducted among emergency medicine physicians or residents found that online and LAN-based eLearning may be as effective as self-directed/face-to-face learning for improving physicians' knowledge, skills and satisfaction in training areas such as ultrasound, ECG training and bio-terrorism.

Anaesthesiology

Three studies[162,166,180] were conducted among anaesthesiologists or anaesthesiology residents in Italy, the US and the UK. The learning content used in these studies was heterogeneous, Appendices IIIA and IIIB. Bello et al.[166] compared online training with face-to-face teaching on the principles and practice of difficult airway management; Edrich et al.[162] implemented web-based training in the use of lung ultrasound to exclude pneumothorax; and Sharma et al.[180] focused on internet and simulation-based training on tracheoesophageal echocardiography. The eLearning content in all three studies was self-developed but not validated, and the interventions were not based on a learning theory. The studies used individual eLearning pedagogy, where the learning content was self-instructional. Bello et al.[166] used a blackboard platform for content and learning management. Both studies included an interactive component in the eLearning intervention, however only Bello et al.[166] used learning analytics or provided learners with feedback. Bello et al.[166] compared eLearning with face-to-face learning and reported that online and LAN-based eLearning may be as effective as face-to-face learning for improving physicians' knowledge and skills scores. The study reported higher satisfaction among physicians in the online and LAN-

based group. Edrich et al.[162] compared online and LAN-based eLearning with self-directed and face-to-face learning and reported that online and LAN-based eLearning may be as effective as face-to-face learning for improving physicians' skills, Figure 2.9. Sharma et al.[180] compared blended learning with self-directed learning and reported higher knowledge scores among physicians in the blended learning group, Figure 2.6. Studies among anaesthesiology physicians or residents found that online and LAN-based eLearning and blended learning may be effective, or as effective, as self-directed/face-to-face learning in improving physicians' knowledge, skills and satisfaction in echocardiography and airway management.

Radiology and radiation oncology

Two studies[128,192] were conducted among radiation oncologists and one study[156] was conducted among radiologists. The three studies were conducted in Canada, Australia and the USA. The learning content used in these studies was heterogeneous, Appendices IIIA and IIIF. Girgis et al.[192] focused on a consultation skills program for oncologists; Alfieri[128] focused on web-based radiation oncology training; and Wang et al.[156] evaluated a computer-based interactive simulation to teach contrast reaction management to radiology trainees. The eLearning content in all three studies was self-developed, and based on a learning theory in the studies by Alfieri et al.[128] and Girgis et al.,[192] however, the learning content was validated only in the study by Alfieri et al.[128] Alfieri et al.[128] used individual eLearning pedagogy and self-instructional materials to facilitate learning. Girgis et al.[192] used collaborative eLearning pedagogy where learners were involved in regular meetings and discussion forums. Wang et al.[156] used a facilitated eLearning pedagogy where a faculty member or tutor facilitated during lectures and presentations, or after the reading of text books or self-instructional materials.

LMS was not used in any of the studies. All three studies included an interactive component in the eLearning intervention, but only Alfieri et al.[128] reported

providing learning analytics or feedback to learners. Alfieri et al.[128] compared online and LAN-based eLearning with self-directed learning, and reported that online and LAN-based eLearning intervention may be effective for improving physicians' knowledge compared with self-directed learning, Figure 2.6. Girgis et al.[192] compared blended learning with face-to-face learning and reported that online and LAN-based eLearning may be equally as effective as face-to-face learning for improving patient outcomes, Figure 2.21. Wang et al.[156] compared online and LAN-based eLearning with self-directed learning and found that online and LAN-based eLearning was as effective as self-directed learning for improving physicians' knowledge. Overall, studies among radiologists or radiation oncologists found that online and LAN-based eLearning and blended learning may be effective, or as effective, as self-directed/face-to-face learning in improving knowledge, satisfaction and patient reported outcomes in oncology and consultation skills training.

Obstetrics and gynaecology

Two studies[179,188] were conducted among obstetricians and gynaecologists; both were multi-centre studies. One study[188] was conducted in the Netherlands and the UK, while the other study[179] was conducted in Argentina, Brazil, the Democratic Republic of Congo, India, the Philippines, South Africa and Thailand. The learning content focused on EBM for reproductive health in both studies, (Appendices IIIC and IV) and was self-developed. The eLearning interventions were not based on a learning theory and were not validated in either study. Both studies used collaborative eLearning pedagogy where learners were involved in regular meetings and discussion forums. LMS was not used in either study. One study[188] included an interactive component in the intervention and both studies reported providing learning analytics or feedback to learners. One study[188] compared blended learning with face-to-face learning and reported that blended learning may be as effective as face-to-face learning for improving physicians' knowledge and attitude. The other study[179] compared blended learning with self-directed learning and found that blended learning may be effective for improving

physicians' knowledge (SMD 0.80, 95% CI 0.51 to 1.09; very low quality), Figure 2.6, and skills (SMD 0.39, 95% CI 0.11 to 0.67; very low quality), Figure 2.10. Studies among obstetricians and gynaecologists found that blended learning may be effective, or as effective, as self-directed/face-to-face learning in improving knowledge, skills and attitudes in EBM training.

Urology

Kerfoot et al.[211] conducted a multi-centre study in the USA and Canada among urologists and urology residents. The study used spaced education for urology training, Appendix III. The eLearning content for the study was from a free or open source platform and it was based on learning theory. The learning content in the intervention was validated and used individual eLearning pedagogy where the learning content was self-instructional. Kerfoot et al.[211] compared the effectiveness of two different types of online eLearning (spaced education vs bolus cohort) on knowledge, and found that online and LAN-based eLearning (spaced education) may be as effective as bolus education for improving physicians' knowledge scores, Figure 2.7.

Other specialties

Studies from other specialties, including multi-specialty and multi-disciplinary, were grouped under ‘other specialty.’ Hearty et al.[137] compared an eLearning surgical training module with self-directed learning (text book) among orthopaedic residents, and found higher knowledge scores (large effect size, low quality) in the online and LAN eLearning group, Figure 2.7. The learning content used in the intervention was on the ‘closed reduction and pinning of paediatric supracondylar fractures’, Appendix III. The study used individual learning pedagogy and the eLearning intervention contained an interactive component and provided learning analytics and feedback to learners. The eLearning content was self-developed but not based on a learning theory or validated. LMS was not used in the study.

Viguier et al.[142] compared online training in skin cancer diagnosis with self-directed training among rheumatologists, and reported higher knowledge scores (moderate effect size; very low quality) among the eLearning group (Figure 2.7; Appendix III). The study used individual learning pedagogy and the eLearning content was self-developed, but not based on a learning theory or validated. LMS was not used in the study, and the eLearning intervention did not contain an interactive component or provide learning analytics or feedback to learners.

Cabrera-Muffly et al.[147] compared online otolaryngology educational modules with self-directed learning among residents enrolled in an otolaryngology residency program in the USA, Appendix III. The authors reported that eLearning may be as effective as self-directed learning on physicians' knowledge scores, Figure 2.6. Individual learning pedagogy was used and the eLearning content was self-developed, however, it was not based on a learning theory and was not validated. The eLearning intervention did not use LMS or interactivity and the study did not report providing learning analytics or feedback to learners.

Enders et al.[152] compared co-operative, Internet and self-directed/face-to-face learning courses for introductory biostatistics among public health graduate students in the USA, and reported that eLearning may be as effective as self-directed/face-to-face learning on physicians' knowledge scores. The learning content used in the intervention was an ‘introductory biostatistics course’, Appendix III. Individual learning pedagogy was used, and the eLearning content was self-developed but was not based on a learning theory and was not validated. LMS was not used in the study. The eLearning intervention in the study contained an interactive component but did not report providing learning analytics or feedback to learners.

Thomas et al.[223] compared a web-based tutorial on gastroendoscopy with self-directed learning among gastroenterologists in the USA and found that eLearning may be effective for improving physicians' knowledge scores, Figure 2.6. The learning content used in the intervention was a web-based tutorial in gastro-

endoscopy vs no tutorial, Appendix III. Individual learning pedagogy was used and the eLearning content was self-developed, but was not based on a learning theory and was not validated. LMS was not used in the study. The study did not use interactivity in the eLearning intervention and it did not report providing learning analytics or feedback to learners.

Ten studies were conducted among physicians from multiple specialties',[130,133,135,143,155,182,201,206,214,224] of which five[130,133,135,136,143] reported that online and LAN-based eLearning may be effective compared with self-directed learning for improving physicians' knowledge scores. Cullinan et al.[133] compared an online module on geriatric pharmacology with self-directed learning and reported higher knowledge scores in the eLearning group, (SMD 1.54, 95% CI 1.18 to 1.91; good quality), Figure 2.7. Short et al.[155] reported online and LAN-based eLearning may be equally as effective as self-directed learning for improving physicians' knowledge. Harris et al.[136] assessed physicians' attitude and reported that online eLearning may be effective for improving physicians' attitude compared to self-directed learning. Two studies[155,201] assessed practice or behaviour change. Xiao et al.[201] reported that online and LAN-based eLearning may be effective in changing physicians' behaviour compared to self-directed learning, (M-H RR 2.82, 95% CI 1.35 to 5.91; very low quality), Figure 2.20. Mixed results were observed in the study by Short et al.[155] Shaw et al.[214] compared online and LAN-based eLearning with other forms of online and LAN-based eLearning and reported that online and LAN-based eLearning may be equally effective as the other eLearning intervention evaluated for improving physicians' knowledge. The study reported mixed results for satisfaction, and practice or behaviour change. Estrada et al.[206] reported online and LAN-based eLearning may be equally as effective as the other eLearning intervention evaluated in improving patient outcomes. Perkins et al.[182] compared blended learning with face-to-face learning and reported that blended learning may be equally as effective as face-to-face learning for improving physicians' knowledge, (SMD -0.08, 95% CI -0.15 to -0.02; good

quality evidence), Figure 2.7, and skills (SMD -0.14, 95% CI -0.20 to -0.07; good quality evidence), Figure 2.10. The cost of the intervention was lower for the blended learning group than the face-to-face learning.

Schroter et al.[190] compared an interactive online DNAT with online self-directed learning among medical doctors and nurses in Wales and Germany. In the study, only outcomes for post-registration medical doctors were included, Appendices IIIA and IIID. The learning content focused on diabetes guidelines. The study reported that the online and LAN-based interventions were equally as effective for improving physicians' knowledge (Figure 2.6), satisfaction (Figure 2.17), and practice or behaviour change (Figure 2.20). The specialty was not specified in two studies.[169,189] Hadley et al.[169] compared a clinically integrated EBM eLearning course with face-to-face teaching and reported that online and LAN-based eLearning may be equally as effective as the face-to-face learning for improving physicians' knowledge, Figure 2.6. Kronick et al.[189] compared a 3-hour training session on using the World Wide Web to research patient-related questions (blended learning) with self-directed learning (no training), and reported mixed results on physicians' satisfaction, Figure 2.16.

Effects of eLearning by training method and focus

Cognitive, procedural and diagnostic training

Twenty-two studies[133,140,142,144,145,147,151,153,158,162,168,173,175,176,178,180,181,183,197,201,207,210] focused on delivering cognitive, procedural and diagnostic skills training. Ali et al.[181] compared blended ATLS with a standard course and reported that blended learning may be equally as effective as face-to-face learning for improving physicians' knowledge, skills and satisfaction. Barthelemy et al.[173] compared web-based ECG training with face-to-face training and reported that eLearning may be as effective as face-to-face training, Figure 2.9. Cabrera-Muffly et al.[147] compared online otolaryngology educational training with self-directed training among residents enrolled in a otolaryngology residency program, and found that

online otolaryngology educational training was as effective as self-directed training for improving residents' knowledge, Figure 2.6. Cullinan et al.[133] compared an online module on geriatric pharmacology with self-directed learning and reported higher knowledge scores in the eLearning group, (SMD 1.54, 95% CI 1.18 to 1.91; good quality), Figure 2.7. Dolan et al.[151] compared the effects of online education compared to standard curriculum on the quality of resident-delivered care. The study reported that the online education was as effective as the standard curriculum for improving physicians' knowledge scores, Figure 2.8. Inappropriate screening rates for osteoporosis were also similar in both groups, Figure 2.22. Ferguson et al.[153] compared the influence of a frailty education module with self-directed training on surgical residents' estimates of lobectomy risk and found that online frailty education was as effective as the standard curriculum for improving physicians' knowledge, Figure 2.6. Franchi et al.[207] evaluated the effects of an eLearning educational program compared to an eLearning refresher course on the basic notions of geriatric pharmacology to improve the quality of drug prescription in hospitalised elderly patients. The online education program was as effective as the eLearning refresher course in improving patient outcomes, Figure 2.22. Koppe et al.[158] assessed whether an online Balint group improved GPs' and GP registrars' psychological medicine skills and work-related affect, and reduced perceptions of professional isolation. The study reported that the online Balint group improved rural doctors' psychological medicine skills and work-related affect (SMD 4.24, 95% CI 1.99 to 6.49; low quality), Figure 2.10. Putnam et al.[178] compared a resident safety workshop to online curriculum alone on residents' patient safety perceptions and behaviours, and reported that both interventions were equally effective for improving physicians' attitude scores, Figure 2.14. Satterwhite et al.[140] compared web-based Microsurgery Essentials teaching with self-directed learning and reported higher knowledge scores for the intervention group (SMD 1.21, 95% CI 0.15 to 2.27; low quality), Figure 2.6. Thompson et al.[144] compared a web-based tutorial for gastroendoscopy with self-directed learning and found higher knowledge scores for the web-based tutorial group, Figure 2.6.

Pape-Koehler et al.[197] compared surgical performance for completing a laparoscopic cholecystectomy in a Pelvic-Trainer within a multimedia training group, a practical training group, a combination and a self-directed training group, and reported no difference in skills in the multimedia training group and self-directed training group, Figure 2.9. Shariff et al.[175] compared a colorectal surgical procedure (anterior resection) to teach and assess cognitive skills using multimedia training vs didactic lectures and reported that both interventions were equally effective for improving physicians' knowledge, Figure 2.9. Grover et al.[210] compared arterial live placement (AL) and central line placement (CVL) with or without web-based curriculum and reported that both interventions were equally effective for improving physicians' knowledge, Figure 2.6. Chenkin et al.[168] compared web-based ultrasound-guided vascular access training with didactic training, and found that both interventions were equally effective for improving physicians' knowledge (Figure 2.7), skills (Figure 2.10), and satisfaction (Figure 2.17) between the groups. Wilkinson et al.[176] compared technology-driven simulation-based cardiac ultrasonography teaching with conventional teaching, and found that technology-driven simulation-based cardiac ultrasonography was as effective as conventional teaching for improving physicians' skills, Figure 2.11. Edrich et al.[162] compared web-based training in the use of lung ultrasound to exclude pneumothorax with face-to-face training and self-directed training (control). The study reported that the web-based training in ultrasound use was as effective as self-directed training on improving physicians' skills, Figure 2.9. Platz et al.[183] compared web-based basic ultrasonographic principles and the EFAST vs classroom teaching, and reported that both interventions were equally effective for improving physicians' knowledge, Figure 2.6; mixed results were observed for satisfaction. Sharma et al.[180] compared web-based echocardiography blended learning with a non-Internet group and observed higher knowledge scores for learners in the blended learning group, Figure 2.6. Gold et al.[145] compared an Internet CD-ROM thoracic surgery eLearning system vs self-directed learning and reported mixed results for knowledge and satisfaction. Xiao et al.[201] compared paper-based training on

central venous catheter insertion vs a video-based training group and self-directed training. Learners from the video group exhibited a positive change in practice or behaviour change (sterile practice) when compared to the controls and the paper-based training group, (M-H RR 2.82, 95% CI 1.35 to 5.91; very low quality), Figure 2.20. Viguier et al.[142] compared online training in skin cancer diagnosis for rheumatologists with no training, and found that online training improved rheumatologists' knowledge in skin cancer diagnosis compared to no training, (SMD 0.43, 95% CI 0.09 to 0.76; very low quality), Figure 2.6. Overall, the majority of studies that assessed cognitive, procedural and diagnostic skills found that online and LAN-based eLearning was effective, or as effective, as self-directed/face-to-face learning, or other forms of learning, in improving physicians' skills.

Spaced education

Five studies[135,163,164,214,220] evaluated the effectiveness of spaced education. The spaced education methodology applies two learning principles on learning and memory. The first principle is the spacing effect: information presented and repeated over intervals of time increases the uptake of knowledge. The second principle is the testing effect: information presented in a 'test' format, rather than the reading format, improves long-term retention of knowledge. Kerfoot et al.[220] compared spaced education in hypertension management with identical content in an online posting. The study reported that both interventions were equally effective for improving physicians' practice or behaviour change, Figure 2.19. Matzie et al.[163] compared spaced education emails, which taught learners how to provide effective feedback, with no intervention. The study found higher satisfaction amongst participants in the intervention group compared to those who did not receive the intervention, (M-H RR 1.13, 95% CI 1.03 to 1.23; low quality), Figure 2.17. Pernar et al.[164] compared spaced education emails to improve teaching skills, with no emails, and reported that both interventions were equally as effective in improving physicians' satisfaction, Figure 2.17. Gyorki et al.[135] compared an online spaced education program on breast cancer with self-

directed training, and found an improvement in knowledge scores in the intervention group compared to the self-directed training group. Shaw et al.[214] compared an online spaced education program and a slideshow-based online program to improve knowledge and compliance with national patient safety goals (NPSG) vs self-directed learning. The study reported that both interventions were equally effective for improving physicians' knowledge but mixed results was reported for satisfaction, Figure 2.17, and practice or behaviour change between the groups. Overall, the majority of the studies that assessed the effectiveness of online and LAN-based eLearning (spaced education) found that online and LAN-based eLearning or blended learning was effective, or as effective, as self-directed learning or the other forms of eLearning evaluated in improving physicians' knowledge, practice or behaviour change, compliance and satisfaction.

Evidence-based medicine, biostatistics, critical appraisal skills and information retrieval training

Three studies[169,179,188] evaluated the effectiveness of online and LAN-based training or blended learning on EBM for doctors and reported that online and LAN-based eLearning was effective, or as effective, as other forms of learning in improving learners' knowledge, appraisal skills and attitude. Kulier et al.[188] compared an eLearning course on basic EBM with face-to-face learning and reported that both interventions were equally effective for improving physicians' knowledge (SMD 3.5, 95% CI -2.7 to 9.8; effect size small to large; very low quality evidence) and attitude.

Kulier et al.[179] compared a blended course on basic EBM with self-directed learning and reported improvement in physicians' knowledge and skills for the blended learning group compared to the self-directed learning group, Figure 2.7. Hadley et al.[169] compared an eLearning course on EBM with face-to-face learning and reported that both interventions were equally effective for

improving physicians' knowledge (SMD -0.17, 95% CI -0.49 to 0.14; effect size small to large; low quality evidence), Figure 2.6.

Four studies[152,160,172,189] evaluated the effectiveness of online and LAN-based training or blended learning on doctors' critical appraisal skills and information retrieval. All studies reported that online and LAN-based eLearning was effective, or as effective, as other forms of learning in improving learners' knowledge, appraisal skills and attitude. Macrae et al.[160] and McLeod et al.[172] focused on teaching appraisal skills using an Internet-based journal club. Macrae et al.[160] compared teaching appraisal skills using the Internet vs the provision of clinical articles. The study reported an improvement in physicians' skills in the Internet group compared to the clinical articles group (large effect size; low quality). McLeod et al.[172] compared critical appraisal skills using the Internet and emails vs a moderated journal club and reported higher knowledge scores for participants in the moderated journal club group compared to the Internet group. Enders et al.[152] compared cooperative and Internet learning with face-to-face learning (small group sessions) on an Internet-based introductory biostatistics course, and found that both interventions were equally effective for improving physicians' knowledge (Figure 2.7) and skills (Figure 2.10) between the groups. Kronick et al.[189] compared a 3-hour training session on using the Internet for information retrieval vs self-directed learning in a sample of rural physicians, with mixed results reported on physicians' satisfaction, Figure 2.16.

Saxon et al.[213] assessed a novel bio-statistical educational tool and hyperlink-embedded journal articles vs manuscripts without hyperlinks for improving bio-statistical knowledge among internal medicine residents. The study reported that hyperlink-embedded journal articles may be as effective as manuscripts without hyperlinks for improving residents' bio-statistical knowledge.

Overall, the majority of the studies that assessed the effectiveness of online and LAN-based eLearning for EBM, biostatistics, critical appraisal skills and information retrieval found that online and LAN-based eLearning, or blended

learning may be effective, or as effective, as self-directed/face-to-face learning or other forms of learning in improving physicians' knowledge, appraisal skills and attitude.

Continuing medical education and continuing professional development

Seven studies[8,129,138,155,174,200,208] evaluated the effectiveness of online and LAN-based CME or CPD training. The learning interventions in the seven studies were heterogeneous and provided CME or CPD training to doctors on a range of topics: to increase chlamydia screening;[208] cholesterol management;[8] oncogenetics;[138,174] type 2 diabetes mellitus and systolic heart failure;[200] to improve knowledge on ARIA and GINA guidelines;[129] and IPV.[155] Allison[208] compared multi-component Internet CME with Internet-based CME and reported practice or behaviour change in the multi-component Internet CME. Fordis et al.[8] compared online CME on cholesterol management (intervention 1) with live and interactive CME (intervention 2) and a 'no intervention' control group. The study reported higher knowledge scores for participants in the online CME group; mixed results were observed for practice or behaviour change. Two studies[138 174] compared an eLearning CPD module on oncogenetics with self-directed/face-to-face training. One study[138] reported higher knowledge scores in the eLearning group while the other study[174] reported that online oncogenetics CPD may be as effective as face-to-face training for improving physicians' skills. Weston et al.[200] compared an online type 2 diabetes seminar with an online systolic heart failure seminar, and found mixed results for practice or behaviour change, Figure 2.20. Braido[129] assessed the effectiveness of a CME course for GPs to improve ARIA and GINA guidelines uptake and compliance with asthma management. The study compared the CME to self-directed training and reported higher knowledge, practice or behaviour change scores, and a cost advantage for the online CME group. Short et al.[155] compared an online IPV CME program with self-directed training, and found that both interventions were equally effective in improving physicians' knowledge; however, mixed results were observed for practice or behaviour change. Overall, the majority of the studies that assessed

the effectiveness of online CME or CPD found that online and LAN-based eLearning may be effective, or as effective, as self-directed/face-to-face learning or other forms of learning, in improving physicians' knowledge, skills and practice or behaviour change.

Clinical practice guidelines

Nine studies[129,146,148,149,154,170,180,202] examined online eLearning for training in the use of guidelines. Bell et al.[148] compared a web-based tutorial system, (i.e. SAGE guidelines) to print-based guidelines on care after myocardial infarction among family medicine and internal medicine residents. The study reported that both interventions were equally effective for improving physicians' knowledge, however, physicians' satisfaction with the intervention was higher for the SAGE group compared with the print-based guidelines group, (SMD 0.68, 95% CI 0.36 to 0.99; low quality), Figure 2.16.

Braido et al.[129] compared a CME/CPD course for improving knowledge of allergic rhinitis and the ARIA and GINA guidelines vs self-directed training among GPs. The study reported an improvement in knowledge, behaviour change and cost containment for the CME/CPD training group compared to the self-directed training group.

Sharma et al.[180] compared an Internet and simulation-based training program (blended) on transoesophageal echocardiography learning vs guidelines among anaesthetic trainees, and reported an improvement in knowledge for the blended learning group compared to the guidelines training group, (SMD 0.95, 95% CI 0.16 to 1.73; low quality), Figure 2.6.

Sullivan et al.[141] compared interactive web-based training (Collaborative Opioid Prescribing Education [COPE]) with the Veterans Affairs/Department of Defense Clinical Practice Guidelines for management of opioid therapy for chronic pain among internal medicine/medicine residents. The study reported an increase in knowledge with web-based training, (SMD 2.13, 95% CI 1.80 to 2.47; low

quality) Figure 2.7, and mixed results for attitude change. Both interventions were equally effective for improving physicians' satisfaction.

Butzlaff et al.[149] compared computerised guidelines in general practice with self-directed training and found computerised guidelines were as effective as self-directed training for improving physicians' knowledge, Figure 6. Hemmati et al.[170] compared the use of CPR curriculum guidelines via the Internet with face-to-face lectures and reported that both interventions were equally effective for improving physicians' knowledge, Figure 2.6; however, physicians' satisfaction with the intervention was higher for the Internet group, (SMD 3.48, 95% CI 2.77 to 4.18; low quality).

Le et al.[154] compared a distance eLearning program on paediatric asthma consisting of Web- or CD-ROM–based multimedia learning modules and two teleconference calls vs self-directed learning. The study reported an attitude change in the eLearning group compared to the self-directed learning group, Figure 2.14; however, both interventions were equally effective in improving physicians practice or behaviour change, Figure 2.18.

Stewart et al.[146] compared case-based learning of evidence-based practice guidelines (type 2 diabetes prevention) with a wait-listed control group; mixed results were observed for knowledge scores, Figure 2.6; however, both interventions were equally effective in improving physicians' practice or behaviour change, Figure 2.18. Dayton et al.[202] compared an Internet-based decision support system to apply the ATS or CDC guidelines for tuberculosis prevention therapy vs guideline cards (self-directed learning). The study reported practice or behaviour change in the intervention group compared with the self-directed learning group, (M-H Random RR 1.56, 95% CI 1.01 to 2.40; low quality), Figure 2.20. Overall, the majority of the studies that assessed the effectiveness of online and LAN-based eLearning in clinical practice guidelines training found that online and LAN-based eLearning or blended learning may be

effective, or as effective, as self-directed/face-to-face learning in improving physicians' knowledge and practice or behaviour change.

Communication skills training

Daetwyler et al.[191] compared ‘doc.com’ and web OSCE with no intervention (self-directed learning) and reported that blended learning may improve physicians' practice or behaviour change when compared to self-directed learning. Lee et al.[159] compared online cross-cultural communication skills and PACT questions training vs standard curriculum (no intervention), and found that online cross-cultural communication training improved communication skills in family medicine clerkship students. Schmitz et al.[177] compared an online course on mastering difficult family conversations in surgical care with self-directed training (control group). Little et al.[219] compared web-based training in the use of CRP test at point-of-care, in enhanced communication skills, or in both CRP and enhanced communication vs usual care, the study reported Internet training achieved important reductions in antibiotics prescribing for respiratory-tract infections, (M-H Random RR 0.68, 95% CI 0.64 to 0.74; good quality evidence). Yardley et al.[215] compared web-based training in the use of the CRP test, in communication skills and use of a patient booklet, or training in both vs usual care. The study reported GPs in the intervention groups had very positive perceptions of the intervention and the web-based training, and felt that taking part in the interventions had helped them to reduce antibiotic prescribing. However, the details presented in the study were insufficient to make a judgement on the effectiveness of the interventions.

Antibiotics prescribing training

Five studies[204,205,215,219,221] evaluated the use of eLearning in training to reduce antibiotics prescribing compared to self-directed training. Butler[204,205,215,219,221] compared the Stemming the Tide of Antibiotic Resistance (STAR) online educational program with a self-directed learning intervention and reported a reduction in antibiotic prescription rates in the intervention group compared with

the self-directed learning group. Legare et al.[221] compared 'DECISION + 2', a shared decision-making training program designed to reduce the overuse of antibiotics for acute respiratory infections vs self-directed training. The study found a reduction in the percentage of patients who decided to use antibiotics after consultation (Decision+2) compared to the self-directed training group, (M-H Random RR 2.80, 95% CI 1.44 to 5.44; good quality), Figure 2.22. Little et al.[219] and Yardley et al.[215] presented the results from the Genomics to combat Resistance against Antibiotics in Community acquired lower respiratory tract infections in Europe (GRACE) trial. The trial compared online training in the use of a CRP test at point-of-care, in enhanced communication skills, or in both versus self-directed learning,[219] (M-H Random RR 0.68, 95% CI 0.64 to 0.74; good quality), Figure 2.20, and noted differences in satisfaction among the communication group.[215] The antibiotic prescription rate was lower in the CRP training group compared to the self-directed group,[219] Mixed results were observed for GPs' and patients' attitude in the study by Yardley et al.[215] Meeker et al.[204] compared the effects of three online behavioural interventions (implemented alone or in combination): suggested alternative (an EHR-based intervention most closely resembling traditional clinical decision support systems); accountable justification (also an EHR-based intervention that prompts clinicians seeking to prescribe an antibiotic to explicitly justify - in a free text response - his or her treatment decision); and peer comparison (an email-based intervention that ranks clinicians from highest to lowest on inappropriate antibiotic prescribing rates). The study reported that the use of 'accountable justification and peer comparison' as behavioural interventions resulted in lower rates of inappropriate antibiotic prescribing for acute respiratory tract infections compared to no intervention, (SMD 0.76, 95% CI 0.07 to 1.45; low quality), Figure 2.18. All studies that assessed the effectiveness of online and LAN-based or blended learning to reduce antibiotics prescribing found that the interventions were effective, or as effective, as self-directed or face-to-face learning, or other forms of learning, in improving physicians' practice or behaviour change (i.e. reducing antibiotic prescription rates) and satisfaction.

DISCUSSION

The online eLearning intervention studies included in this review were heterogeneous in terms of learning content; the professional specialty evaluated, the outcomes and outcome measures, as well as the comparator used to evaluate their effectiveness. Thus, individual study data could not be pooled to yield summary effects across intervention types.

Summary of main results

Ninety-three randomised controlled trials involving 16,895 participants were included in this review. Two studies were carried out in LMICs, whereas the remaining studies were conducted in high-income countries. Most studies targeted PCPs (n=28), surgeons (n=12), general internists (n=12), and paediatricians (n=8). A range of online and LAN-based educational interventions in cognitive, procedural and diagnostic skills training were evaluated: spaced education, EBM training, CME and CPD, and communication skills training.

The results for the primary and secondary outcomes varied across studies: some studies demonstrated the beneficial effects of online and LAN-based eLearning/blended learning, while some indicated no effect eLearning in comparison to self-directed/face-to-face learning. Only one study[172] found that face-to-face learning resulted in higher knowledge scores than an online and LAN-based intervention. However, based on the equivocal findings and the potential risks of bias within the included studies, it is difficult to draw any firm conclusions.

None of the included studies reported any unintended/adverse effects of the interventions on learners. Only three studies reported on the costs of the eLearning intervention, with one study reporting a cost-minimisation for the intervention group.

Overall completeness and applicability of the evidence

The studies evaluating online and LAN-based eLearning included in the review included participants from diverse and multiple specialties and disciplines. The majority of studies were conducted in high-income countries. Our review showed a paucity of data on the cost-effectiveness of online and LAN-based eLearning, and blended learning, with none of the included studies performing a cost-effectiveness analysis. Only three studies[129,182,205] assessed the cost of developing and maintaining an online eLearning intervention. Consequently, a firm conclusion on the cost and cost-effectiveness of the interventions cannot be made from the available evidence.

Although the effects of online and LAN-based eLearning on medical doctors' behaviour change was reported in a few studies, its impact on clinical or patient outcomes was not measured or reported in these studies. Only seven studies[151,192,205-207,220,221] reported on patient outcomes. The unintended effects of online eLearning were not reported in any of the included studies.

Educational interventions underpinned by a learning theory are more likely to be effective.[225] The review found that only 23 studies used an eLearning intervention that was based on a learning theory. The learning pedagogies used in the eLearning interventions were heterogeneous: seven studies used a collaborative learning pedagogy; 13 studies used facilitated learning pedagogy; and the remainder used individual learning pedagogy. Only seven studies used LMS for learning content management. Forty-six studies utilised interactivity and 23 of the interventions provided feedback to learners. Learning theory and pedagogy, the use of LMS, and the inclusion of interactivity and the provision of feedback are important aspects to consider when designing and managing eLearning curriculums. Hence, applicability of an eLearning intervention may only be limited to its current setting and not generalisable to other geographic or socio-economic backgrounds.

Competency-based medical education is gaining traction as a solution to address the challenges associated with the current time-based models used in physician training. However, none of the included studies in this systematic review used a competency-based educational framework. Educational assessment instruments must be both reliable and valid for study results to be credible. Our review found that validated outcome measurement tools were only used in 16 of the 45 studies that measured learners' knowledge; in six of the 16 studies that measured skills; in seven of the nine studies that measured learners' attitude; in seven of the 25 studies that measured learners' satisfaction; and in five of the 24 studies that measured practice or behaviour change.

Quality of the evidence

Overall, the risk of bias for most studies was judged to be unclear (due to missing or incomplete information), with instances where there was a potentially high risk of attrition bias (more than 25% of studies), and detection and 'other bias' (more than 25% of studies) identified. The majority of studies did not provide information on the method of randomisation and sequence allocation. Likewise, a high proportion of studies (75 studies; 82%) did not provide sufficient information on the blinding of outcome assessors and hence were judged to have an unclear risk of bias. Thirty-two studies (35%) reported incomplete outcome data and nine studies (10%) reported baseline differences in participant characteristics and were judged to be at high risk of bias.

Twenty[8,129,132,134,135,138,139,144,145,148,155,165-167,172,196,212-214,224] of the 54 studies that assessed knowledge did not provide any comparable data to estimate the effect of the intervention and therefore, were judged at high risk of 'other bias'. Likewise, four[157,159,166,186] of the 25 studies assessing skills; three of the nine studies assessing attitude;[138,165,169] and 16[128,131,132,135-137,145,147,154,161,166,174,185,191,210,215] of the 27 studies assessing satisfaction did not provide comparable data.

According to the GRADE criteria, the quality of the evidence was very low for knowledge, and low for the other primary outcomes, due to the unclear and high

risk of bias, inconsistency and publication bias. The evidence was primarily downgraded due to the high level of information that was unknown across the included studies, and therefore, deemed to be at an overall unclear risk of bias. Likewise, we downgraded the evidence by one level due to 'inconsistency', because of the heterogeneity in the study results, as well as the high heterogeneity across the population, intervention types and outcome measurement instruments used. The 'low to very low quality' evidence suggests that further research will be valuable in increasing the reliability and precision of effect estimates and the confidence we can place in them (i.e. GRADE).

Potential biases in the review process

Twenty-five studies await classification because we currently do not have enough information about them to make a confident assessment on their eligibility for inclusion in the review. We have contacted the authors for details about the missing information; however, to date no response has been received. Without additional information from the corresponding authors, it is difficult to gauge the effect of not including these studies in the final review. However, we aimed to minimise any potential biases in our review by strictly adhering to the guidelines outlined by Higgins and Green.[116]

Agreement and disagreement with other studies and reviews

We are not aware of any other systematic reviews of RCTs that have evaluated online and LAN-based eLearning for medical doctors' education. One review focused on the effectiveness of eLearning in surgical education among medical and dental students, surgeons and oral health specialists.[97] The study reported and pooled data from 38 non-randomised studies with or without controls. Among the studies, eLearning was used as an intervention in three different ways: 1) to teach cases through virtual patients, 2) to teach theoretical knowledge through online tutorials or other means, and 3) to teach surgical skills. The majority of the included studies in the review reported knowledge gain from eLearning. Another review[99] reported on the effectiveness of CME for GPs, and assessed the

effectiveness of different types of CME on GP's satisfaction, knowledge and clinical practice, and patient outcomes. The review included RCTs, non-RCTs, interrupted time-series, and before-after studies, and found that eight of the 11 included studies reported improvement in at least one of the outcomes of interest. Jwayyed et al.[226] reported the effectiveness of technology-assisted education with self-directed/face-to-face teaching methods among graduate medical students, attending nursing residents, and a combination of subjects, and presented the results among residents in emergency medicine, internal medicine, surgery, paediatrics, radiology, 'other' and a combination of residents. The review compared heterogeneous technologies such as CD-ROM/computer-based, simulation, virtual reality, and web-based as a whole, but failed to identify the best technology-assisted education. In comparison, our review specifically focused only on online and LAN-based eLearning. Liu et al.[98] reported on the effectiveness of blended learning among healthcare professionals (medical students, nursing students, nurses, physicians, public health workers and others) and compared blended learning with no intervention and non-blended learning (eLearning or face-to-face learning). The review included 56 studies and found that blended learning had a consistently positive effect (SMD pooled effect 1.40, 95% CI 1.04 to 1.77) compared to no intervention, and to be more effective than, or at least as effective as, non-blended instruction (SMD pooled effect: 0.81, 95% CI 0.57 to 1.05) for improving post-intervention knowledge scores in a variety of health professionals.

Our review, in comparison to other reviews,[97-99,226] compared online and LAN-based eLearning with self-directed/face-to-face learning and other forms of learning, on physicians' knowledge, skills, satisfaction and clinical practice, and patient outcomes, and only included evidence from RCTs and cRCT'S to establish causal conclusions.

AUTHORS' CONCLUSIONS

Implications for practice

This review has several potentially important practical implications. It provides crucial information on the usage, effectiveness and applicability of online and LAN-based eLearning for training medical doctors from diverse specialties. In areas with a shortage of medical teachers, online eLearning offers some potential benefits. However, several practical issues this systematic review has highlighted that need to be considered before eLearning courses are rolled out, these include similarity in participants and their training settings, interventions and their learning theories, pedagogies underpinning the interventions, the usage of LMS, the level of interactivity and feedback included in the intervention, the cost of establishing and maintaining an online course (including server costs), and accreditation by professional bodies. Furthermore, the low quality of the evidence from studies, and the lack of evidence on the cost-effectiveness of the technology may limit the applicability of the findings.

Implications for research

In our review, we came across inconsistencies in how online and LAN-based eLearning interventions were reported. This review revealed some critical elements that may improve our understanding of the effectiveness of eLearning interventions such as the psychometric properties of the measurement instruments, the underpinning learning theories, assessment, eLearning content validation, piloting, validation of the eLearning intervention, baseline evaluation of the learning outcomes, use of LMS, and the level of interactivity and feedback provided. These elements which may enhance the learning experience of participants were inadequately reported. We attempted to evaluate the impact of these elements on effectiveness; however, due to a lack of sufficient data we were unable to do so. Future studies evaluating the effectiveness of online and LAN-based eLearning interventions should adequately report on these critical technological features, and use consistent, reliable and validated outcome measures (e.g. Universal assessment of knowledge using MCQs, Objective

Structured Clinical Examination for assessing skills) so that comparisons can be made between studies. Furthermore, adequately powered and well reported RCTs in LMICs are needed to adequately evaluate the effectiveness and cost-effectiveness of the interventions; to replicate the findings in a diverse range of settings; and to provide a conclusive answer regarding their implementation, sustainability and cost savings in the training of medical doctors.

STRUCTURED CHAPTER SUMMARY

The chapter addresses the effectiveness component of the HTA.

In summary:

1. The systematic review of 93 RCTs showed that online eLearning and blended learning has been used to train medical doctors in various specialities, e.g. primary care practitioners, surgeons, residents and physicians.
2. In the majority of studies, online eLearning or blended learning when compared with self-directed or face-to-face learning resulted in higher or equivalent post-intervention knowledge, skills, attitude, satisfaction and practice or behaviour changes among physicians in the intervention groups.
3. The overall quality of the evidence from the included studies according to the GRADE criteria was judged to be very low.

CHAPTER III: RETURN ON INVESTMENT IN BLENDED VS FACE-TO-FACE ADVANCED CARDIAC LIFE SUPPORT TRAINING IN SINGAPORE

CHAPTER OVERVIEW

Chapter I provided a background to the issues surrounding the shortage of healthcare professionals worldwide and in Singapore, its effect on healthcare access and the limitations of existing systematic reviews, while Chapter II addressed the effectiveness component of the health technology assessment (HTA), however due to a lack of primary studies assessing cost; the cost-effectiveness of eLearning interventions could not be addressed within the systematic review. Chapter II reported on the heterogenous eLearning and blended learning approaches, full cost evaluation of all eLearning approaches was beyond the scope and time frame of this degree program.

Studies included in the chapter II suggest that B-ACLS may be as effective as F-ACLS (perhaps not better). Therefore, this chapter addresses the cost aspects of the HTA by comparing the cost of a blended advanced cardiac life support (B-ACLS) course with a face-to-face advanced cardiac life support (F-ACLS) course by using the B-ACLS course as an exemplar. The reason for choice of the ACLS course for the cost comparison among the various eLearning and blended courses was purely opportunistic, as this course was offered in both blended learning and face-to-face modes in Singapore.

This chapter provides evidence on the magnitude of difference in costs and return on investment (ROI) of using the technology B-ACLS instead of F-ACLS. The 'Introduction' provides an overview of ACLS training in Singapore. The details of the cost-comparison and the ROI computation are presented in the 'Methods' and the findings and their implications are presented in the 'Results' and 'Discussion' sections of the chapter respectively.

INTRODUCTION

Competency in advanced cardiac life support (ACLS) is a core component of many undergraduate[227,228] and postgraduate medical curricula.[229,230] Each year, more than 1.5 million medical professionals around the world attend advanced resuscitation courses. With pressure on budgets across healthcare systems[231-233] there is a constant search for more cost-effective alternatives to traditional training.

The growing adoption of the Internet has revolutionised the delivery of healthcare education.[234] Traditional face-to-face ACLS (F-ACLS) training has evolved from passive (classroom learning) to active learning technologies such as eLearning, blended learning and simulation.[235] Typical F-ACLS training is a 12-hour course offered by hospitals and private training providers, which in Singapore is provided by the Singapore First Aid Training Centre (SFATC),[236] which consists of both didactic (face-to-face) and case-based discussion in an interactive learning environment. The courses tend to cover the following topics: advanced airway management, recognition of cardiac arrest rhythms and arrhythmias, and management of medical emergencies (i.e. respiratory arrest, witnessed ventricular fibrillation, persistent ventricular tachycardia, pulseless electrical activity, asystole, bradycardia, acute coronary syndromes, pharmacology of commonly utilised cardiovascular drugs and their administration). Upon successful completion of the theory and practical assessment, the participant is awarded an ACLS certificate, which is valid for 2-years.

Alternatives such as DVD[237,238] or electronic learning (eLearning) and blended learning solutions[239] have proven to be effective alternatives to F-ACLS training.[240-243] Blended ACLS (B-ACLS) offered to physicians' is typically conducted in three parts,[236] Figure 3.1. Part 1 is offered online and participants are given up to 60 days to complete it. Participants have 24/7 access to the online lessons and materials and learn through interactive lessons, video presentations and progressively-staged quizzes. The B-ACLS course was not based on any

specific learning theory and did not use LMS to track learners' knowledge, skills gain. Participants need to complete the 'Part 1' theory test before they can proceed to Part 2 and 3. In Part 2, participants receive hands-on practice across various clinical scenarios, such as cardiac arrest, bradycardia and shock, under the guidance of ACLS instructors. Part 3 is the practical assessment.

Although studies[244-246] have shown favourable results with B-ACLS training, there is a dearth of studies assessing its cost and return on investment (ROI). Chapter II reported that B-ACLS was non-inferior for theoretical knowledge and technical skill acquisition compared to conventional course with a non-inferiority definition of 5% difference.[182] Assuming equal effectiveness of B-ACLS and F-ACLS, this study compared the cost, cost-savings, and ROI of the B-ACLS and F-ACLS courses offered to physicians' at a training centre[236] in Singapore.

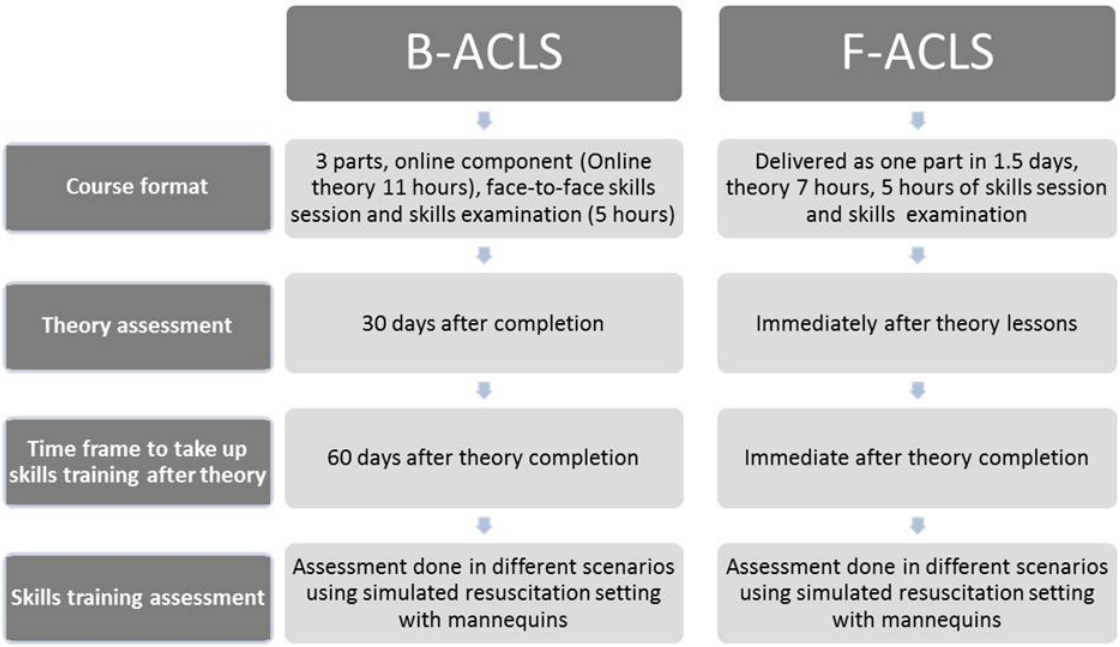


Figure 3.1: Course characteristics of blended vs face-to-face advanced cardiac life support training

METHODS

This study compares the costs of a B-ACLS and a F-ACLS course offered to physicians' at SFATC[236] and evaluates the ROI to the training provider by comparing benefits over costs (cost-savings if the B-ACLS course is used in place of the F-ACLS course) over a 5-year time horizon. Cost data as of April 2016 was collected from the training provider and validated by a physician from another training provider to ensure generalisability of findings to other ACLS training programs in Singapore.

Cost

F-ACLS is offered as a 1.5-day course with an average intake of five learners per class and is conducted 14 times a year, while B-ACL training is offered as a 0.6-day course (5 hours) with an average intake of three learners per class, and is conducted 15 times a year. Direct and indirect costs of both the B-ACLS and F-ACLS courses were obtained from the training provider. Fixed costs included costs for facilities, hardware, software, maintenance and course development/production, and revision costs, Table 3.1. Facility cost was calculated based on the utilisation percentage of the facility for B-ACLS (3.5%) and F-ACLS (7%) of the overall facility cost ($95,238).

Variable costs change with the number of sessions per year and includes instructor costs, learner costs (productivity loss) and travel costs, Table 3.1. Productivity loss is the cost to the employer each time the learner is away on training. This was computed by multiplying the total number of learners, their average hourly salary, and the hours they spent on both travel and training. Average travel costs for the B-ACLS and F-ACLS courses were $14 and $28, respectively. The 5-year cost was computed by multiplying the travel cost by the number of learners per class by the number of classes per year. All costs presented in this paper were calculated in Singapore dollars (SGD) and converted to US dollars (USD) with a time-discounting of 4% of the total cost over the life of the course.[247] As of 1st January 2016, SGD $1.00 equalled USD$0.700 and

USD$1.00 equalled SGD $1.428 (http://www.x-rates.com, accessed 19.01.16). Detailed cost computation is presented in the supplementary file available at https://drive.google.com/open?id=1M27J_rJeOiIhLe8D98W82c3i8-Y-446T

Benefits

The benefits considered for this analysis were the cost savings between B-ACLS and F-ACLS. ROI is a comparison of the net benefit (dollar benefits relative to the cost of the program). In this study, ROI was computed by dividing the cost savings between B-ACLS and F-ACLS by the total cost of B-ACLS, expressed as a percentage and ratio. Calculations were done using Microsoft Excel, Version 2010.

Assumptions

As data was not collected, the following assumptions were made in this study:

- The lifespan of the B-ACLS and F-ACLS courses was 5 years. This assumption was made because the revision cycle of the ACLS scientific update is every 5 years.[248] Hence, the current course could be used for the next 5 years, without modifications to the course content.
- The average annual compensation for trainees who are usually physicians (registrar level) was assumed to be SGD $120,000 (equivalent to USD $83,939).[249]

The analysis was performed from the societal perspective and the outcome measures were:

- Total savings over the lifespan of the course
- Average savings per month for B-ACLS
- ROI % and ratio
- Months to break even for B-ACLS

Sensitivity analysis

Multiple univariate sensitivity analyses were performed on input variables to test their impact on the outcomes (Table 3.2). The plausible ranges for the input variables were obtained by expert opinion.

RESULTS

Table 3.1 shows the costs for conducting the F-ACLS and B-ACLS courses. Fixed costs for F-ACLS was 7% lower than B-ACLS, this was primarily due to higher start-up cost for B-ACLS. However, the variable cost was 3.6 times higher for F-ACLS, primarily due to the to the higher productivity loss cost, the cost to the employer each time the learner is away on training. Recurring development (revision and updating) costs accounted for 13% and 4% of the fixed cost for the B-ACLS course and the F-ACLS course, respectively. The annual cost of productivity loss, travel costs, and reading material costs was lower by 27%, 32% and 32% respectively in the B-ACLS course when compared to the F-ACLS course. Instructor costs were 36% lower for the B-ACLS group than the F-ACLS group. The estimated annual cost was 1.7 times higher for F-ACLS compared to B-ACLS. Similarly, the discounted total cost of training over the life of the course (5 years) was 2.6 times higher for the F-ACLS course compared to the B-ACLS course.

The cost-savings and ROI is presented in Table 3.1. B-ACLS training for physicians provides the best training value with an ROI of 160% over the course of its lifespan. For every dollar invested in B-ACLS, an organisation will save USD $1.60 in training costs. In business terms, one US dollar invested brings 160% return in 5 years. This translates to a 61% saving over the lifespan of the course if B-ACLS is used instead of F-ACLS.

Months to break-even for B-ACLS training were estimated to be 38, (Table 3.1). If there are at least 15 B-ACLS sessions per year with three learners in each

session, and 14 F-ACLS sessions for per year with five learners in each session, the cost advantage for B-ACLS increases steadily over F-ACLS with an increasing number of sessions per year. Figure 3.2 shows the projected cost-differential between F-ACLS and B-ACLS for increasing sessions per year. Figure 3.3 shows the results of the sensitivity analyses performed using the most and least favourable conditions for all variables. The model was most sensitive to variations in life expectancy of the B-ACLS, followed by the class duration of the B-ACLS course (Figure 3.3). The ROI for the sensitivity analysis ranged from 15% to 370% for the least favourable conditions, with an average of 179% favouring B-ACLS, and from 49% to 400% for the most favourable conditions, with an average of 197% favouring B-ACLS.

Table 3.1: Course and cost characteristics of blended vs face-to-face advanced cardiac life support training

Variables	B-ACLS	F-ACLS
Course characteristics		
Course duration (days)	0.6[I]	1.5
Life expectancy of course (years)	5.0	5.0
Average number of learners per class	3.0	5.0
Average number of classes per year	15	14
Total learners trained per year	45	70
Cost characteristics		
Fixed costs (per annum)		
Programmer cost	$6,864	$2,684
Facility/hosting costs	$3,333	$6,667
Server set-up cost (hardware), maintenance cost	$2,101	-
Production costs	$17,708*	$16,106**
Learning content revision cost	$1,334	$3,758
Variable costs (per annum)		
Instructor costs	$1,283	$3,579
Learners' productivity loss cost	$10,057	$37,547
Travel cost	$630	$1961
Reading material cost	$158	$490
Total annual cost	$43,467	$72,793
Total discounted cost of training over the life of the course[I]	$107,960	$280,162
Cost-saving and return on investment		
Total savings over the life of the course (F-ACLS – B-ACLS)		$172,202
Average savings per month		$2,870
% savings over life of the course (total savings/total cost F-ACLS)		61%
Months to break even		37.62
ROI (total savings/total cost of B-ACLS)		160%

All costs in USD (1SGD=0.70USD).
[I]Discount rate of 4% was used to compute the cost of training over the life of the course (5-years).
*Includes purchase of hardware, software, simulator equipment and internal labour cost.
**Equipment rental cost.
B-ACLS: blended advanced cardiac life support; F-ACLS: face-to-face advanced cardiac life support; ROI: return-on-investment.

Table 3.2: Impact of variables on return on investment

Variables	Base	Low	High
B-ACLS			
Number of learners per class	3	1	6
Number of classes per year	15	10	20
Class duration (days)	0.6	0.1	3
Life expectancy of the course (years)	5	2	10
F-ACLS			
Number of learners per class	5	2	10
Number of classes per year	14	10	20
Class duration (days)	1.5	0.5	3
Life expectancy of the course (years)	5	2	10

B-ACLS: blended advanced cardiac life support; F-ACLS: face-to-face advanced cardiac life support; ranges obtained from expert opinion

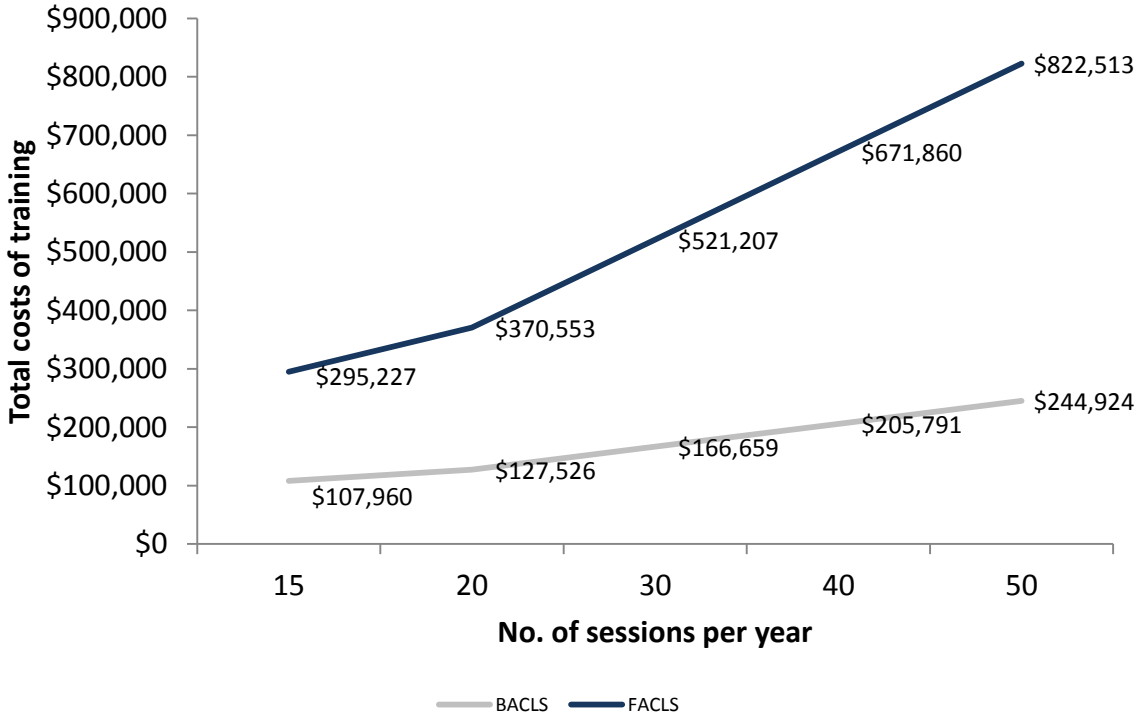


Figure 3.2: Five-year cost of B-ACLS and F-ACLS by number of sessions per year

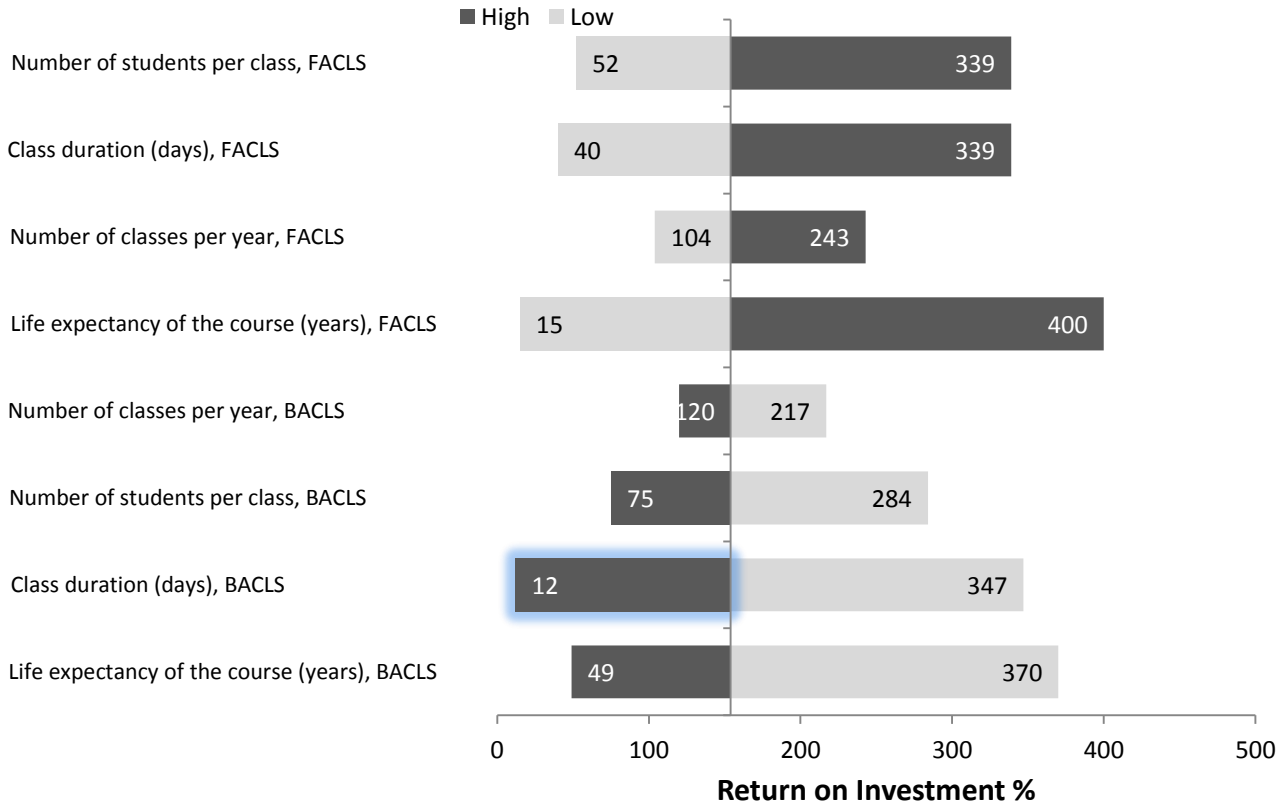


Figure 3.3: Tornado plot depicting change in return on investment due to change of one input at a time. Highlighted bar (class duration) indicates the low training value of the blended advance cardiac life support course.

DISCUSSION

Blended learning a combination of traditional face-to-face learning and asynchronous or synchronous eLearning, is now widely used in life support training.[181,250-252] The International Liaison Committee of Resuscitation evaluated the use of eLearning for basic life support training and passed recommendations to consider video- or computer-based learning as an alternative to instructor-delivered life support training.[253,254] At this juncture, our study planned to determine the cost-savings and ROI of B-ACLS vs F-ACLS within Singapore.

Studies worldwide have assessed the effectiveness of the blended ACLS/ALS/ATLS training and have showed that they achieved similar learning outcomes to face-to-face courses[181,250-252] at reduced costs.[182] Ali et al assessed the potential of eLearning (telemedicine technology) for teaching ATLS and found that knowledge and skills scores were similar for the eLearning and the standard ATLS course.[181] Furthermore, three randomized controlled trials evaluated eLearning before[252] or after[250,251] standard face-to-face ALS training. Two of these studies[251,252] found no difference in knowledge or skills between the eLearning intervention and the standard intervention, whereas the third found small increases in knowledge domains in the e-ALS group.[255] Another open-label randomised controlled trial[182] found that a blended approach to ALS training, which included eLearning, reduced the duration and costs of face-to-face training by one half. The blended and conventional approaches had similar outcomes for knowledge- and skill-based domains. However, success rates in the CASTest were 6% lower in the blended ALS group than in the conventional ALS group.[182] But not much is known about the cost-savings or return on investment of this new technology to the provider.

The current study showed that the B-ACLS course provides 61% cost-saving over F-ACLS over 5 years to the provider and a 160% ROI, both in the base case and across a wide range of assumptions. The ROI (%) of 160 indicates that the course not only pays for itself, but it saves cost and time. So for every dollar

invested in B-ACLS, the organisation can save up to 1.60 SGD dollars in training costs in 5 years. Although there may be a substantial initial outlay for B-ACLS, the marginal cost of training approaches zero in the third year. Our systematic review presented in chapter I identified several advantages of B-ACLS course. [182,252,256,257] The technology allows the trainer to use a combination of digital media and face-to-face instruction to improve efficiency of learning. It also offers adequate time for the trainer to update and enhance the learning content as trainers' time spent in the classroom for a B-ACLS course is one-third of the time spent in an F-ACLS course. Another advantage of B-ACLS is that it offers learners the ability to vary the learning pace to suit their learning style and work commitments.

Limitations

Our study involved several methodological limitations. First, we only included cost savings attributable to the reduction in training days and the productivity loss cost of the learner. Changes in workflow, such as increased workflow efficiency, trainer productivity, increased learner productivity, and the effects of training on patient care were not factored into the analysis, as the supporting data were not available. Thus, we believe the actual savings may be higher. Further studies are necessary to accurately understand the full impact of the training on direct patient care. Albeit it advantages, eLearning and blended learning does have some challenges, they may not suit all practitioners because of the differences in learning style, age, access to computers, and computer literacy. This was not considered in the study and hence the cost-savings may be influenced by the learners' preferences for B-ACLS or F-ACLS. Finally, as our study was based on a single site, the findings may not be generalisable. ROI can be used both to justify a planned investment and to evaluate the extent to which the desired return was achieved. However, it cannot measure all aspects of educational success. Issues such as whether learners liked the program or not, whether learners experienced increased motivation and satisfaction from

participating in the program, or the extent to which learners' personal objectives were achieved cannot be quantified in monetary value.

The blended mode of ACLS training for physicians provides significant cost-saving to the provider. These savings could be used to enhance the use of technology to further improve the physicians' learning experience. Further studies on this topic should assess the cost-effectiveness of the B-ACLS compared to F-ACLS using objective assessment of the learners' knowledge, practical skills and their retention. This would lend greater support for including blended teaching approaches in ACLS/ALS training worldwide.

CONCLUSION

This study provides crucial costs and a ROI comparison of the two different ACLS training approaches in Singapore. B-ACLS had a high positive ROI when compared with F-ACLS. Although B-ACLS has a high capital cost, the annual cost of the training is cheaper than F-ACLS. Its ROI will improve further if the development costs become proportionately less in the future. Implementation of B-ACLS in place of F-ACLS in hospitals and academic centres may potentially lead to greater cost and time-savings. However, given the acknowledged limitation of the ROI approach and the acknowledged lack of ability to generalize the results from this one costing study, firm conclusions on cost-savings of other eLearning and blended learning technologies cannot be drawn. Further studies of costing, cost-effectiveness of eLearning and blended learning are needed to conclusively prove its cost-saving potential and cost-effectiveness.

STRUCTURED CHAPTER SUMMARY

This chapter addressed the cost component of the HTA. Elearning and blended learning refers to a heterogenous group of interventions, assessing the cost-saving potential of all these technologies in beyond the scope of this program. This chapter evaluated the cost, cost savings, and return on investment between a blended and face-to-face advance cardiac life support course in Singapore, as a case-study, adding economics data to the evidence of effectiveness from chapter II. This component of the HTA has identified that the annual cost of B-ACLS 60% lower than F-ACLS, discounted 5-year cost 39% lower than F-ACLS, and that productivity loss cost account for 52% and 23% of the costs among the F-ACLS and B-ACLS respectively. Finally, this study concluded that B-ACLS yielded a 160% return on the money invested; i.e., B-ACLS yielded $1.60 for every dollar spent. There would be 61% savings over the life of the course if B-ACLS was used instead of F-ACLS. However, based on this single case-study of B-ACLS training firm conclusion on cost-saving potential of eLearning and blended learning technologies cannot be drawn.

CHAPTER IV: CAN OPTOMETRISTS' SCOPE OF PRACTICE IN SINGAPORE BE EXPANDED? – A SURVEY OF OPTOMETRISTS AND OPTICIANS IN SINGAPORE

CHAPTER OVERVIEW

Chapter I highlights the Singapore's healthcare access issues in specialist outpatient clinics for ophthalmology. This may be due to the lack of effective primary eye care in the community. Optometrists worldwide are the primary eye care providers and they act as gate keepers to refer patients to secondary and tertiary eye care. Chapter II addressed the effectiveness component of the health technology assessment (HTA) and reported on the heterogenous eLearning and blended learning approaches for CME and CPD and Chapter III examined the cost-saving potential of a blended learning course (B-ACLS) in comparison to face-to-face course In Singapore, not much is known about optometrist role and their willingness to take up CPE through online/blended learning mode. This chapter assesses the applicability and acceptance aspect of the eLearning and blended learning to train optometrist for an extended primary care role, to address workforce shortage in Singapore.

The introduction section describes the roles played by optometrists and opticians and in Singapore and its implications on primary eye care in Singapore. The conduct and analysis of the online survey of optometrists and opticians are described in the methods section of this chapter. Finally, the findings and its implications are presented in the results and discussion section of the chapter respectively. While study one and two in this HTA focused on medical staff, permission to use a nation-wide register of optometrist and optician in Singapore presented a unique opportunity, and increased the feasibility of undertaking an applicability and acceptability study. Hence, this final component, study III is based upon allied health professional perspectives.

INTRODUCTION

Optometrist's role in eye-care delivery has evolved worldwide. In the last two decades, technological advancements in spectacle and contact lens technology, low-vision services, and public health refractive services, have given the profession a platform to deliver a broader scope of primary eye care to the community.[224] In some countries, primary eye care is exclusively within the scope of practice of ophthalmologists, while other countries rely on a variety of professions. In France, primary eye care services are almost exclusively provided by ophthalmologists, whereas in the UK, optometrists are the primary eye care providers. In Germany, both ophthalmologists and optometrists provide essential elements of primary eye care.[223] In Japan, an optometrist's scope of practice is limited to the diagnosis and treatment of refraction. In New Zealand, credentialed optometrists are permitted to prescribe the full range of topical eye medications excluding glaucoma medicines. In Nigeria, optometrists are permitted to perform comprehensive eye examinations to correct refractive errors, orthoptics, low vision, ocular first aid, and the treatment of minor eye diseases that do not pose a threat to the integrity of the visual system.[258] In South Africa, optometrists can perform ocular diagnostic services. In Israel, optometrists with a 4-year academic degree are permitted to provide visual function services.[223] In 2005, the World Council of Optometry (WCO) developed a Global Competency-Based Model of Scope of Practice in Optometry to reconcile variability in the scope of optometric practice internationally.[258]

This competency model[258] includes four categories of services:

1. Optical technology services

   Management and dispensing of ophthalmic lenses, ophthalmic frames and other ophthalmic devices that correct defects of the visual system.

2. Visual function services

   Optical technology services, plus investigation, examination, measurement, diagnosis and correction/management of defects of the visual system.

3. Ocular diagnostic services

Optical technology services, plus visual function services, plus investigation, examination and evaluation of the eye and adnexa, and associated systemic factors, to detect, diagnose and manage disease.

4. Ocular therapeutic services

Optical technology services, plus visual function services, plus ocular diagnostic services, plus the use of pharmaceutical agents and other procedures to manage ocular conditions/disease.

The model allows for objective comparisons of the scope of practice between countries and provides a vertical career ladder for individuals seeking to expand their scope of clinical practice (includes four categories of clinical care). Each category requires a set of competencies; the minimum required for qualification as an optometrist is the demonstration of competence in the provision of optical technology services, which includes refraction and the dispensing of ophthalmic lenses.

Optometrists' and opticians' scope of practice in Singapore

Optometrists in Singapore provide a range of primary eye care services, including refraction, the prescription of optical appliances, and the detection of ocular abnormalities using binocular vision tests, ophthalmoscopy or fundoscopy, retinoscopy, slit-lamp examination, tonometry and visual field testing.[29,259] Optometrists are trained to detect common eye conditions such as cataracts, dry eyes, squints in children, and more sight-threatening eye diseases such as glaucoma, diabetic retinopathy, and age-related macular degeneration to enable early intervention. In hospitals, optometrists conduct various eye examinations and work closely with doctors to co-manage various eye diseases. They also refer patients to ophthalmologist for further treatment if necessary. On the other hand, opticians often work together with optometrists, and some may perform refraction, interpret prescriptions from medical practitioners and optometrists; supply, prepare and dispense optical lenses (except contact lenses);

and fit and adjust optical appliances. However the scope of practice of optometrists and opticians in Singapore depends on their level of training, experience and competence.[29,259]

Extended role in primary eye care

The prevalence of myopia in Singapore is among the highest in the world.[260] Accordingly, there has always been a high demand for both optometrists and opticians to manage these patients who require prescriptions for glasses and contact lenses. Besides this, Singapore also has one of the fastest ageing populations in the world today.[261] This is likely to considerably increase the prevalence of important sight-threatening conditions that commonly affect the elderly, such as cataract, glaucoma, age-related macular degeneration and diabetic retinopathy. The current polyclinic model is costly, as physicians are required to assess diabetic retinopathy when this can be performed by trained optometrists. Moreover, physicians commonly lack the time to grade images, which results in delays in detection and referral.[262] Consequently, specialist outpatient clinics are treating an overwhelming number of simple cases (e.g. dry eyes, early stage cataracts, annual eye screening for diabetic retinopathy) that could be better managed by optometrists,[25,26] which would in turn, allow ophthalmologists to concentrate on managing more urgent and complex eye diseases.

It is possible to empower optometrists to take a more active role in eye care provision.[25] However, not much is currently known about how equipped opticians and optometrists in Singapore are to take on an active primary eye care role. This study aimed to assess participating opticians' and optometrists' current scope of practice in Singapore, their knowledge of primary eye care, their views on expanding their role in primary eye care, their preference for continuing professional education, and their referral behaviour.

METHODS

This cross-sectional study was conducted using an anonymous online self-administered questionnaire. An advisory group of five members was convened to guide the development of the survey instrument. This group included academic optometrists, practising optometrists/opticians working in private practices, and members of the Optometrists & Opticians Board (OOB). Questionnaire items were derived from literature and from chapter II for identifying barriers of eLearning and blended learning. Group members provided feedback on the first draft of the survey, indicating whether the questions were easily understood and clinically relevant. Amendments were made to the survey based on the feedback received and it was piloted by 20 optometrists from the National Healthcare Group to further establish the questionnaires' face validity. Further refinements were made to the questionnaire (wording, question placement, inclusion of additional questions) based on feedback received during the pilot study

The questionnaire

The questionnaire was organised into eight sections containing 36 questions in total (Appendix VI). Questions within each section required yes/no responses and Likert scales were used for questions related to barriers and preferences. The survey was designed to be completed within 25 minutes. The questionnaire also provided respondents with several opportunities to add free-text comments. For example, respondents were asked to comment on any additional advantages and/or disadvantages not captured by the statements already included in the survey. The final survey question also asked respondents to make further comment in the free-text box provided, on any aspect of the scope of optometrists'/opticians' practice and their views on playing an extended primary eye care role in their place of practice. Ethics approval for this research was granted by the National Healthcare Group's domain specific review board (2015/00549) and the University of Adelaide Human Research Ethics Committee Office (HREC) (H-2015-237). The research was carried out in accordance with the tenets of the Declaration of Helsinki. Participants in the study had the ability

to withdraw at any time without prejudice and informed consent was established when a participant chose to undertake the questionnaire.

The finalised survey was distributed by email via Survey Monkey to all Singapore-based optometrists/opticians registered with the OOB membership database along with a cover letter and participant information sheet explaining the purpose of the survey and a request for their consent to complete the survey. The OOB database contains approximately 80% of all opticians and optometrists in Singapore. The initial mailout took place in July 2016. Seven reminder mailouts were then sent, the first after 10 days and the last after 90 days, in an effort to maximise the response rate.

Results from the online responses were exported into PASW Statistics 18 for data analysis. Interval data generated by the Likert scales were transformed into grades and the gradings were described using mode, median and interquartile ranges. Free-text responses were coded and assigned to categorical variables by the lead author (PP). Responses to individual questions were analysed as simple proportions of all valid responses and, where appropriate, by subgroup, in particular by optometrists' credentials. Frequencies were presented as % valid (n absolute/n valid), as the number of valid values differed from item-to-item. Proportions were compared using the Chi-square test to determine associations between optometrists' responses and a number of categorical variables, including age-groups, gender, mode of practice, credentials, awareness of and preferred mode for CPE. Where appropriate, continuous variables were presented as mean ± SD and were statistically compared using the t-test/median test. Where appropriate, associations between the various factors were analysed using stepwise logistic regression (backward elimination)/ordinary least squares regression adjusting for age, gender, type of practice, credentials, the number of patients seen, self-rated primary eye care knowledge and awareness of CPE. A p value of < 0.05 was deemed statistically significant.

RESULTS

Sample characteristics

Of the 787 email invitations sent, 237 completed the online survey (response rate of 30%). The respondents included 67 males (28%) and 170 females (72%). The majority of respondents were Chinese (95%); 50% had a diploma; 34% had a bachelor's degree; 14% had a master’s degree; and 1% had a doctorate degree in optometry. Participants were graduates of Singapore Polytechnic (56%); University of Manchester (15%); Pennsylvania College of Optometry (14%); Cardiff University (3%); and the University of Melbourne (2%), Table 4.1.

The average number of years in practice for optometrists and opticians was 12 ± 7.4 years. Thirty-seven per cent of the optometrists/opticians worked in private practice as single or partner owners; 28% worked in a government restructured hospital; 14% in chain stores; 9% in academic set-ups; 4% in a private hospital; 6% in a private optometry clinic; and 1% in other places (manufacturing, place not specified). The current professional designation for 97% of the respondents was optometrist, two respondents (0.8%) described their designation as optician (refraction and dispensing) and one respondent (0.4%) described his current designation as optician (contact lens practitioner). Four respondents did not state their current designation in practice.

Current scope of practice and extended role

The current role of surveyed optometrists and opticians in Singapore is shown in Table 4.5. The majority of optometrists and opticians (75%) felt there was scope for them to extend their role into other areas, such as screening for eye diseases and co-managing simple eye conditions with ophthalmologists in hospitals and primary eye care settings. Currently, however, eye screening was done by fewer than 3% of the survey respondent optometrists and opticians in Singapore.

Table 4.1: Characteristics of survey respondents

Variables	Categories	Sample n=237 (%)
Age group	≤ 30 years	75 (32)
	30 – 39 years	125 (53)
	40 – 49 years	11 (5)
	50 – 59 years	18 (8)
	≥ 60 years	8 (3)
Gender	Male	67 (28)
	Female	170 (72)
Credentials	Diploma	119 (50)
	Bachelor's degree	80 (34)
	Master's degree	33 (14)
	PhD	3 (1)
	Other	2 (1)
Institution of highest qualification in optometry	Singapore Polytechnic	133 (56)
	University of Manchester	36 (15)
	Pennsylvania College of Optometry	34 (14)
	Cardiff University	8 (3)
	University of Melbourne	4 (2)
	Other*	22 (9)
Years in practice (Mean ±SD)		12 ± 7
No. of patients seen at the practice in a month (Mean ±SD)		176 ± 180

*Other included Association of British Dispensing Opticians; Ngnn Ann Polytechnic; University of Bradford; Hong Kong Polytechnic University; Aston University; Auckland University; Glasgow Caledonian University; National University of Malaysia; Queensland University of Technology; Singapore Institute of Management; University of Wales; University of New South Wales; and not specified by two respondents.

Table 4.2: Optometrists' and opticians' views on continuing professional education and scope for an extended primary care role

Variables	Categories	n=237 (%)
Do you feel optometrists/opticians should undertake CPE?	Yes	178 (75)
Are you aware of any CPE courses available to increase optometrists' knowledge on screening for eye conditions such as cataract, age related macular degeneration, glaucoma and/or diabetic retinopathy in Singapore?	Yes	64 (27)
Approximately how many hours of CPE have you undertaken in the past year?	<10 hours	31 (13)
	10 to <20 hours	49 (21)
	20 to <40 hours	88 (37)
	40 to <60 hours	49 (21)
	60 ≥ hours	19 (8)
Do you think there is scope for the optometrist to play extended roles in the hospital, primary eye care setups?	Yes	177 (75)

CPE: continuing professional education.

Optometrists working in government restructured hospitals (OR: 37.3, 95% CI: 3.4-414.4) and private hospitals/clinics (OR: 12.4, 95% CI: 2.4-63.2) were more likely to perform diagnostic refraction than their counterparts working in academic/research setups (Table 4.6). Similarly, optometrists working in private settings were more likely to perform contact lens fitting and dispensing than optometrists in academic/research settings. (OR: 14.8, 95% CI: 3.0-71.2). On the other hand, optometrists in the government settings (OR: 0.6, 95% CI: 0.2-2.2) and private settings (OR: 0.3, 95% CI: 0.1-1.0) were less likely to perform topography and pachymetry. Determinants of an extended role in the sample of Singaporean optometrists surveyed included their credentials, place of practice, current role in practice, confidence in screening for glaucoma and their awareness of available CPE courses in primary eye care (Table 4.6).

Self-rated primary eye care knowledge and confidence in screening and co-management

Optometrists' and opticians' primary eye care knowledge and confidence in screening and co-managing simple eye conditions with guidance from ophthalmologists, were assessed on a scale from one to 10, with one referring to very poor knowledge and 10 referring to excellent knowledge. The results showed that the average self-rating of primary eye care knowledge was 8.2 ± 1.4, (Table 4.3) with 15.6% of respondents having a knowledge score of more than eight. Table 4.1 and Figure 4.1 show self-reported knowledge scores by optometrists' credentials.

Table 4.3: Self-rated knowledge and confidence in co-managing eye conditions by optometrists' credentials

Variables	Overall	Credentials (Mean ± SD)				p-value[‡]
	n=237	Diploma	Bachelors	Masters	Doctorate	
Self-rated primary eye care knowledge score[I]	8.2 (1.4)	7.7 ± 1.6	8.5 ± 1.1	9.0 ± 0.7	9.0 ± 0.0	0.0001
Confidence in screening for eye conditions						
Cataract	2.7 (1.5)	3.2 ± 1.7	2.2 ± 1.0	1.8 ± 0.9	1.7 ± 1.2	0.0001
Diabetic retinopathy	3.7 (1.9)	4.4 ± 2.0	3.1 ± 1.5	2.7 ± 1.4	2.7 ± 0.6	0.0001
Chronic glaucoma	4.0 (1.9)	4.6 ± 2.1	3.6 ± 1.6	3.2 ± 1.4	2.7 ± 0.6	0.0040
Age-related macular degeneration	3.8 (1.8)	4.4 ± 2.0	3.3 ± 1.4	3.0 ± 1.4	2.7 ± 0.6	0.0001
Confidence in co-managing eye conditions in primary eye care setting with guidance from ophthalmologist						
Cataract	2.7 (1.7)	3.1 ± 1.8	2.3 ± 1.5	1.8 ± 0.8	2.3 ± 1.2	0.0001
Diabetic retinopathy	3.3 (1.8)	3.9 ± 1.9	3.0 ± 1.5	2.2 ± 1.1	2.3 ± 1.2	0.0001
Chronic glaucoma	3.5 (1.9)	3.9 ± 1.9	3.2 ± 1.7	2.4 ± 1.1	2.3 ± 1.2	0.0060
Age-related macular degeneration	3.4 (1.8)	3.9 ± 1.9	3.1 ± 1.6	2.4 ± 1.2	2.3 ± 1.2	0.0020

[I]Scale range 1 to 10 (1=very poor; 10=excellent).

[‡]Median test.

Optometrist's confidence in screening and co-managing common eye conditions such as cataracts, diabetic retinopathy, chronic glaucoma and age-related macular degeneration was generally low; average scores ranged from 2.7 to 4.0 (Table 4.3). Multivariate analysis showed that the self-rated primary eye care knowledge increased with optometrist's credentials. Optometrists with bachelor's, master's and doctorate degrees were more likely to report higher knowledge scores (Table 4.7).

Continuing professional education for opticians and optometrists

Seventy-five per cent of optometrists (n=178) felt they should undertake regular CPE to improve their primary eye care knowledge. Approximately 25% of optometrists (n=60) had undertaken previous training in eye screening. A majority were from the private sector (61.7%); 20% were from government restructured hospitals; and 18.3% from academic/research institutes. They attended training programs listed on the OOB website (31%); through the Singapore Optometry Association (27.6%); in government restructured hospitals (20.7%); and at industry sponsored training events (15.5%) and conferences (5.2%). Similarly, 21.1% (n=50) had previously undertaken training in co-managing minor eye conditions. Only 27% of the Singaporean optometrists surveyed were aware of CPE courses on primary eye care for conditions such as cataracts, glaucoma, age related macular degeneration and diabetic retinopathy. Sixty-eight optometrists/opticians (28.7%) reported undertaking more than 40 hours of CPE in the past year.

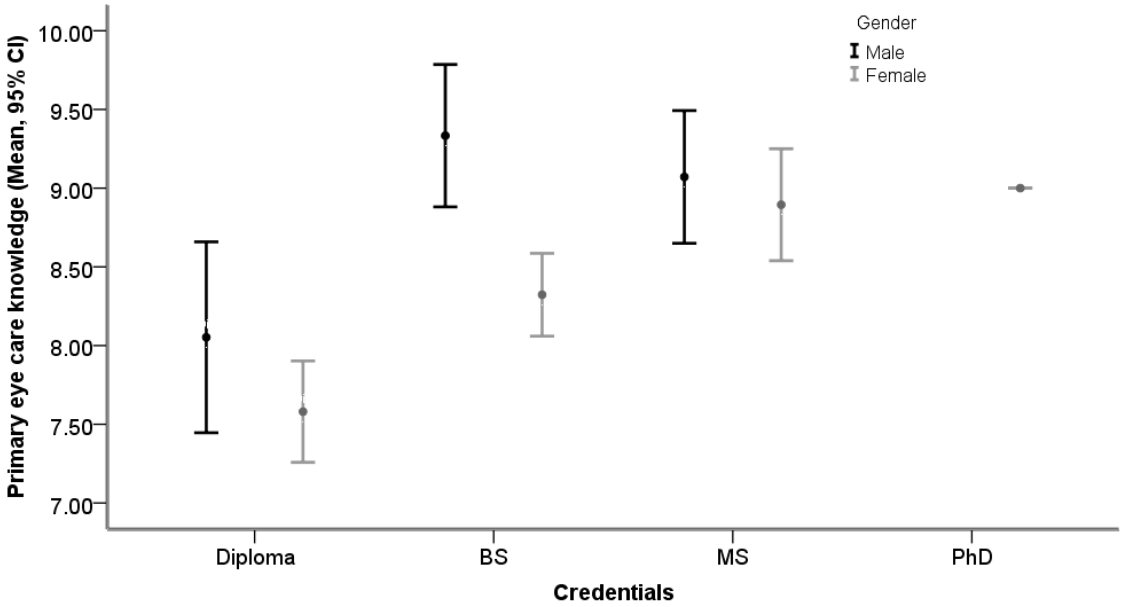


Figure 4.1: Optometrists' primary eye care knowledge by gender and credentials

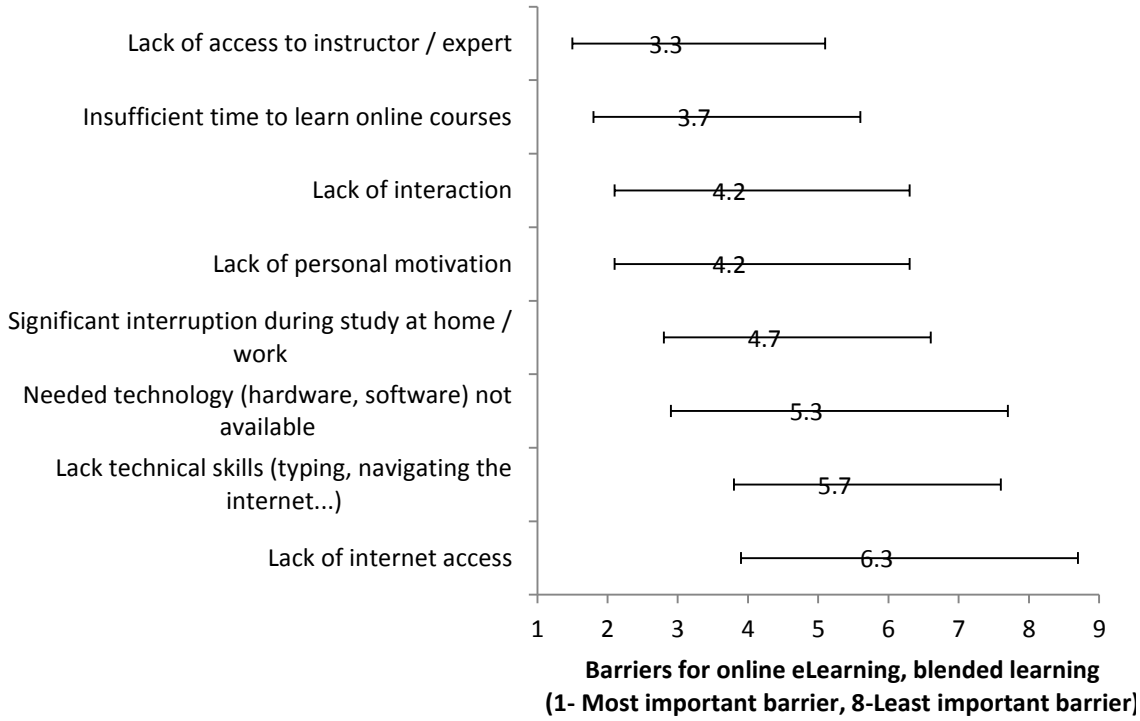


Figure 4.2: Barriers for online eLearning, blended learning by mean rank order

Table 4.5: Optometrists' and opticians' current role(s) in practice

Current role(s)	n = 234*	%	Competency class
Diagnostic refraction	216	92.3%	II
Colour vision assessment	153	65.4%	II
Contact lens fitting and dispensing	146	62.4%	I
Spectacle dispensing	131	56.0%	I
Fundus examination	111	47.4%	III
Ocular photography	101	43.2%	III
Topography/pachymetry	91	38.9%	III
Visual field analysis	69	29.5%	II
Tomography	47	20.1%	III
Ultrasound (A and B)	39	16.7%	III
Specular microscopy	35	15.0%	III
Low vision management	31	13.3%	II
Electro diagnostics	3	1.3%	III
Binocular vision tests	6	2.6%	II
Eye screening	6	2.6%	II
Fundus photo reading	1	0.4%	III
LASIK surgery assistance	3	1.3%	-
Lens edging	1	0.4%	I
Orthoptics	1	0.4%	II
Optical coherence tomography,	3	1.3%	III
Post-op review	1	0.4%	-
Pre-op counselling	2	0.9%	-
Retinal detachment, central serous	1	0.4%	-
Research	3	1.3%	-
Slit lamp photography	2	0.9%	III
Teaching and administration	7	3.0%	-
Tonometry	7	3.0%	III

*Mutually exclusive categories, does not add up to the total (three participants skipped this question); – Not classificable

Table 4.6: Predictors of optometrist's current job scope[1]

Category	Odds ratio	95% confidence interval	
		Upper	Lower
Current scope, diagnostic refraction			
Optometrists in academic/research settings	1.0	*Reference*	
Optometrists in government settings	37.3	3.4	414.4
Optometrists in private settings	12.4	2.4	63.2
Current scope, spectacle dispensing			
Optometrists in government settings	0.03	0.003	0.4
Optometrists in private settings	5.4	1.3	22.7
Current scope, contact lens fitting and dispensing			
Optometrists in government settings	0.2	0.1	1.5
Optometrists in private settings	14.8	3.0	71.2
Current scope, low vision management			
Self-reported primary eye care knowledge score	2.8	1.4	5.5
Current scope, visual field analysis			
Optometrists in government settings	0.1	0.03	0.6
Optometrists in private settings	0.2	0.04	0.6
Current scope, ocular photography			
Self-reported primary eye care knowledge score	1.9	1.3	2.8
Current scope, Tomography			
Females (Reference: Males)	0.2	0.03	1.0
Current scope[1], colour vision assessment			
Self-reported primary eye care knowledge score	1.9	1.3	2.7
Current scope, Topography/Pachymetry			
Optometrists in government settings[4]	0.6	0.2	2.2
Optometrists in private settings	0.3	0.1	1.0

[1]Adjusted for age, gender, credentials, place of practice, self-rated primary eye care knowledge score, range: 1 to 10 (1=Not confident at all, 10=Very confident), awareness of continuing professional education courses .

Table 4.7: Significant positive predictors‡ of optometrist's' self-rated primary eye care knowledge, and confidence in screening and co-management

Category	exp(Coefficient)	95% confidence interval	
		Upper	Lower
Self-rated primary eye care knowledge			
Diploma	1.00		
Bachelor's degree	2.17	1.44	3.25
Master's degree	2.43	1.42	4.16
Doctorate	5.57	1.13	27.48
Low vision management	2.39	1.38	4.13
Colour vision assessment	1.96	1.26	3.05
Confidence in screening for cataract			
Doctorate	1.00		
Diploma	5.55	1.03	30.10
Confidence in screening for diabetic retinopathy			
Females	1.81	1.05	3.12
Current practice: Spectacle dispensing (Yes)	2.40	1.19	4.82
Confidence in screening for age-related macular degeneration			
≤ 30 years of age	1.00		
50 – 59 years of age	3.53	1.32	9.42
Doctorate	1.00		
Diploma	7.43	1.01	54.92
Current practice: Spectacle dispensing (Yes)	2.14	1.07	4.29

‡adjusted for age, gender, credentials, place of practice, current role in practice, and awareness of continuing professional education in primary eye care.

Preferred mode for continuing professional education

The blended learning course, defined as a combination of both eLearning and face-to-face learning, was the most preferred mode of delivery for CPE (46.8%) followed by online eLearning courses (29.5%), didactic lectures (21.5%) and conferences (1.7%). Optometrists were asked to rank the enablers and barriers to eLearning and blended learning. They chose 'better efficiency' as the foremost enabler for blended learning (mean rank, SD: 1.3, 0.5) followed by 'lower cost' (mean rank, SD: 1.7, 0.7) and 'flexibility in training' (mean rank, SD: 1.9, 0.8).

Similarly, the enablers for eLearning were ‘flexibility’ (mean rank, SD: 1.2, 0.6) and ‘lower cost’ (mean rank, SD: 1.8, 1.0). Barriers to eLearning and blended learning are presented in Figure 4.2. Lack of access to an instructor/expert was identified as the greatest barrier. Optometrists from government restructured hospitals were more likely to select didactic lectures as their preferred delivery mode for CPE compared to their counterparts working in private chain stores/clinics/hospitals (OR: 2.4, 95% CI: 1.1-5.2). Optometrists who reported they had an extended role in hospital and primary eye care settings were more likely to prefer blended learning courses for the delivery of CPE compared to those who were not sure of their extended role (OR: 2.7, 95% CI: 1.3-5.6). Male optometrists preferred online eLearning courses for the delivery of CPE than female optometrists (OR: 2.3, 95% CI: 1.1-2.1). Optometrists with a bachelor’s degree were more likely to prefer online eLearning courses as the delivery mode for CPE compared to optometrists with a master’s degree. (OR: 3.8, 95% CI: 1.1-13.1). Optometrists who were not sure about their extended role in hospital and primary eye care settings were more likely to prefer online eLearning courses as the delivery mode for CPE compared to those who reported they had an extended role (OR: 2.5, 95% CI: 1.1-5.3).

Priority topics for continuing professional education

Respondents were asked to rank topics for CPE in order of importance. Glaucoma was identified as the most important topic (mean rank, SD: 1.8, 0.9), followed by diabetic retinopathy (mean rank, SD: 1.7, 0.8) and age-related macular degeneration (mean rank, SD: 2.0, 0.9). Other priority topics included anterior eye conditions, binocular vision, cataracts, contact lens complications, corneal conditions, central retinal artery occlusion flashes and floaters, diagnostic tools for assessing common eye conditions, hypertensive retinopathy, strabismus, low vision, ocular inflammation, orthokeratology, ophthalmic imaging, the latest developments in managing options for common eye conditions, myopic degeneration, neuro-ophtalmology, ocular pharmacology, orthoptics, paediatric eye problems, keratoconus, systemic diseases and the eye, geriatric eye

conditions, paediatric optometry, retinal holes, retinal pathologies, retinal detachment, therapeutic contact lenses, vascular occlusive disease and vitreo-retinal conditions.

Willingness-to-pay for continuing professional education

Optometrists were asked how much they would be willing to pay ($SGD) for a 24-hour short course on primary eye care if it was a) not recognised as a professional development course; b) was subsidised 50% by their employer; c) was a recognised professional development course; and d) was recognised as a prior learning course (approximately 5-10%) that lead to a university postgraduate qualification. Optometrists reported that they would be willing to pay on an average $23 ± 44 (SD) (median: $10) if it was an unrecognised professional development course; $109 ± 653 (SD) (median: $50) if was an employer subsidised course; $156 ± 1311 (SD) (median: $50) if it was an accredited professional development course; and $335 ± 1584 (SD) (median: $50) if the course lead to a postgraduate degree.

Opticians' and optometrists' referral behaviour

The majority of optometrists (66.7%; n=158) reported referring patients to GPs or ophthalmologists in specialist outpatient clinics (SOCs) for treatment. Referral rates varied significantly by optometrists' practice: 81.8% in government restructured hospitals; 71.4% in academic/research settings; and 79.3% in private chain stores/clinics/hospitals, (chi-square, $p<0.0001$). On average, optometrists referred 3 ± 3 and 10 ± 26 patients per month to GPs and ophthalmologists at SOCs, respectively. Patients were referred for cataracts (62%); diabetic retinopathy (55.3%); chronic glaucoma (48.1%); acute glaucoma (39.2%) and age related macular degeneration (56.1%). Of the patients referred to GPs and SOCs, optometrists received feedback on patients' course of treatment in about 42.6% of cases (n=66): 17.3% received feedback by email; 10.9% received feedback through letters; 4.2% received feedback verbally through patients; 3.8%

received feedback through the phone; 3.8% via SMS; and 3.4% received direct feedback from doctors (face-to-face).

Optometrists aged ≤30 years (OR: 6.8, 95% CI: 1.2-38.2) were more likely to refer patients to GPs or ophthalmologists compared with optometrists aged 50-59 years. Optometrists working in government restructured hospitals were more likely to refer patients to GPs or ophthalmologists compared with those working in private settings (OR: 5.6, 95% CI: 2.7-11.6). Similarly, optometrists with higher self-reported primary eye care knowledge compared to those with lower primary eye care knowledge were less likely to refer patients to GPs or ophthalmologists (OR: 0.77, 95% CI: 0.61-0.98).

DISCUSSION

The role of optometrists in Singapore has traditionally been focused on the detection and correction of refractive error and the referral of eye diseases. However, in recent years, optometrists have started to play an active role in the provision of eye care in Singapore. Given these developments, it was timely to survey the profession to determine their current clinical practice, training needs and applicability and acceptance aspect of the eLearning and blended learning to train them for an extended primary eye care role.

Optometrists' scope of practice in Singapore

The online survey had a modest response rate of 30%, which is comparable to other online surveys conducted among optometrists.[263,264] The survey findings showed that the majority of optometrists surveyed provide optical technology services (category 1) and visual function services (category 2) as per the WCOs' global model. Their role depended on their place of practice, their primary eye care knowledge, and their awareness of CPE. Optometrists working in academic/research settings reported extended roles that included visual field analysis and topography/pachymetry while optometrists working in government restructured hospitals and private hospitals were restricted to diagnostic refraction, colour vision assessment, and contact lens fitting and dispensing.

Three in four optometrists felt that there was scope for them to extend their role in hospital and primary care settings in areas such as screening for eye diseases and co-managing simple eye conditions alongside ophthalmologists. Interestingly, optometrists who endorsed an extended role in this sample reported a higher degree of primary eye care knowledge, however their confidence in screening and co-managing conditions was low. Elsewhere in Singapore, polyclinics and clinics run by GPs refer patients to optometrists for tele-ophthalmology services and for co-management of the patient together with the ophthalmologist based at the hospital.[262,265] In hospitals, optometrists conduct eye examinations and co-manage eye diseases with ophthalmologists.[259] A study conducted at a primary care setting in Singapore showed that an optometrist supported tele-ophthalmology system was successful in accurately detecting the causes of chronic blurred vision.[266] Harper et al[267] reported that 96% of UK optometrists undertook extended roles with a significant degree of autonomy. The extended roles included the provision of glaucoma care, services in medical retina/diabetes, cataract, corneal clinic services, and specific treatments or interventions including laser capsulotomy, laser iridotomy, selective laser trabeculoplasty, and anti-VEGF injections.[267] Despite the fact that optometrists see value in an extended prescribing role, there could be several barriers to its successful implementation, most notably, remuneration and the outlay of time and cost of training. The current survey did not explore these barriers and further work is needed.

Knowledge and the co-management of ocular disease

Overall, we found that optometrists' self-rated primary eye care knowledge was high, 15.6% had a knowledge score of more than eight (excellent). Optometrists with higher levels of tertiary education overall reported higher primary eye care knowledge, however, their confidence in screening and co-managing specific eye conditions such as cataracts, diabetic retinopathy, chronic glaucoma and age-related macular degeneration was low when compared with optometrists elsewhere.[268,269] This could be due to differences in training and legislation

across settings. Interestingly, in our study, older optometrists with diplomas reported higher scores for screening and co-managing eye conditions than their counterparts with higher tertiary qualifications. This may indicate that experienced optometrists (with diplomas) are more independent on-the-job learners. For example, despite not having completed a course specifically related to the management of cataracts, diabetic retinopathy or age related macular degeneration, experienced optometrists (with diplomas), may be more confident in their ability to keep their training up-to-date through on the job training and self-learning. This study shows the role expansion potential for experienced optometrists in Singapore.

Continuing professional education

Almost a third of the optometrists surveyed reported undertaking 40 or more hours of CPE in the previous year. This is consistent with OOB, which requires a minimum of 50 CPE credits per qualifying period of 2 years (October to the following September) for optometrists.[270] This is in line with CPE guidelines in other countries such as the UK, France and Germany, which require professionals to undertake a minimum number of training hours to keep their knowledge up-to-date. Some of the priority topics for CPE identified by optometrists were glaucoma, diabetic retinopathy, age-related macular degeneration, and anterior segment conditions. They preferred blended learning and online eLearning over face-to-face learning as the training mode for their CPE. This reflects the changing training preferences of optometrists and opticians for co-managing age related eye conditions in the rapidly ageing Singapore population. However, the study has also identified some barriers to online eLearning and blended learning, addressing these barriers may lead to wider acceptance of the technology. Additionally, the study respondents reported that were willing to pay, on average, SGD$23 for a non-accredited CPE course and SGD$156 for an accredited CPE course. However, WTP estimates from optometrists elsewhere are not available for a meaningful comparison.

Referral, communication with medical practitioners

Two in three optometrists in Singapore reported referring patients to GPs or ophthalmologists. The referral rates varied significantly by practice and ranged from 71.4-81.8%, which is higher than studies elsewhere.[271,272] The differences between referral rates in our study and elsewhere could be due to factors such as optometrists' competency, clinical practice guidelines, healthcare access issues and local legislations.

Limitations

It is acknowledged the study had a couple of limitations. Firstly, the survey response rate was low (30%) even after seven email reminders. Response bias was not accessed as characteristics of survey non-responders was unavailable. This could affect the generalisability of the findings. Second, the outcomes reported in the survey were self-reported and consequently prone to response/selection bias in favour of conscientious optometrists or those with a particular interest in role expansion. Third, the self-reported primary eye care knowledge and confidence in co-managing chronic eye conditions results, may be under- or overestimated for legislative or professional reasons. Lastly, the survey has only identified respondents stated preferences for eLearning over other learning formats, but not experiences and perspectives obtained after eLearning. Hence, results are tentative in terms of acceptability. Despite the limitations, this survey provides valuable insights into optometrists' scope of practice, their views on extended primary care roles, their level of primary eye care knowledge, preference for CPE modes and their referral behaviour in Singapore. These insights could aid the development of CPE that equips the Singapore optometrist and optician for an extended primary care role.

Implications for education and future research

In Singapore, there is a substantial need for primary eye care services such as refraction, annual eye examination and low vision.[273] With only 2.7 ophthalmologists per 100,000 persons,[273] it is looking at solutions to equip optometrists to provide primary eye care. Currently six primary-care facility offer optometrist lead primary eye care service.[262] Expanding this service to all primary care settings in Singapore would require more optometrists who could confidently provide ocular diagnostic services (category 3) and ocular therapeutic services (category 4). This would require substantial CPE, on-the-job and formal training, and legislative support. eLearning and blended learning technologies can be used to scale up the much needed training initiatives to meet primary eye care demands in the community. Future studies should aim to objectively assess optometrists' knowledge, compare diagnostic accuracy/agreement with ophthalmologists for the detection of common ocular conditions seen in primary eye care settings and assess additional context specific elements that would impact eLearning and blended learning implementation and subsequent adoption

CONCLUSION

This is the first survey of optometrists in Singapore that explores their scope of practice, knowledge, confidence in screening and co-managing minor eye conditions, and their views on CPE and referral. Optometrists in Singapore represent a skilled but underutilised resource that currently only provides category 1 and 2 services per the WCO model. Although optometrists self-reported that their primary eye care knowledge was high, their confidence in screening and co-managing chronic eye conditions was modest. Enabling them to expand their primary eye care role would require further training, especially to improve their confidence in screening and co-managing patients. Blended learning and eLearning is their preferred choice for CPE.

STRUCTURED CHAPTER SUMMARY

This chapter has contextualised the acceptability aspect of the health technology. It presents the findings from a cross-sectional survey of optometrists and opticians in Singapore on their current scope of practice, primary eye care knowledge, views on extended roles in primary eye care, preferred mode of learning for continuing professional education, and referral behaviour.

In summary Singapore optometrists and opticians' current roles were limited to diagnostic refraction (92%), colour vision assessment (65%), contact lens fitting and dispensing (62%) amongst others. The survey found that average self-rated primary eye care knowledge was 8.2 ± 1.4, score range 1-10 (1-Very poor, 10-Excellent). Their self-rated confidence scores for screening for cataract, diabetic retinopathy, chronic glaucoma and age-related macular degeneration were 2.7 ± 1.5, 3.7 ± 1.9, 4.0 ± 1.0 and 2.7 ± 1.5 respectively. From these results, it is reasonable to draw the following conclusions: that three-fourth of the optometrists felt that they should undertake regular CPE to improve their primary eye care knowledge, and that blended learning (eLearning and traditional face-to-face lectures) (46.8%) was the most preferred mode for CPE delivery.

CHAPTER V: THESIS DISCUSSION

In the era of the Internet, post-registration health professional education has moved away from classroom-based didactic teaching to active eLearning, where the learner has control over their learning - it can be undertaken anywhere and at any time (i.e. at their convenience).[274] ELearning offers many advantages to the busy post-registration healthcare professional as it enables him/her to continue their professional development while they manage their clinical/healthcare centric duties. It could also be used for inter-professional education (IPE) in healthcare, for example, to enable task-shifting from one professional group to the other, as a means to address healthcare access issues.[275] Many universities and medical schools worldwide are offering eLearning and blended learning programs to train post-registration medical professionals.[276] Given these developments, this health technology assessment combines effectiveness and cost-saving potential of a eLearning technology with the assessment of its acceptance to address healthcare professionals' training needs, represents a significant and timely contribution to the knowledge base.

PRINCIPAL FINDINGS

Is online and LAN-based eLearning effective for training post-registration medical doctors?

Numerous randomised controlled trials have evaluated the effectiveness of online and LAN-based eLearning for training medical doctors, but not much is known about its overall effectiveness and cost-effectiveness. Chapter II describes a Cochrane systematic review was conducted to assess the effectiveness and cost-effectiveness of online and LAN-based eLearning compared to self-directed, face-to-face learning and blended learning on physicians' knowledge, skills, attitude, satisfaction and any adverse effects. We searched seven bibliographic databases for RCTs, cRCTs and quasi-randomised trials published between January 1990 and March 2017 evaluating the effectiveness of online and LAN-based eLearning. We identified 27,488 records of which 27,326 were excluded

after title and abstract screening as they did not meet the reviews' inclusion criteria. Full-text screening was conducted on the remaining 162 articles, leaving 93 articles that were included in the review.[100]

The online eLearning intervention studies included in this review were heterogeneous in terms of the learning theories used in the intervention, learning content, the specialty evaluated, outcomes and outcome measures, as well as the comparator used to evaluate their effectiveness. Consequently, individual study data could not be pooled to yield summary effects across intervention types, and hence the results are presented in a narrative summary. Overall, evidence from the studies showed inconsistent effects (no difference between the intervention and comparator on post-intervention scores) of online and LAN-based eLearning on physicians' knowledge, skills, attitude, satisfaction, practice or behaviour change, and patient outcomes. Effect sizes ranged from small to large and the quality of the evidence ranged from very low to low. The quality of the evidence according to GRADE criteria was also judged to be very low.

Twenty-one studies reported higher knowledge score (small to large effect size; very low quality) for the intervention while 20 studies reported no difference in knowledge between the groups. Seven studies reported higher skill score in the intervention (large effect size; low quality) while thirteen studies reported no difference in skill score between the groups. One study reported higher attitude score for the intervention (very low quality), while 4 studies reported no difference in attitude score between the groups. Four studies reported higher post-intervention physician satisfaction with the intervention (large effect size; low quality), while six studies reported no difference in satisfaction between the groups. Eight studies reported higher post-intervention practice or behaviour change for the ODE group (small to moderate effect size; low quality) while five studies reported no difference in practice or behaviour change between the groups. One study reported higher improvement in patient outcome, while three others reported no difference in patient outcome between the groups. None of the

included studies reported any unintended/adverse effects, cost-effectiveness of the interventions.

Among studies that compared eLearning/blended learning with self-directed learning/face-to-face learning (n=26), higher post-intervention scores were reported for knowledge (n=21); skills (n=7); attitude (n=1); satisfaction (n=4) and practice or behaviour change (n=8). The effect size for the outcomes ranged from small to large, and the quality of the evidence was very low to low. Fourteen studies compared eLearning with other forms of eLearning and reported higher post-intervention knowledge scores (large effect size; very low quality) in the intervention group. The unintended or adverse effects, and the cost-effectiveness of the interventions, were not reported among the included studies.

The results on the primary and secondary outcomes varied across studies: some studies demonstrated the beneficial effects of online and LAN-based eLearning, while others indicated no effect. However, based on the equivocal findings and the potential risks of bias associated with the included studies it is difficult to draw any firm conclusions on the effectiveness and cost-effectiveness of the interventions examined.

Does online eLearning or blended learning offer cost-savings? – A cost comparison of a blended ACLS and face-to-face ACLS course

Chapter II also identified a dearth of studies on the cost of online, LAN-based eLearning and blended learning. To address this, the second study presented in chapter III investigated whether a blended learning course would provide cost-savings and a higher ROI compared with face-to-face learning.

The ACLS is mandatory for all medical doctors in Singapore. The certification courses are offered in restructured hospitals and training providers in Singapore. The certification is valid for 2 years, thereafter refresher training in indicated. A typical F-ACLS is a 12-hour face-to-face didactic course with case-based discussion in an interactive learning environment. B-ACLS is typically

conducted in three parts. Part 1 is offered online in which the participant learns through interactive lessons, video presentations and progressively-staged quizzes. Participants are given up to 60 days to complete Part 1 online and need to complete the Part 1 theory test before they can proceed to Part 2 and 3 (5 hours). In Part 2, participants have hands-on practice on the various clinical scenarios, such as cardiac arrest, bradycardia and shock, under the guidance of ACLS instructors. Part 3 is the practical assessment.

The direct and indirect costs of B-ACLS and F-ACLS training were obtained from the training provider. Fixed costs included costs for facilities, hardware, software, maintenance, and course development/production and revision costs. Variable costs included instructor costs, learner costs (productivity loss) and travel costs. The benefits considered for this analysis were the cost savings if B-ACLS was implemented instead of F-ACLS. ROI was computed by dividing the cost savings between B-ACLS and F-ACLS by the total cost of B-ACLS, expressed as a percentage and ratio. Our analysis showed that B-ACLS would provide cost-savings of $172,202 over 5 years with a ROI of 160%. Sensitivity analysis showed that the ROI would range between 15 to 370% for the least favourable conditions, with an average of 179% favouring B-ACLS, and from 49 to 400% for the most favourable conditions, with an average of 197% favouring B-ACLS.

This study provides a crucial costs and a ROI comparison of the two different ACLS training approaches in Singapore. Although B-ACLS has a high capital cost, the annual cost of the training is cheaper than F-ACLS. The ROI will improve further if its development costs become proportionately less in the future. However, based on this single case-study of B-ACLS training firm conclusion on cost-saving potential of eLearning and blended learning technologies cannot be drawn.

Is eLearning or blended learning acceptable for training other healthcare professions in Singapore? - Acceptability of online eLearning for training optometrists and opticians in Singapore

Chapter II and III assessed the effectiveness and cost of eLearning and blended learning, however not much is known about the applicability and acceptability of this new technology to train healthcare professionals in Singapore. Chapter IV addressed this.

Globally, optometrists are the gatekeepers of primary eye care; however, in Singapore their role is still limited to refraction and spectacle dispensing. Due to a shortage of primary eye care professionals, specialist outpatient clinics in hospitals are seeing an increasing number of referrals for simple eye conditions, which could be managed by trained optometrists in primary eye care settings. This study evaluated the role of opticians and optometrists in Singapore and explored whether there is scope to extend their role by increasing their knowledge and confidence through eLearning.

An anonymous online cross-sectional study was conducted using a self-administered questionnaire among optometrists and opticians registered with the OOB. The questionnaire was organised into eight sections and contained a total of 36 questions. It assessed optometrists' and opticians' self-reported primary eye care knowledge, their current roles, views on an extended role, needs for CPE and their view on suitable modes for CPE delivery.

A total of 237 optometrists and opticians completed the survey (response rate 30%). Their current roles were limited to diagnostic refraction (92%); colour vision assessment (65%); and contact lens fitting and dispensing (62%) amongst others. Their average self-rated primary eye care knowledge was 8.2 ± 1.4 (score range 1-10; 1 = very poor, 10 = excellent). Self-rated confidence scores for screening for cataract, diabetic retinopathy, chronic glaucoma and age-related macular degeneration were 2.7 ± 1.5; 3.7 ± 1.9; 4.0 ± 1.0; and 2.7 ± 1.5,

respectively. Three fourths of optometrists surveyed felt they should undertake regular CPE to improve their primary eye care knowledge. Blended learning (eLearning combined with traditional face-to-face lectures) was their preferred mode for CPE delivery (46.8%).

The study found that optometrists and opticians in Singapore are underutilised primary eye care providers. Although their self-reported primary eye care knowledge was high, their confidence in screening and co-managing chronic eye conditions was modest. Enabling them to undertake an extended primary eye care role would require further training. Optometrists and opticians preferred mode for primary eye care training was blended learning and eLearning.

Strengths and limitations

This thesis was primarily limited by the lack of evidence on the cost-effectiveness of online and LAN-based eLearning, which was not measured or reported in the RCTs included in the systematic review. To address this limitation, we sought to compare the cost-effectiveness and ROI of a blended ACLS training program with a face-to-face ACLS program for physicians; however, the training provider was not willing to disclose the effectiveness data (ACLS skills scores, theory scores) due to issues with confidentiality. As we were unable to compare the cost-effectiveness of the courses as planned, the cost-savings and ROI were calculated instead.

In chapter III, the cost savings of B-ACLS over F-ACLS were evaluated, taking into account the reduction in training time and cost of productivity loss of the learner. This may or may not limit the magnitude of savings as other costs such as increased trainer productivity, increased efficiency and its effects on patient care were not accounted for. This could be a limitation. Additionally, the cost-study was based on a single training centre and may not be generalisable. Hence, based on this single case-study of B-ACLS training firm conclusion on cost-saving potential of eLearning and blended learning technologies cannot be drawn.

Chapter IV, - the cross-sectional study of acceptability and applicability had a few limitations that need to be mentioned. First, the study only included optometrists whose email addresses were on the OOB database, thus, registered optometrists and opticians whose email addresses were missing or outdated may have been missed. The low survey response rate and response biases inherent in surveys are some of the other weaknesses.

The major strength of this thesis is the Cochrane systematic review on the effectiveness of online and LAN-based eLearning, which was conducted in accordance with the Cochrane Handbook for Systematic Reviews of Interventions, Version 5.1.0.[116] The review provides a summary of the evidence of online and LAN-based eLearning compared to other forms of learning along with an assessment on its quality. Other strengths include the combination of evidence from the comprehensive systematic review and the primary studies: the systematic review assessed the effectiveness of online and LAN-based eLearning while the primary studies addressed issues surrounding the costs (Study II) and acceptability (Study III) of the online eLearning mode of training.

Health technology assessment summary

There is worldwide shortage of healthcare professionals,[3,127] and in Singapore this has led to healthcare access issues especially in specialist outpatient clinics at hospitals.[2,4,5] ELearning has been proposed as mode of training to address the shortage of healthcare professionals and to equip healthcare professionals for task-shifting to ease healthcare access issues. Also, there has been an exponential growth in the use of eLearning technologies worldwide[277] and in Singapore.[278] This has created challenges to the governments' worldwide on finding ways to manage its finite resource on technologies which provide best health outcomes at lower cost. Many studies worldwide have also shown the effectiveness of eLearning for training nurses,[11] physiotherapists,[12] pharmacists[13] and optometrists.[14] Also, given the global thrust on inter-professional education for healthcare professionals, we assumed that technology if found effective could be

applied to train other healthcare professionals including the optometrists. This HTA assessed: 1) the effectiveness of the technology among post-registration medical doctors worldwide, 2) cost-saving potential of the technology for training physicians in Singapore and 3) acceptance of the technology among optometrists and opticians in Singapore.

Effectiveness

The effectiveness component of the HTA was conducted through a Cochrane systematic review of 93 RCTs involving 16,895 participants predominantly from high-income countries. Most studies targeted PCPs (n=28), surgeons (n=12), general internists (n=12), and paediatricians (n=8). A heterogeneous range of online and LAN-based educational interventions in cognitive, procedural and diagnostic skills training were evaluated, including spaced education, EBM training, CME and CPD, and communication skills training. The outcomes were assessed using a combination of standardised and non-standardised assessment tools. The majority of studies were based on a connectivism learning theory, where the learning occurs through specific online resources designed to keep learners up-to-date. Very few studies were based on cognitivism learning theory (where learning involves abstraction, analysis, synthesis, evaluation, decision-making and critical thinking), constructivism learning theory (where learning involves communication between learner and teacher) and behaviourism learning theory (where leaning involves positive and negative reinforcement through the provision of feedback). The systematic review identified certain key characteristics used in the eLearning interventions amongst the included studies, those were 1) establish a theoretical basis for the eLearning intervention (learning theory). A combination of the four identified theoretical approaches (connectivism, cognitivism, behaviourism and constructivism) may enhance the effectiveness of eLearning; 2) pilot testing the eLearning intervention before wider rollout; 3) the pedagogical approach used in the intervention (individual vs facilitated vs collaborative eLearning); and 4) the usage of a learning LMS to facilitate delivery of learning content and grading of assessments. However, due

to the inconsistent reporting of these characteristics in the primary studies, their effects on learning outcomes could not be ascertained.

Figure 5.1: Key characteristics of eLearning interventions

Overall, the effectiveness evidence showed that online and LAN-based eLearning, and blended learning, may be as effective as traditional learning in improving physicians' knowledge, skills, attitude and satisfaction.

Although this systematic review only addressed the effectiveness of online eLearning for training post-registration medical doctors, it may be applied to train other healthcare professionals as well. Many studies worldwide have also shown its effectiveness in training nurses,[11] physiotherapists,[12] pharmacists[13] and optometrists.[14] Given online eLearning has wider applicability and proven effectiveness, the technology could be used for the interprofessional training of post-registration medical doctors and post-registration healthcare professionals. Such an initiative would encourage collaborative learning and facilitate task-shifting, which could address the problem of fragmentation in health care.

Cost analysis

The effectiveness component of the HTA identified a lack of RCTs assessing the cost-effectiveness of the technology, hence we assessed the cost-saving potential

of the technology using B-ACLS training for physicians as an exemplar. ROI is a form of economic evaluation that values the financial return of an intervention against the total costs of its delivery. The ROI is the benefit minus the cost expressed as a proportion of the cost.

Studies worldwide that have assessed the effectiveness of blended ACLS/ALS training for physicians found that they achieved similar learning outcomes as face-to-face courses.[181,250-252] To evaluate the cost-saving and ROI potential of the technology, we compared the cost of B-ACLS training with F-ACLS training and quantified the cost-saving and ROI to the training provider as an exemplar. The estimated annual cost was 1.7 times higher for F-ACLS than for B-ACLS and the discounted total cost of training over the life of the course (5 years) was 2.6 times higher for the F-ACLS course than the B-ACLS course. For every dollar invested in B-ACLS, the training provider will save USD $1.60 in training costs. This translates to 61% in savings over the lifespan of the course if B-ACLS is implemented instead of F-ACLS.

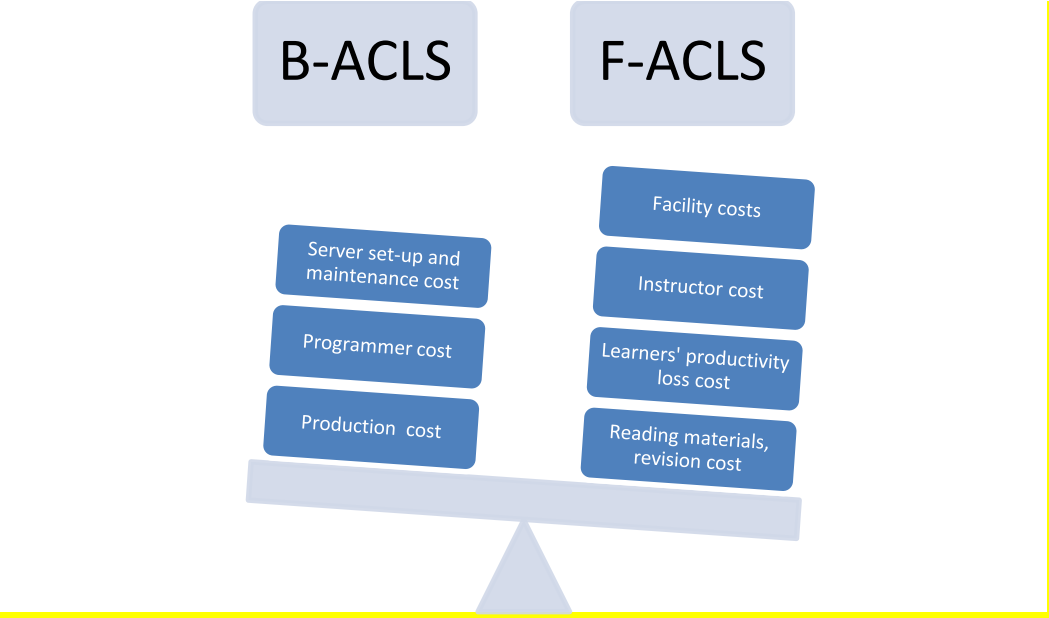


Figure 5.2: Cost-advantage of B-ACLS over F-ACLS

Although blended learning would incur additional start-up costs (set-up costs, programmer costs and production costs) it would break-even by ~3 years and would tilt the balance in favour of B-ACLS. In comparison, an F-ACLS course would incur higher facility, instructor, productivity loss for learner, material and revision costs. The study found B-ACLS to be cost-saving; the findings may not be generalisable to other settings due to differences in training, trainer and technological characteristics. Hence, based on this single case-study of B-ACLS training firm conclusion on cost-saving potential of eLearning and blended learning technologies cannot be drawn. However based on the learnings from this study hospitals, organisations, universities and governments in Singapore and elsewhere looking to adopt eLearning and blended learning technologies can explore accessing financial sustainability of the technology through ROI, alongside an assessment of their effectiveness and cost-effectiveness.

Acceptability/applicability

The effectiveness study within the HTA project showed that online eLearning and blended learning is as effective as traditional learning and has cost-saving potential. We wanted to know if this technology could be used to train and equip optometrists and opticians in Singapore for an extended role in primary eye care, so some simple primary eye care tasks could be shifted from ophthalmologists to optometrists in order to ease healthcare access issues at specialist outpatient clinics in hospitals. In doing so, this HTA not only addressed issues around the technology's effectiveness and cost, it contextualised its acceptability and transferability in a local setting. An online survey of optometrists and opticians in Singapore was conducted to access their current scope of practice in Singapore, their knowledge of primary eye care, their views on expanding their role in primary eye care, their preference for continuing professional education, their referral behaviour and to assess their acceptability of online eLearning and blended learning for their continuing professional education.

The current scope of practice of optometrists and opticians in Singapore is limited. Although they are keen to take on an extended role in primary eye care, their confidence in screening and co-managing chronic eye conditions is modest. Hence, further training through CPE programs would be required to improve their confidence in screening and co-managing patients and equip them for an expanded primary eye care role. Blended learning and eLearning is their preferred choice for the delivery of CPE.

Implications for practice

Postgraduate trainees in Singapore and worldwide, can attend in-hospital lectures and seminars, yet the pressure of clinical responsibilities and shift work often restricts their training opportunities. For senior doctors, there is the added pressure of keeping-up-to date with medical advances. ELearning, which permits self-directed training at an individual's own rate, time and place, could be advantageous to them. With technological advancement and the changing healthcare needs of the broader population, postgraduate medical training is evolving to meet the challenges of educating doctors in a changing environment. ELearning and a blended approach to teaching is as a viable way to meet these challenges as it can support a wide range of learning activities, which are readily accessible and can be tailor-made to meet specific learning objectives.

In Singapore, universities and polytechnics, as part of the SkillsFuture initiative to drive lifelong learning, are offering bite-sized online eLearning courses. Two of the three medical schools in Singapore have already started using flipped classroom strategies to train undergraduate medical students. These flipped classrooms require substantial pre-class preparation while time in-class is focused on active student-centred learning activities.

This systematic review synthesised evidence from 93 randomised controlled trials from the following medical specialties: primary care, surgery, general or internal medicine, paediatrics, emergency medicine, anaesthesiology, radiation oncology, obstetrics and gynaecology, urology, gastroenterology, orthopaedics,

rheumatology, public health and radiology. The review findings suggest that online LAN-based eLearning and blended learning may have a beneficial, or at least an equally beneficial effect, on learners' knowledge, skills, attitude, satisfaction, and practice or behaviour change, compared to self-directed/face-to-face learning or other forms of learning, however, the cost-effectiveness of the intervention remains largely unknown. Few studies reported on the cost of the intervention alone. Studies that reported on the effectiveness of eLearning were heterogeneous in terms of eLearning intervention characteristics such as the use of learning theory, LMS, interactivity and feedback. Overall, the quality of the studies assessing eLearning effectiveness was found to be low.

We compared the cost of the same ACLS training course, offered in a face-to-face environment or as a blended learning program, and found that blended ACLS provided cost-savings and a positive ROI to the training provider.

Long waiting times at specialist outpatient settings in secondary and tertiary eye care in Singapore is partly due to a lack of effective primary eye care. Globally, optometrists are the gate-keepers of primary eye care. In Singapore, their role is often restricted to dispensing and refraction. Our study showed that optometrists and opticians are keen to take on extended roles to help address the shortage of primary eye care professionals in Singapore. However, their knowledge and confidence to take on extended roles and handle chronic eye conditions were modest. A majority of them expressed their willingness to undertake blended/eLearning courses to enhance their primary eye care knowledge.

This study has practical and theoretical implications for teachers, trainers, policy makers, universities, training institutes and the government.

Teachers

Postgraduate teachers and trainers must be aware of eLearning technologies and the changing learning environment, and should tailor their curricula and pedagogical models to cater to the new breed of post-registration medical

professionals. In order to achieve this teachers and trainers need to be trained eLearning pedagogical models and eCurriculum development. Efforts to scale up eLearning should begin with pilot studies of feasibility, acceptance, cost-effectiveness and return of investment to identify potential for expansion and institutionalisation if proven successful.

Implications for policy

Policy makers

Although there has been some progress in the adoption of eLearning technologies across universities and hospitals in Singapore, the current post-registration training system in Singapore is not optimally equipped to accommodate the changing needs of the new generation of post-registrations medical/health professionals. Academic institutes and training may require some changes to their technical infrastructure, professional development systems, pedagogy and curriculum design to stay relevant and ahead. They should also work towards appropriate policies and technologies to provide up-to-date empirical evidence in the rapidly evolving medical education landscape.

Universities

Online and/or blended learning courses may offer cost-savings and a higher ROI to training providers; however based on cost-saving from a single case-study firm conclusion on cost-saving potential of technologies cannot be drawn. Accordingly, universities and academic training institutes should access cost-effectiveness of eLearning and blended learning courses while also ascertaining its financial sustainability. Our review of the evidence from RCTs suggests that medical doctors access and use different technologies, which vary considerably across the different medical specialties and health professions. Education providers and university policy makers need to take this variability into account and develop plans to support the current and future technological needs of post-registration medical/healthcare professionals.

Government and Ministry of Health

Singapore's healthcare woes include an ageing population, rising demand for specialist care , an over-reliance on foreign trained doctors in the public sector and an exodus of doctors to the private sector and overseas for training. To address these issues, the government can consider to implement policies to establish a favourable technological environment in universities and in hospitals and thus facilitate ubiquitous interprofessional eLearning and blended training for post-registration healthcare professionals. Such an initiative would facilitate lifelong learning for busy post-registration healthcare professionals and equip them for role expansion across the healthcare continuum. Developing and implementing interprofessional courses could collectively address the training needs of medical doctors, optometrists and other healthcare professionals. Such an effort could in turn help address issues created by the fragmentation of health care in primary, secondary and tertiary care centres, and thus, improve healthcare access for the population at large.

CONCLUDING REMARKS

There is a global shortage of healthcare professionals including post-registration healthcare professionals; eLearning could potentially contribute to capacity building to address skill based the shortages. The use of eLearning has increased rapidly creating challenges to governments worldwide on finding ways to manage its finite resource on learning technologies. The doctoral candidate, who is a physician in Indian system of medicine and medical educator, has attempted to ascertain the effectiveness, cost and acceptance of online eLearning for training post-registration healthcare professionals, to inform policymakers make evidence based funding decisions on its adoption.

This health technology assessment uses a multi-method approach. It summarises findings from three studies: 1) a Cochrane systematic review of RCTs evaluating the effectiveness of online and LAN-based eLearning among medical doctors; 2) a cost-comparison study of blended ACLS training and face-to-face ACLS training among physicians in Singapore; and 3) online survey of optometrists and opticians in Singapore was conducted to access their current scope of practice in Singapore, their knowledge of primary eye care, their views on expanding their role in primary eye care, their preference for CPE, their referral behaviour and to assess their acceptability of online eLearning and blended learning for their continuing professional education.

This thesis found that online eLearning and blended learning refers to group of heterogenous interventions, with different learning theories, learning content, comparators and outcomes, intervention duration and assessment. They were used to train medical doctors in various specialties, e.g. primary care practitioners, surgeons, residents and physicians. Empirical evidence from 93 RCTs show that online and LAN-based eLearning and blended learning may improve physicians' knowledge, skills, attitude, satisfaction, practice or behaviour change, and patient outcomes; however the quality of the evidence is very low. The thesis found lack of RCT's assessing cost-effectiveness of the heterogenous online eLearning and blended learning, a cost-comparison study of blended ACLS training with face-to-face training was used an exemplar to understand the cost-saving potential of the online, blended learning technology. The thesis found that B-ACLS course provided significant cost savings to the provider and a positive ROI. It should be more widely adopted as the preferred mode of ACLS training. Although there were many eLearning, blended learning interventions we were not able to ascertain the cost-savings and ROI of these interventions as such an evaluation was beyond the scope and time requirement of this degree program. Hospitals, organisations, universities and governments looking to adopt eLearning and blended learning technologies should also consider questions of financial viability through ROI, besides assessing its effectiveness.

The effectiveness and cost components of the HTA showed that online eLearning and blended learning is as effective as traditional learning and may save cost. However, firm conclusion on cost-saving potential of eLearning and blended learning technologies cannot be drawn. We also wanted to know if this technology could be used to train optometrists and opticians in Singapore and equip them for an extended role in primary care, which may help to shift some simple primary eye care tasks from ophthalmologists to optometrists to help ease healthcare access issues at specialist hospital outpatient clinics. In doing so, this HTA not only addressed questions around the effectiveness and cost of the technology but contextualised its acceptability and transferability in a local setting. The thesis determined that eLearning and blended learning is optometrists' and opticians' preferred choice for CPE. It also found that self-reported primary eye care knowledge was high, while confidence in screening and co-managing chronic eye conditions was moderate. This thesis identified a knowledge gap around the screening and co-managing of chronic eye conditions among optometrists and opticians in Singapore. Enabling them to expand their primary eye care role would require further training, especially to improve their knowledge and confidence in screening and co-managing patients.

This thesis has several potentially important practical implications. It provides crucial information on the usage, effectiveness and applicability of online and LAN-based eLearning, and blended learning, for training post-registration health professionals from diverse disciplines and specialties. In areas with a shortage of medical teachers, online eLearning offers some potential benefits. Although this HTA only addressed the effectiveness and cost of eLearning and blended learning for training post-registration medical doctors, the technology could be used for IPE involving post-registration medical doctors and other post-registration healthcare professionals. Such an initiative would encourage collaborative learning and facilitate task-shifting, which could address the problem of fragmentation in health care.

PhD's contribution to knowledge

This PhD made the following direct contributions to the field of medical education:

1. This thesis explored a novel research area and contributed to the scarce evidence-base on online eLearning-based interventions for training medical doctors using the rigorous Cochrane approach. Previous studies have documented the effectiveness of online eLearning for undergraduate health professionals without due consideration to the typologies.
2. Given the lack of data on cost and the cost-effectiveness of online eLearning and blended learning, this thesis made an original contribution by obtaining data on B-ACLS and F-ACLS training and compared the cost and ROI to the training provider.
3. Besides providing evidence on the effectiveness and cost of online eLearning and blended learning, this thesis also assessed the acceptability of the technology among optometrists and opticians in Singapore.
4. The PhD candidate led the research that formed the basis for this thesis, acknowledging and referencing the efforts of others where applicable. The candidate has authored three academic papers (one that has been accepted for publication and two that are *in press*) related to this thesis during his doctoral studies.
5. The PhD candidate helped build research capacity in Singapore. He provided training in research methodology, systematic reviews and meta-analysis and made substantial contributions to related research projects.

This PhD made the following indirect contributions to the online eLearning, and medical and health professional education fields:

1. The findings of this thesis provide much needed evidence to inform educators' and policymakers' decisions on the use of online eLearning technologies for training medical doctors. However, the findings from this thesis should be compared with the findings from studies conducted in other setting to assess transferability of findings.

2. Organisations such as the World Health Organisation and the World Bank can use the findings from chapter II to identify effective online eLearning pedagogies for medical/health workforce training.
3. This thesis identified several critical components of online eLearning technologies, such as the use of pedagogical features namely individual, facilitated and collaborative learning, and technical features, such as interactivity, feedback function of the intervention, validation of pedagogy and the intervention. These features could guide development of online eLearning technologies and would also be useful as a benchmark for assessing the technical features of future studies.

In conclusion, not much is currently known about the effectiveness, cost and acceptability of online eLearning for training post-registration healthcare professionals. This thesis helped to address this knowledge gap by assessing the effectiveness, cost-advantage and acceptability of this technology among a broader group of health professionals. In countries with shortage of post-registration professionals or in areas with geographical access limitations online eLearning could be used to address the shortage of post-registration healthcare professionals as it provides greater access to education and training at a lower cost. This thesis also found it is an acceptable mode of training to deliver CME and CPD.

PhD's learning points

The HTA assessed the evidence base, cost-saving, ROI and acceptability of online eLearning and blended learning for training post-registration healthcare professionals.

1. The effectiveness component of the HTA helped me:
    a. engage in an original research study;
    b. gain topic-related and methodological expertise on online and LAN-based eLearning and blended learning;
    c. acquire key "generic" and "transferable" skills in the design and conduct of systematic reviews; and
    d. develop functional networks of mentoring and research partnerships with Cochrane collaboration, inter-university and hospital collaboration.

2. The cost evaluation of the HTA helped me:
    a. gain knowledge in building Microsoft Excel based ROI models;
    b. gain topic related expertise on advance cardiac life support course; and
    c. develop new training industry partnerships.

3. The acceptability survey of the HTA helped me:
    a. engage in an original research study;
    b. gain topic-related expertise in primary eye care in Singapore;
    c. acquire key 'generic' and 'transferable' skills in design and conduct of online surveys; and
    d. develop functional networks of research with optometrists and opticians.

FUTURE DIRECTIONS

Online eLearning and blended learning may be effective for training medical doctors on certain topics or subject areas. However, there were stark differences between the types of online learning used among the included studies - differences explained by the extent of technology use. For example, eLearning can range from the simple provision of a single online lecture to an expansive set of interactive lectures built upon validated learning theory, and delivered and managed using a learning management system that tracks learning analytics and provides a greater level of interaction and feedback to learners. Hence, future studies evaluating the effectiveness of online eLearning should take into account the level of technology used. Furthermore, future studies evaluating the intervention should seek to address several unanswered questions such as the cost-effectiveness of online eLearning, its acceptability, barriers to its adoption, and learner's readiness to switch from classroom learning to complete online eLearning or flipped classroom learning.

Furthermore, future research on online and LAN-based eLearning should focus on multicentered randomised controlled trials for interprofessional education. There is also a need for a standardised approach to the measurement, evaluation and reporting of studies examining the effectiveness of online and LAN-based eLearning. For online and LAN-based eLearning to be implemented nationally, as well as internationally, further high-quality studies addressing the above concerns are needed.

The findings of this thesis, together with the existing body of evidence, emphasise the need for educational institutes and universities worldwide to rethink education beyond the classroom and consider the possibility of rolling out interprofessional education and certification programs using flipped classrooms or online eLearning programs, designed to address the changing learning needs of healthcare professionals.

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cost-saving, return on investment, break-even, extended scope practice, optometrists, opticians, primary eye care, survey, Singapore.

APPENDIX I A: COCHRANE SYSTEMATIC REVIEW PROTOCOL

Protocol available at
http://onlinelibrary.wiley.com/doi/10.1002/14651858.CD012108/epdf

APPENDIX I B: SEARCH STRATEGY

SR: Medline (Ovid) search strategy

exp education, professional or not education, veterinary or

2. Education, Predentalor

3. Education, Premedicalor

4. exp Students, Health Occupationsor

5. ((medic* or premedic* or dent* or laborator* or predent* or midwi?e* or nurs* or nutrition* or orthop* or podiat* or pharmac* or psycholog* or psychiatr* or health or healthcare or occupational therap* or physiotherap* or physical therap* or clinical or surg* or radiolog* or obstetric* or gyn?ecolog* or orthodont* or An?esthesi* or Dermatolog* or Oncolog* or Rheumatolog* or Neurolog* or Patholog* or P?ediatric* or Cardiolog* or Urolog*) adj3 (student* or graduate* or undergraduate* or staff or personnel or practitioner* or clerk* or fellow* or internship* or residen* or educat* or train* or novice* or tutor*)).tw,kf.

6. oror1-5

7. Computer-Assisted Instructionor

8. exp Internetor

9. Computer Simulationor

10. Patient Simulationor

11. softwareor

12. Mobile Applicationsor

13. User-Computer Interfaceor

14. Video Gamesor

15. Web Browseror

16. Education, Distanceor

17. Computersor

18. exp Microcomputersor

19. exp Cell Phonesor

20. Games, Experimentalor

21. exp Models, Anatomicor

22. Audiovisual Aidsor

23. Educational Technologyor

24. Electronic Mailor

25. exp Telemedicineor

26. Telenursingor

27. Telecommunicationsor

28. Webcastsor

29. exp Videoconferencingor

30. ((computer* or digital* or hybrid or blended or mixed mode or distance or remote* or electronic or mobile or online* or interactiv* or multimedia or internet or web* or virtual* or game* or gaming or Videogame* or Videogaming) adj3 (classroom* or course* or educat* or instruct* or learn* or lecture* or simulat* or train* or teach* or tutor* or platform*)).tw,kf.

31. (Simulat* adj3 (course* or educat* or instruct* or learn* or train* or teach* or platform* or high-fidelity)).tw,kf.

32. e-learn*.tw,kf.

33. elearn*.tw,kf.

34. m-learn*.tw,kf.

35. mlearn*.tw,kf.

36. smartphone*.tw,kf.

37. smart-phone*.tw,kf.

38. ((mobile or cell) adj2 phone*).tw,kf.

39. iphone*.tw,kf.

40. android*.tw,kf.

41. ipad*.tw,kf.

42. Personal digital assistant*.tw,kf.

43. handheld computer*.tw,kf.

44. Mobile App?.tw,kf.

45. Mobile Application?.tw,kf.

46. webcast*.tw,kf.

47. webinar*.tw,kf.

48. flipped classroom*.tw,kf.

49. Serious game*.tw,kf.

50. Serious gaming.tw,kf.

51. Patient Simulat*.tw,kf.

52. Virtual patient*.tw,kf.

53. ((educat* or instruct* or learn* or simulat* or train* or teach* or interactiv*) adj2 technolog*).tw,kf.

54. Massive Open Online Course?.tw,kf.

55. Mooc?.tw,kf.

56. (Canvas network or Coursera or Coursesites or edx or Futurelearn or iversity or miriada x or moodle or novoed or openlearning or open2study or plato or spoc or udacity or pingpong).tw,kf.

57. oror7-56

58. 6 and 57

59. Education.fs.

60. Educationor

61. Teachingor

62. Learningor

63. exp Inservice Trainingor

64. Curriculumor

65. educat*.tw,kf.

66. learn*.tw,kf.

67. train*.tw,kf.

68. instruct*.tw,kf.

69. teach*.tw,kf.

70. oror59-69

71. Health Personnelor

72. exp Allied Health Personnelor

73. Anatomistsor

74. "Coroners and Medical Examiners"or

75. exp Dental Staffor

76. exp Dentistsor
77. Health Educatorsor
78. Infection Control Practitionersor
79. Medical Laboratory Personnelor
80. exp Medical Staffor
81. exp Nursesor
82. exp Nursing Staffor
83. Personnel, Hospitalor
84. Pharmacistsor
85. exp Physiciansor
86. Physician*.tw,kf.
87. Doctor*.tw,kf.
88. Nurs*.tw,kf.
89. Surg*.tw,kf.
90. Health Personnel.tw,kf.
91. healthcare professional*.tw,kf.
92. radiolog*.tw,kf.
93. dentist*.tw,kf.
94. Pharmacist*.tw,kf.
95. Hospital Administrator*.tw,kf.
96. Podiatr*.tw,kf.
97. Psycholog*.tw,kf.
98. Psychiatr*.tw,kf.
99. An?esthesi*.tw,kf.
100. Clinician*.tw,kf.
101. Dermatolog*.tw,kf.
102. General practioner*.tw,kf.
103. Cardiolog*.tw,kf.
104. Oncolog*.tw,kf.
105. Rheumatolog*.tw,kf.
106. Neurolog*.tw,kf.

107. Patholog*.tw,kf.
108. P?ediatric*.tw,kf.
109. Physiotherap*.tw,kf.
110. Physical therap*.tw,kf.
111. Occupational therap*.tw,kf.
112. dieti?ian*.tw,kf.
113. Dietetic*.tw,kf.
114. midwi?e*.tw,kf.
115. nutrition*.tw,kf.
116. orthopti*.tw,kf.
117. obstetric*.tw,kf.
118. gyn?ecolog*.tw,kf.
119. orthodont*.tw,kf.
120. Urolog*.tw,kf.
121. oror71-120
122. Health Occupationsor
123. exp Allied Health Occupationsor
124. Biomedical Engineeringor
125. Chiropracticor
126. exp Dentistryor
127. exp Evidence-Based Practiceor
128. exp Medicineor
129. exp Nursingor
130. Dieteticsor
131. Optometryor
132. Orthopticsor
133. exp Pharmacologyor
134. exp Pharmacyor
135. Podiatryor
136. Psychology, Medicalor
137. Serologyor

138. Specializationor

139. exp Surgical Procedures, Operativeor

140. exp Radiographyor

141. oror122-140

142. 121 or 141

143. 57 and 70 and 142

144. Psychomotor Performanceor

145. motor skillsor

146. ((psychomotor or procedural or technical) adj3 skill*).tw,kf.

147. (psychomotor adj3 performance).tw,kf.

148. oror144-147

149. 6 and 148

150. 58 or 143 or 149

151. limit 150 to yr="1990 -Current"

SR: Embase (Elsevier) search strategy

#71.153

#71.149 OR #71.151 OR #71.152 AND [1990-2015]orpy

Feb 27, 2015

#71.152

#71.6 AND #71.148

Feb 27, 2015

#71.151

#71.96 AND #71.111 AND #71.150

Feb 27, 2015

#71.150

#71.127 OR #71.143

Feb 27, 2015

#71.149

#71.6 AND #71.96

Feb 27, 2015

#71.148

#71.144 OR #71.145 OR #71.146 OR #71.147

Feb 27, 2015

#71.147

'motor performance'orde

Feb 27, 2015

#71.146

'psychomotor development'orde

Feb 27, 2015

#71.145

'psychomotor activity'orde

Feb 27, 2015

#71.144

'psychomotor performance'orde

Feb 27, 2015

#71.143

#71.128 OR #71.129 OR #71.130 OR #71.131 OR #71.132 OR #71.133 OR #71.134 OR #71.135 OR #71.136 OR #71.137 OR #71.138 OR #71.139 OR #71.140 OR #71.141 OR #71.142

Feb 27, 2015

#71.142

'radiography'orexp

Feb 27, 2015

#71.141

'surgery'orexp

Feb 27, 2015

#71.140

'pharmaceutics'orde

Feb 27, 2015

#71.139

'optometry'orde

Feb 27, 2015

#71.138

'nursing'orexp

Feb 27, 2015

#71.137

'evidence based nursing'orde

Feb 27, 2015

#71.136

'evidence based emergency medicine'orde

Feb 27, 2015

#71.135

'evidence based medicine'orde

Feb 27, 2015

#71.134

'evidence based dentistry'orde

Feb 27, 2015

#71.133

'evidence based practice'orde

Feb 27, 2015

#71.132

'biomedical engineering'orde

Feb 27, 2015

#71.131

'biomedicine'orexp NOT ('veterinary medicine'orde OR 'telemedicine'orde OR 'visible human project'orde)

Feb 27, 2015

#71.130

'paramedical profession'orde

Feb 27, 2015

#71.129

'nursing as a profession'orde

Feb 27, 2015

#71.128

'medical profession'orde

Feb 27, 2015

#71.127

#71.112 OR #71.113 OR #71.114 OR #71.115 OR #71.116 OR #71.117 OR #71.118 OR #71.119 OR #71.120 OR #71.121 OR #71.122 OR #71.123 OR #71.124 OR #71.125 OR #71.126

Feb 27, 2015

#71.126

'health educator'orde

Feb 27, 2015

#71.125

'paramedical personnel'orexp

Feb 27, 2015

#71.124

'nursing home personnel'orde

Feb 27, 2015

#71.123

'mental health care personnel'orde

Feb 27, 2015

#71.122

'resident'orde

Feb 27, 2015

#71.121

'psychotherapist'orde

Feb 27, 2015

#71.120

'physician assistant'orde

Feb 27, 2015

#71.119

'physician'orexp

Feb 27, 2015

#71.118

'medical staff'orde

Feb 27, 2015

#71.117

'medical specialist'orde

Feb 27, 2015

#71.116

'medical expert'orexp

Feb 27, 2015

#71.115

'coroner'orde

Feb 27, 2015

#71.114

'medical personnel'orde

Feb 27, 2015

#71.113

'hospital personnel'orexp

Feb 27, 2015

#71.112

'health care personnel'orde

Feb 27, 2015

#71.111

#71.97 OR #71.98 OR #71.99 OR #71.100 OR #71.101 OR #71.102 OR #71.103 OR #71.104 OR #71.105 OR #71.106 OR #71.107 OR #71.108 OR #71.109 OR #71.110

Feb 27, 2015

#71.110

'learning'orde

Feb 27, 2015

#71.109

'teaching'orde

Feb 27, 2015

#71.108

'postgraduate education'orde

Feb 27, 2015

#71.107

'postdoctoral education'orde

Feb 27, 2015

#71.106

'masters education'orde

Feb 27, 2015

#71.105

'interdisciplinary education'orde

Feb 27, 2015

#71.104

'in service training'orde

Feb 27, 2015

#71.103

'education program'orde

Feb 27, 2015

#71.102

'doctoral education'orde

Feb 27, 2015

#71.101

'curriculum development'orde

Feb 27, 2015

#71.100

'curriculum'orde

Feb 27, 2015

#71.99

'continuing education'orde

Feb 27, 2015

#71.98

'computerized adaptive testing'orde

Feb 27, 2015

#71.97

'education'orde

Feb 27, 2015

#71.96

#71.7 OR #71.8 OR #71.9 OR #71.10 OR #71.11 OR #71.12 OR #71.13 OR #71.14 OR #71.15 OR #71.16 OR #71.17 OR #71.18 OR #71.19 OR #71.20 OR #71.21 OR #71.22 OR #71.23 OR #71.24 OR #71.25 OR #71.26 OR #71.27 OR #71.28 OR #71.29 OR #71.30 OR #71.31 OR #71.32 OR #71.33 OR #71.34 OR #71.35 OR #71.36 OR #71.37 OR #71.38 OR #71.39 OR #71.40 OR #71.41 OR #71.42 OR #71.43 OR #71.44 OR #71.45 OR #71.46 OR #71.47 OR #71.48 OR #71.49 OR #71.50 OR #71.51 OR #71.52 OR #71.53 OR #71.54 OR #71.55 OR #71.56 OR #71.57 OR #71.58 OR #71.59 OR #71.60 OR #71.61 OR #71.62 OR #71.63 OR #71.64 OR #71.65 OR #71.66 OR #71.67 OR #71.68 OR #71.69 OR #71.70 OR #71.71 OR #71.72 OR #71.73 OR #71.74 OR #71.75 OR #71.76 OR #71.77 OR #71.78 OR #71.79 OR #71.80 OR #71.81 OR #71.82 OR #71.83 OR #71.84 OR #71.85 OR #71.86 OR #71.87 OR #71.88 OR #71.89 OR #71.90 OR #71.91 OR #71.92 OR #71.93 OR #71.94 OR #71.95

Feb 27, 2015

#71.95

'canvas network':ab,ti OR coursera:ab,ti OR coursesites:ab,ti OR edx:ab,ti OR futurelearn:ab,ti OR iversity:ab,ti OR 'miriada x':ab,ti OR moodle:ab,ti OR novoed:ab,ti OR openlearning:ab,ti OR open2study:ab,ti OR plato:ab,ti OR spoc:ab,ti OR udacity:ab,ti OR pingpong:ab,ti

Feb 27, 2015

#71.94

mooc:ab,ti OR moocs:ab,ti

Feb 27, 2015

#71.93

('massive open online' NEXTor1 course*):ab,ti

Feb 27, 2015

#71.92

((educat* OR instruct* OR learn* OR simulat* OR train* OR teach* OR interactiv*) NEARor2 technolog*):ab,ti

Feb 27, 2015

#71.91

(virtual NEXTor1 patient*):ab,ti

Feb 27, 2015

#71.90

(patient NEXTor1 simulat*):ab,ti

Feb 27, 2015

#71.89

(serious NEXTor1 gaming):ab,ti

Feb 27, 2015

#71.88

(serious NEXTor1 game*):ab,ti

Feb 27, 2015

#71.87

(flipped NEXTor1 classroom*):ab,ti

Feb 27, 2015

#71.86

webinar*:ab,ti

Feb 27, 2015

#71.85

webcast*:ab,ti

Feb 27, 2015

#71.84

(mobile NEXTor1 (application OR applications)):ab,ti

Feb 27, 2015

#71.83

(mobile NEXTor1 (app OR apps)):ab,ti

Feb 27, 2015

#71.82

(handheld NEXTor1 computer*):ab,ti

Feb 27, 2015

#71.81

('personal digital' NEXTor1 assistant*):ab,ti

Feb 27, 2015

#71.80

ipad*:ab,ti

Feb 27, 2015

#71.79

android*:ab,ti

Feb 27, 2015

#71.78

iphone*:ab,ti

Feb 27, 2015

#71.77

((mobile OR cell) NEARor2 phone*):ab,ti

Feb 27, 2015

#71.76

(smart NEXTor1 phone*):ab,ti

Feb 27, 2015

#71.75

smartphone*:ab,ti

Feb 27, 2015

#71.74

mlearn*:ab,ti

Feb 27, 2015

#71.73

(m NEXTor1 learn*):ab,ti

Feb 27, 2015

#71.72

elearn*:ab,ti

Feb 27, 2015

#71.71

(e NEXTor1 learn*):ab,ti

Feb 27, 2015

#71.70

(simulat* NEARor3 (course* OR educat* OR instruct* OR learn* OR train* OR teach* OR platform* OR 'high fidelity')):ab,ti

Feb 27, 2015

#71.69

(videogaming NEARor3 (classroom* OR course* OR educat* OR instruct* OR learn* OR lecture* OR simulat* OR train* OR teach* OR tutor* OR platform*)):ab,ti

Feb 27, 2015

#71.68

(videogame* NEARor3 (classroom* OR course* OR educat* OR instruct* OR learn* OR lecture* OR simulat* OR train* OR teach* OR tutor* OR platform*)):ab,ti

Feb 27, 2015

#71.67

(gaming NEARor3 (classroom* OR course* OR educat* OR instruct* OR learn* OR lecture* OR simulat* OR train* OR teach* OR tutor* OR platform*)):ab,ti

Feb 27, 2015

#71.66

('game-based' NEARor3 (classroom* OR course* OR educat* OR instruct* OR learn* OR lecture* OR simulat* OR train* OR teach* OR tutor* OR platform*)):ab,ti

Feb 27, 2015

#71.65

(game* NEAR or3 (classroom* OR course* OR educat* OR instruct* OR learn* OR lecture* OR simulat* OR train* OR teach* OR tutor* OR platform*)):ab,ti

Feb 27, 2015

#71.64

('virtual-reality' NEAR or3 (classroom* OR course* OR educat* OR instruct* OR learn* OR lecture* OR simulat* OR train* OR teach* OR tutor* OR platform*)):ab,ti

Feb 27, 2015

#71.63

(virtual* NEAR or3 (classroom* OR course* OR educat* OR instruct* OR learn* OR lecture* OR simulat* OR train* OR teach* OR tutor* OR platform*)):ab,ti

Feb 27, 2015

#71.62

('web-based' NEAR or3 (classroom* OR course* OR educat* OR instruct* OR learn* OR lecture* OR simulat* OR train* OR teach* OR tutor* OR platform*)):ab,ti

Feb 27, 2015

#71.61

(web* NEAR or3 (classroom* OR course* OR educat* OR instruct* OR learn* OR lecture* OR simulat* OR train* OR teach* OR tutor* OR platform*)):ab,ti

Feb 27, 2015

#71.60

('internet-based' NEAR or3 (classroom* OR course* OR educat* OR instruct* OR learn* OR lecture* OR simulat* OR train* OR teach* OR tutor* OR platform*)):ab,ti

Feb 27, 2015

#71.59

(internet* NEARor3 (classroom* OR course* OR educat* OR instruct* OR learn* OR lecture* OR simulat* OR train* OR teach* OR tutor* OR platform*)):ab,ti

Feb 27, 2015

#71.58

(multimedia NEARor3 (classroom* OR course* OR educat* OR instruct* OR learn* OR lecture* OR simulat* OR train* OR teach* OR tutor* OR platform*)):ab,ti

Feb 27, 2015

#71.57

(interactiv* NEARor3 (classroom* OR course* OR educat* OR instruct* OR learn* OR lecture* OR simulat* OR train* OR teach* OR tutor* OR platform*)):ab,ti

Feb 27, 2015

#71.56

('online-based' NEARor3 (classroom* OR course* OR educat* OR instruct* OR learn* OR lecture* OR simulat* OR train* OR teach* OR tutor* OR platform*)):ab,ti

Feb 27, 2015

#71.55

(online* NEARor3 (classroom* OR course* OR educat* OR instruct* OR learn* OR lecture* OR simulat* OR train* OR teach* OR tutor* OR platform*)):ab,ti

Feb 27, 2015

#71.54

(mobile NEARor3 (classroom* OR course* OR educat* OR instruct* OR learn* OR lecture* OR simulat* OR train* OR teach* OR tutor* OR platform*)):ab,ti

Feb 27, 2015

#71.53

(electronic NEARor3 (classroom* OR course* OR educat* OR instruct* OR learn* OR lecture* OR simulat* OR train* OR teach* OR tutor* OR platform*)):ab,ti

Feb 27, 2015

#71.52

(remote* NEARor3 (classroom* OR course* OR educat* OR instruct* OR learn* OR lecture* OR simulat* OR train* OR teach* OR tutor* OR platform*)):ab,ti

Feb 27, 2015

#71.51

('distance-based' NEARor3 (classroom* OR course* OR educat* OR instruct* OR learn* OR lecture* OR simulat* OR train* OR teach* OR tutor* OR platform*)):ab,ti

Feb 27, 2015

#71.50

(distance NEARor3 (classroom* OR course* OR educat* OR instruct* OR learn* OR lecture* OR simulat* OR train* OR teach* OR tutor* OR platform*)):ab,ti

Feb 27, 2015

#71.49

('mixed mode' NEARor3 (classroom* OR course* OR educat* OR instruct* OR learn* OR lecture* OR simulat* OR train* OR teach* OR tutor* OR platform*)):ab,ti

Feb 27, 2015

#71.48

(blended NEARor3 (classroom* OR course* OR educat* OR instruct* OR learn* OR lecture* OR simulat* OR train* OR teach* OR tutor* OR platform*)):ab,ti

Feb 27, 2015

#71.47

(hybrid NEARor3 (classroom* OR course* OR educat* OR instruct* OR learn* OR lecture* OR simulat* OR train* OR teach* OR tutor* OR platform*)):ab,ti

Feb 27, 2015

#71.46

(digital* NEARor3 (classroom* OR course* OR educat* OR instruct* OR learn* OR lecture* OR simulat* OR train* OR teach* OR tutor* OR platform*)):ab,ti

Feb 27, 2015

#71.45

('computer-based' NEARor3 (classroom* OR course* OR educat* OR instruct* OR learn* OR lecture* OR simulat* OR train* OR teach* OR tutor* OR platform*)):ab,ti

Feb 27, 2015

#71.44

(computer* NEARor3 (classroom* OR course* OR educat* OR instruct* OR learn* OR lecture* OR simulat* OR train* OR teach* OR tutor* OR platform*)):ab,ti

Feb 27, 2015

#71.43

'vignette'orde

Feb 27, 2015

#71.42

'simulator'orde

Feb 27, 2015

#71.41

'simulation'orde

Feb 27, 2015

#71.40

'radiotherapy simulator'orde

Feb 27, 2015

#71.39

'disease simulation'orde

Feb 27, 2015

#71.38

'audiovisual aid'orde

Feb 27, 2015

#71.37

'visible human project'orde

Feb 27, 2015

#71.36

'educational technology'orde

Feb 27, 2015

#71.35

'audiovisual equipment'orde

Feb 27, 2015

#71.34

'text messaging'orde

Feb 27, 2015

#71.33

'personal digital assistant'orde

Feb 27, 2015

#71.32

'microcomputer'orde

Feb 27, 2015

#71.31

'computer'orde

Feb 27, 2015

#71.30

'videoconferencing'orde

Feb 27, 2015

#71.29

'telehealth'orexp

Feb 27, 2015

#71.28

'webcast'orde

Feb 27, 2015

#71.27

'teleconference'orde

Feb 27, 2015

#71.26

'telecommunication'orde

Feb 27, 2015

#71.25

'social media'orde

Feb 27, 2015

#71.24

'mobile phone'orde

Feb 27, 2015

#71.23

'e-mail'orde

Feb 27, 2015

#71.22

'virtual reality'orde

Feb 27, 2015

#71.21

'internet'orde

Feb 27, 2015

#71.20

'computer simulation'orde

Feb 27, 2015

#71.19

'computer program'orde

Feb 27, 2015

#71.18

'web browser'orde

Feb 27, 2015

#71.17

'radiotherapy software'orde

Feb 27, 2015

#71.16

'orthopedic software'orde

Feb 27, 2015

#71.15

'mobile application'orde

Feb 27, 2015

#71.14

'imaging software'orde

Feb 27, 2015

#71.13

'data analysis software'orde

Feb 27, 2015

#71.12

'communication software'orde

Feb 27, 2015

#71.11

'anaesthesiology software'orde

Feb 27, 2015

#71.10

'computer model'orde

Feb 27, 2015

#71.9

'virtual reality modeling language'orde

Feb 27, 2015

#71.8

'computer interface'orde

Feb 27, 2015

#71.7

'internet'orde

Feb 27, 2015362,348

#71.6

#71.1 OR #71.2 OR #71.3 OR #71.4 OR #71.5

Feb 27, 201517,557

#71.5

'nursing student'orexp

Feb 27, 201544,212

#71.4

'medical student'orexp

Feb 27, 20158,841

#71.3

'paramedical student'orexp

Feb 27, 201582,165

#71.2

'paramedical education'orexp

Feb 27, 2015

#71.1

'medical education'orexp

SR: Cochrane (Wiley) search strategy

#1 ((medic* or premedic* or dent* or laborator* or predent* or midwi*e* or nurs* or nutrition* or orthop* or podiat* or pharmac* or psycholog* or psychiatr* or health or healthcare or (occupational nextor1 therap*) or physiotherap* or (physical nextor1 therap*) or clinical or surg* or radiolog* or obstetric* or gyn*ecolog* or orthodont* or An*esthesi* or Dermatolog* or Oncolog* or Rheumatolog* or Neurolog* or Patholog* or P*ediatric* or Cardiolog* or Urolog*) nearor3 (student* or graduate* or undergraduate* or staff or personnel or practitioner* or clerk* or fellow* or internship* or residen* or educat* or train* or novice* or tutor*)):ti,ab

#2 ((computer* or digital* or hybrid or blended or "mixed mode" or distance or remote* or electronic or mobile or online* or interactiv* or multimedia or internet or web* or virtual* or game* or gaming or Videogame* or Videogaming) nearor3 (classroom* or course* or educat* or instruct* or learn* or lecture* or simulat* or train* or teach* or tutor* or platform*)):ti,ab

#3 (Simulat* nearor3 (course* or educat* or instruct* or learn* or train* or teach* or platform* or high-fidelity)):ti,ab
#4 e-learn*:ti,ab
#5 elearn*:ti,ab
#6 m-learn*:ti,ab
#7 mlearn*:ti,ab
#8 smartphone*:ti,ab
#9 smart-phone*:ti,ab
#10 ((mobile or cell) nearor2 phone*):ti,ab
#11 iphone*:ti,ab
#12 android*:ti,ab
#13 ipad*:ti,ab
#14 ("Personal digital" nextor1 assistant*):ti,ab
#15 (handheld nextor1 computer*):ti,ab
#16 (Mobile nextor1 App):ti,ab
#17 (Mobile nextor1 Apps):ti,ab
#18 (Mobile nextor1 Application):ti,ab
#19 (Mobile nextor1 Applications):ti,ab
#20 webcast*:ti,ab
#21 webinar*:ti,ab
#22 (flipped nextor1 classroom*):ti,ab
#23 (Serious nextor1 game*):ti,ab
#24 (Serious nextor1 gaming):ti,ab
#25 (Patient nextor1 Simulat*):ti,ab
#26 (Virtual nextor1 patient*):ti,ab
#27 ((educat* or instruct* or learn* or simulat* or train* or teach* or interactiv*) nearor2 technolog*):ti,ab
#28 ("Massive Open Online" nextor1 Course*):ti,ab
#29 Mooc:ti,ab
#30 Moocs:ti,ab
#31 ("Canvas network" or Coursera or Coursesites or edx or Futurelearn or iversity or "miriada x" or moodle or novoed or openlearning or open2study or plato or spoc or udacity or pingpong):ti,ab
#32 1-#31
#33 #1 and #32
#34 educat*:ti,ab
#35 learn*:ti,ab
#36 train*:ti,ab
#37 instruct*:ti,ab
#38 teach*:ti,ab
#39 1-#38
#40 Physician*:ti,ab
#41 Doctor*:ti,ab
#42 Nurs*:ti,ab
#43 Surg*:ti,ab
#44 "Health Personnel":ti,ab

#45 (healthcare nextor1 professional*):ti,ab
#46 radiolog*:ti,ab
#47 dentist*:ti,ab
#48 Pharmacist*:ti,ab
#49 (Hospital nextor1 Administrator*):ti,ab
#50 Podiatr*:ti,ab
#51 Psycholog*:ti,ab
#52 Psychiatr*:ti,ab
#53 An*esthesi*:ti,ab
#54 Clinician*:ti,ab
#55 Dermatolog*:ti,ab
#56 (General nextor1 practioner*):ti,ab
#57 Cardiolog*:ti,ab
#58 Oncolog*:ti,ab
#59 Rheumatolog*:ti,ab
#60 Neurolog*:ti,ab
#61 Patholog*:ti,ab
#62 P*ediatric*:ti,ab
#63 Physiotherap*:ti,ab
#64 (Physical nextor1 therap*):ti,ab
#65 (Occupational nextor1 therap*):ti,ab
#66 dieti*ian*:ti,ab
#67 Dietetic*:ti,ab
#68 midwi*e*:ti,ab
#69 nutrition*:ti,ab
#70 orthopti*:ti,ab
#71 obstetric*:ti,ab
#72 gyn*ecolog*:ti,ab
#73 orthodont*:ti,ab
#74 Urolog*:ti,ab
#75 {or #40-#74}
#76 #32 and #39 and #75
#77 ((psychomotor or procedural or technical) nearor3 skill*):ti,ab
#78 (psychomotor nearor3 performance):ti,ab
#79 #77 or #78
#80 #1 and #79
#81 #33 or #76 or #80 Publication Year from 1990 to 2015

SR: PsycINFO (Ovid) search strategy

1. exp graduate education or
2. nursing education or
3. exp Psychology Educationor
4. exp Clinical Methods Trainingor
5. medical students or
6. nursing students or
7. dental students or

8. therapist trainees or
9. ((medic* or premedic* or dent* or laborator* or predent* or midwi?e* or nurs* or nutrition* or orthop* or podiat* or pharmac* or psycholog* or psychiatr* or health or healthcare or occupational therap* or physiotherap* or physical therap* or clinical or surg* or radiolog* or obstetric* or gyn?ecolog* or orthodont* or An?esthesi* or Dermatolog* or Oncolog* or Rheumatolog* or Neurolog* or Patholog* or P?ediatric* or Cardiolog* or Urolog*) adj3 (student* or graduate* or undergraduate* or staff or personnel or practitioner* or clerk* or fellow* or internship* or residen* or educat* or train* or novice* or tutor*)).tw,id.
10. oror1-9
11. exp Computer Assisted Instruction or
12. internet or
13. exp social media or
14. computer mediated communication or
15. exp Computer Simulationor
16. simulation or
17. computer software or
18. computer applications or
19. computer games or
20. simulation games or
21. websites or
22. distance education or
23. learning management systems or
24. computers or
25. instructional media or
26. teaching machines or
27. microcomputers or
28. cellular phones or
29. exp audiovisual instruction or
30. educational audiovisual aids or
31. telemedicine or
32. telecommunications media or
33. teleconferencing or
34. ((computer* or digital* or hybrid or blended or mixed mode or distance or remote* or electronic or mobile or online* or interactiv* or multimedia or internet or web* or virtual* or game* or gaming or Videogame* or Videogaming) adj3 (classroom* or course* or educat* or instruct* or learn* or lecture* or simulat* or train* or teach* or tutor* or platform*)).tw,id.
35. (Simulat* adj3 (course* or educat* or instruct* or learn* or train* or teach* or platform* or high-fidelity)).tw,id.
36. e-learn*.tw,id.
37. elearn*.tw,id.
38. m-learn*.tw,id.
39. mlearn*.tw,id.

40. smartphone*.tw,id.
41. smart-phone*.tw,id.
42. ((mobile or cell) adj2 phone*).tw,id.
43. iphone*.tw,id.
44. android*.tw,id.
45. ipad*.tw,id.
46. Personal digital assistant*.tw,id.
47. handheld computer*.tw,id.
48. Mobile App?.tw,id.
49. Mobile Application?.tw,id.
50. webcast*.tw,id.
51. webinar*.tw,id.
52. flipped classroom*.tw,id.
53. Serious game*.tw,id.
54. Serious gaming.tw,id.
55. Patient Simulat*.tw,id.
56. Virtual patient*.tw,id.
57. ((educat* or instruct* or learn* or simulat* or train* or teach*) adj3 technolog*).tw,id.
58. Massive Open Online Course?.tw,id.
59. Mooc?.tw,id.
60. (Canvas network or Coursera or Coursesites or edx or Futurelearn or iversity or miriada x or moodle or novoed or openlearning or open2study or plato or spoc or udacity or pingpong).tw,id.
61. oror11-60
62. 10 and 61
63. educationor
64. exp continuing education or
65. higher education or
66. postgraduate training or
67. teaching or
68. teaching methods or
69. learning or
70. curriculum or
71. curriculum development or
72. educat*.tw,id.
73. learn*.tw,id.
74. train*.tw,id.
75. instruct*.tw,id.
76. teach*.tw,id.
77. oror63-76
78. exp Health Personnelor
79. clinicians or
80. exp psychologists or
81. therapists or
82. Physician*.tw,id.

83. Doctor*.tw,id.
84. Nurs*.tw,id.
85. Surg*.tw,id.
86. Health Personnel.tw,id.
87. healthcare professional*.tw,id.
88. radiolog*.tw,id.
89. dentist*.tw,id.
90. Pharmacist*.tw,id.
91. Hospital Administrator*.tw,id.
92. Podiatr*.tw,id.
93. Psycholog*.tw,id.
94. Psychiatr*.tw,id.
95. An?esthesi*.tw,id.
96. Clinician*.tw,id.
97. Dermatolog*.tw,id.
98. General practioner*.tw,id.
99. Cardiolog*.tw,id.
100. Oncolog*.tw,id.
101. Rheumatolog*.tw,id.
102. Neurolog*.tw,id.
103. Patholog*.tw,id.
104. P?ediatric*.tw,id.
105. Physiotherap*.tw,id.
106. Physical therap*.tw,id.
107. Occupational therap*.tw,id.
108. dieti?ian*.tw,id.
109. Dietetic*.tw,id.
110. midwi?e*.tw,id.
111. nutrition*.tw,id.
112. orthopti*.tw,id.
113. obstetric*.tw,id.
114. gyn?ecolog*.tw,id.
115. orthodont*.tw,id.
116. Urolog*.tw,id.
117. oror78-116
118. exp paramedical sciences or
119. evidence based practice or
120. exp medical sciences or
121. exp psychology or
122. exp neuroimaging or
123. oror118-122
124. 117 or 123
125. 61 and 77 and 124
126. perceptual motor processes or
127. perceptual motor coordination or
128. exp perceptual motor learning or

129. motor skills or
130. ((psychomotor or procedural or technical) adj3 skill*).tw,id.
131. (psychomotor adj3 performance).tw,id.
132. oror126-131
133. 10 and 132
134. 62 or 125 or 133
135. limit 134 to yr="1990 -Current"

SR: ERIC (Ovid) search strategy

1. exp medical education or not veterinary education or
2. allied health occupations education or
3. medical students or
4. premedical students or
5. nursing students or
6. ((medic* or premedic* or dent* or laborator* or predent* or midwi?e* or nurs* or nutrition* or orthop* or podiat* or pharmac* or psycholog* or psychiatr* or health or healthcare or occupational therap* or physiotherap* or physical therap* or clinical or surg* or radiolog* or obstetric* or gyn?ecolog* or orthodont* or An?esthesi* or Dermatolog* or Oncolog* or Rheumatolog* or Neurolog* or Patholog* or P?ediatric* or Cardiolog* or Urolog*) adj3 (student* or graduate* or undergraduate* or staff or personnel or practitioner* or clerk* or fellow* or internship* or residen* or educat* or train* or novice* or tutor*)).tw.
7. oror1-6
8. exp Computer uses in education or
9. exp internet or
10. Computer Simulation or
11. computer software or
12. computer interfaces or
13. video games or
14. computer games or
15. Web Browsersor
16. distance education or
17. exp computers or
18. exp handheld devices or
19. exp audiovisual aids or
20. educational technology or
21. electronic mail or
22. telecommunications or
23. exp teleconferencing or
24. electronic learning or
25. Computer Mediated Communicationor
26. Blended Learningor
27. ((computer* or digital* or hybrid or blended or mixed mode or distance or remote* or electronic or mobile or online* or interactiv* or multimedia or internet or web* or virtual* or game* or gaming or

Videogame* or Videogaming) adj3 (classroom* or course* or educat* or instruct* or learn* or lecture* or simulat* or train* or teach* or tutor* or platform*)).tw.
28. (Simulat* adj3 (course* or educat* or instruct* or learn* or train* or teach* or platform* or high-fidelity)).tw.
29. e-learn*.tw.
30. elearn*.tw.
31. m-learn*.tw.
32. mlearn*.tw.
33. smartphone*.tw.
34. smart-phone*.tw.
35. ((mobile or cell) adj2 phone*).tw.
36. iphone*.tw.
37. android*.tw.
38. Personal digital assistant*.tw.
39. handheld computer*.tw.
40. Mobile App?.tw.
41. Mobile Application?.tw.
42. webcast*.tw.
43. webinar*.tw.
44. flipped classroom*.tw.
45. Serious game*.tw.
46. Serious gaming.tw.
47. Patient Simulat*.tw.
48. Virtual patient*.tw.
49. ((educat* or instruct* or learn* or simulat* or train* or teach* or interactiv*) adj2 technolog*).tw.
50. Massive Open Online Course?.tw.
51. Mooc?.tw.
52. (Canvas network or Coursera or Coursesites or edx or Futurelearn or iversity or miriada x or moodle or novoed or openlearning or open2study or plato or spoc or udacity or pingpong).tw.
53. oror8-52
54. 7 and 53
55. educationor
56. exp Higher Educationor
57. exp Continuing Educationor
58. teaching methods or
59. Learningor
60. inservice education or
61. Staff Development or
62. curriculum or
63. curriculum development or
64. educat*.tw.
65. learn*.tw.
66. train*.tw.

67. instruct*.tw.
68. teach*.tw.
69. oror55-68
70. exp Health Personnel or
71. physician*.tw.
72. doctor*.tw.
73. nurs*.tw.
74. surg*.tw.
75. health personnel.tw.
76. healthcare professional*.tw.
77. radiolog*.tw.
78. dentist*.tw.
79. Pharmacist*.tw.
80. Hospital Administrator*.tw.
81. Podiatr*.tw.
82. Psychiatr*.tw.
83. Psycholog*.tw.
84. An?esthesi*.tw.
85. Clinician*.tw.
86. Dermatolog*.tw.
87. General practioner
88. Cardiolog*.tw.
89. Oncolog*.tw.
90. Rheumatolog*.tw.
91. Neurolog*.tw.
92. Patholog*.tw.
93. P?ediatric*.tw.
94. Physiotherap*.tw.
95. Physical therap*.tw.
96. Occupational therap*.tw.
97. dieti?ian*.tw.
98. Dietetic*.tw.
99. midwi?e*.tw.
100. nutrition*.tw.
101. orthopti*.tw.
102. obstetric*.tw.
103. gyn?ecolog*.tw.
104. orthodont*.tw.
105. Urolog*.tw.
106. oror70-105
107. exp Health Occupationsor
108. exp Medicine or not Veterinary Medicine or
109. optometry or
110. psychology or
111. specialization or
112. Radiograph*.tw.

113. oror107-112
114. 106 or 113
115. 53 and 69 and 114
116. psychomotor skills or
117. Perceptual Motor Coordinationor
118. ((psychomotor or procedural or technical) adj3 skill*).tw.
119. (psychomotor adj3 performance).tw.
120. oror116-119
121. 7 and 120
122. 54 or 115 or 121
123. limit 122 to yr="1990 -Current"

SR: CINAHL (EBSCO) search strategy

S1 (MH "Education, Health Sciences+")

S2 (MH "Education, Premedical")

S3 (MH "Education, Clinical+")

S4 (MH "Students, Health Occupations+" OR MH "Students, Pre-Nursing")

S5 TI((medic* or premedic* or dent* or laborator* or predent* or midwife or midwives or nurs* or nutrition* or orthop* or podiat* or pharmac* or psycholog* or psychiatr* or health or healthcare or "occupational therap*" or physiotherap* or "physical therap*" or clinical or surg* or radiolog* or obstetric* or gynecolog* or gynaecolog* or orthodont* or anesthesi*or anaesthesi* or Dermatolog* or Oncolog* or Rheumatolog* or Neurolog* or Patholog* or pediatric* or paediatric* or Cardiolog* or Urolog*) N3 (student* or graduate* or undergraduate* or staff or personnel or practitioner* or clerk* or fellow* or internship* or residen* or educat* or train* or novice* or tutor*)) OR AB ((medic* or premedic* or dent* or laborator* or predent* or midwife or midwives or nurs* or nutrition* or orthop* or podiat* or pharmac* or psycholog* or psychiatr* or health or healthcare or "occupational therap*" or physiotherap* or "physical therap*" or clinical or surg* or radiolog* or obstetric* or gynecolog* or gynaecolog* or orthodont* or anesthesi* or anaesthesi* or Dermatolog* or Oncolog* or Rheumatolog* or Neurolog* or Patholog* or pediatric* or paediatric* or Cardiolog* or Urolog*) N3 (student* or graduate* or undergraduate* or staff or personnel or practitioner* or clerk* or fellow* or internship* or residen* or educat* or train* or novice* or tutor*))

S6 S1 OR S2 OR S3 OR S4 OR S5

S7 (MH "Computer Assisted Instruction")

S8 (MH "Internet" OR MH "Social Media" OR MH "World Wide Web Applications")

S9 (MH Virtual Reality)

S10 (MH "Software")

S11 (MH "User-Computer Interface")

S12 (MH "Video Games")

S13 (MH "Web Browsers")

S14 (MH "Education, Non-Traditional")

S15 (MH "Videoconferencing")

S16 (MH "Microcomputers+")

S17 (MH "Educational Technology")

S18 (MH "Simulations+")

S19 (MH "Models, Anatomic+")

S20 (MH "Audiovisuals")

S21 (MH "Electronic Mail")

S22 (MH "Telehealth+")

S23 (MH "Telecommunications")

S24 TI((computer* or digital* or hybrid or blended or "mixed mode" or distance or remote* or electronic or mobile or online* or interactiv* or multimedia or internet or web* or virtual* or game* or gaming or videogame* or videogaming) N3 (classroom* or course* or educat* or instruct* or learn* or lecture* or simulat* or train* or teach* or tutor* or platform*)) OR AB ((computer* or digital* or hybrid or blended or "mixed mode" or distance or remote* or electronic or mobile or online* or interactiv* or multimedia or internet or web* or virtual* or game* or gaming or videogame* or videogaming) N3 (classroom* or course* or educat* or instruct* or learn* or lecture* or simulat* or train* or teach* or tutor* or platform*))

S25 TI(Simulat* N3 (course* or educat* or instruct* or learn* or train* or teach* or platform* or "high-fidelity")) OR AB (Simulat* N3 (course* or educat* or instruct* or learn* or train* or teach* or platform* or "high-fidelity"))

S26 TI e-learn* OR AB e-learn*

S27 TI elearn* OR AB elearn*

S28 TI m-learn* OR AB m-learn*

S29 TI mlearn* OR AB mlearn*

S30 TI smartphone* OR AB smartphone*

S31 TI smart-phone* OR AB smart-phone*

S32 TI (((mobile or cell) N2 phone*)) OR AB (((mobile or cell) N2 phone*))

S33 TI iphone* OR AB iphone*

S34 TI android* OR AB android*

S35 TI ipad* OR AB ipad*

S36 TI "Personal digital assistant*" OR AB "Personal digital assistant*"

S37 TI "handheld computer*" OR AB "handheld computer*"

S38 TI "Mobile App" OR AB "Mobile App" OR TI "Mobile Apps" OR AB "Mobile Apps"

S39 TI "Mobile Application" OR AB "Mobile Application" OR TI "Mobile Applications" OR AB "Mobile Applications"

S40 TI webcast* OR AB webcast*

S41 TI webinar* OR AB webinar*

S42 TI "flipped classroom*" OR AU "flipped classroom*"

S43 TI "serious game*" OR AB "serious game*"

S44 TI "serious game*" OR AB "serious game*"

S45 TI "serious gaming" OR AB "serious gaming"

S46 TI "patient simulat*" OR AB "patient simulat*"

S47 TI "virtual patient*" OR AB "virtual patient*"

S48 TI((educat* or instruct* or learn* or simulat* or train* or teach* or interactiv*) N2 technolog*) OR AB ((educat* or instruct* or learn* or simulat* or train* or teach* or interactiv*) N2 technolog*)

S49 TI "Massive Open Online Course*" OR AB "Massive Open Online Course*"

S50 TI Mooc OR AB Mooc OR TI Moocs OR AB Moocs

S51 TI (("Canvas network" or Coursera or Coursesites or edx or Futurelearn or iversity or "miriada x" or moodle or novoed or openlearning or open2study or plato or spoc or udacity or pingpong)) OR AB (("Canvas network" or Coursera or Coursesites or edx or Futurelearn or iversity or "miriada x" or moodle or novoed or openlearning or open2study or plato or spoc or udacity or pingpong))

S52 S7 OR S8 OR S9 OR S10 OR S11 OR S12 OR S13 OR S14 OR S15 OR S16 OR S17 OR S18 OR S19 OR S20 OR S21 OR S22 OR S23 OR S24 OR S25 OR S26 OR S27 OR S28 OR S29 OR S30 OR S31 OR S32 OR S33 OR S34 OR S35 OR S36 OR S37 OR S38 OR S39 OR S40 OR S41 OR S42 OR S43 OR S44 OR S45 OR S46 OR S47 OR S48 OR S49 OR S50 OR S51

S53 S6 AND S52

S54 (MW "ed")

S55 (MH "Education")

S56 (MH "Teaching")

S57 (MH "Learning")

S58 (MH "Staff Development+" OR MH "Refresher Courses")

S59 (MH "Curriculum" OR MH "Curriculum Development")

S60 TI educat* OR AB educat*

S61 TI learn* OR AB learn*

S62 TI train* OR AB train*

S63 TI instruct* OR AB instruct*

S64 TI teach* OR AB teach*

S65 S54 OR S55 OR S56 OR S57 OR S58 OR S59 OR S60 OR S61 OR S62

OR S63 OR S64
S66 (MH "Health Personnel")
S67 (MH "Allied Health Personnel+")
S68 (MH "Alternative Health Personnel+")
S69 (MH "Nurses+")
S70 (MH "Personnel, Health Facility+")
S71 (MH "Pharmacists")
S72 (MH "Midwives+")
S73 (MH "Physicians+")
S74 (MH "Operating Room Personnel+")
S75 TI physician* OR AB physician*
S76 TI doctor* OR AB doctor*
S77 TI nurs* OR AB nurs*
S78 TI surg* OR AB surg*
S79 TI "health personnel*" OR AB "health personnel*"
S80 TI "healthcare professional*" OR AB "healthcare professional*"
S81 TI radiolog* OR AB radiolog*
S82 TI dentist* OR AB dentist*
S83 TI pharmacist* OR AB pharmacist*
S84 TI "hospital administrator*" OR AB "hospital administrator*"
S85 TI podiatr* OR AB podiatr*
S86 TI psycholog* OR AB psycholog*
S87 TI psychiatr* OR AB psychiatr*
S88 TI anesthesi* OR AB anesthesi* OR TI anaesthesi* OR AB anaesthesi*
S89 TI clinician* OR AB clinician*
S90 TI dermatolog* OR dermatolog*
S91 TI "General practioner*" OR AB "General practioner*"
S92 TI cardiolog* OR AB cardiolog*
S93 TI oncolog* OR AB oncolog*
S94 TI rheumatolog* OR AB rheumatolog*
S95 TI neurolog* OR AB neurolog*
S96 TI patholog* OR AB patholog*
S97 TI pediatric* OR AB pediatric* OR TI paediatric* OR AB paediatric*
S98 TI physiotherap* OR AB physiotherap*
S99 TI "physical therap*" OR AB "physical therap*"
S100 TI "occupational therap*" OR AB "occupational therap*"
S101 TI dietician* OR AB dietician* OR TI dietitian* AB dietitian*
S102 TI dietetic* OR AB dietetic*

S103 TI midwife OR AB midwife OR TI midwives OR AB midwives

S104 TI nutrition* OR AB nutrition*

S105 TI orthopti* OR AB orthopti*

S106 TI obstetric* OR AB obstetric*

S107 TI gynecolog* OR AB gynecolog* OR TI gynaecolog* OR AB gynaecolog*

S108 TI orthodont* OR AB orthodont*

S109 TI urolog* OR AB urolog*

S110 S66 OR S67 OR S68 OR S69 OR S70 OR S71 OR S72 OR S73 OR S74 OR S75 OR S76 OR S77 OR S78 OR S79 OR S80 OR S81 OR S82 OR S83 OR S84 OR S85 OR S86 OR S87 OR S88 OR S89 OR S90 OR S91 OR S92 OR S93 OR S94 OR S95 OR S96 OR S97 OR S98 OR S99 OR S100 OR S101 OR S102 OR S103 OR S104 OR S105 OR S106 OR S107 OR S108 OR S109

S111 (MH "Health Occupations")

S112 (MH "Allied Health Professions")

S113 (MH "Biomedical Engineering")

S114 (MH "Chiropractic")

S115 (MH "Dentistry+")

S116 (MH "Professional Practice, Evidence-Based+")

S117 (MH "Medicine+")

S118 (MH "Nursing Care+")

S119 (MH "Audiology") OR (MH "Dental Hygiene") OR (MH "Dietetics") OR (MH "Emergency Medical Technicians") OR (MH "Medical Assisting") OR (MH "Physician Assistants") OR (MH "Public Health Nutrition") OR (MH "Speech-Language Pathology") OR (MM "Technology, Radiologic")

S120 (MH "Optometry") OR (MH "Podiatry") OR (MH "Serology") OR (MH "Specialization")

S121 (MH "Pharmacy and Pharmacology+")

S122 (MH "Radiography+")

S123 (MH "Surgery, Operative+")

S124 (MH "Midwifery+")

S125 S111 OR S112 OR S113 OR S114 OR S115 OR S116 OR S117 OR S118 OR S119 OR S120 OR S121 OR S122 OR S123 OR S124

S126 S110 OR S125

S127 S52 AND S65 AND S126

S128 (MH "Psychomotor Performance") OR (MH "Motor Skills")

S129 (MH "Psychomotor Performance") OR (MH "Motor Skills")

S130 TI (((psychomotor or procedural or technical) N3 skill*)) OR AB (((psychomotor or procedural or technical) N3 skill*))

S131 TI (psychomotor N3 performance) OR AB (psychomotor N3 performance)
S132 S128 OR S129 OR S130 OR S131
S133 S6 AND S132
S134 S53 OR S127 OR S133
S135 S53 OR S127 OR S133

Limiters - Published Date: 19900101-20151231

SR: Web of Science Core Collection (Thomas Reuters) search strategy

#1 TS=(((medic* or premedic* or dent* or laborator* or predent* or midwi*e* or nurs* or nutrition* or orthop* or podiat* or pharmac* or psycholog* or psychiatr* or health or healthcare or "occupational therap*" or physiotherap* or "physical therap*" or clinical or surg* or radiolog* or obstetric* or gyn*ecolog* or orthodont* or An*esthesi* or Dermatolog* or Oncolog* or Rheumatolog* or Neurolog* or Patholog* or P*ediatric* or Cardiolog* or Urolog*) NEARor3 (student* or graduate* or undergraduate* or staff or personnel or practitioner* or clerk* or fellow* or internship* or residen* or educat* or train* or novice* or tutor*)))
#2 TS= (((computer* or digital* or hybrid or blended or "mixed mode" or distance or remote* or electronic or mobile or online* or interactiv* or multimedia or internet or web* or virtual* or game* or gaming or Videogame* or Videogaming) NEARor3 (classroom* or course* or educat* or instruct* or learn* or lecture* or simulat* or train* or teach* or tutor* or platform*)))
#3 TS= (((Simulat*) NEARor3 (course* or educat* or instruct* or learn* or train* or teach* or platform* or "high-fidelity"))
#4 TS= (((educat* or instruct* or learn* or simulat* or train* or teach* or interactiv*) NEARor2 (technolog*)))
#5 TS=("Canvas network" or Coursera or Coursesites or edx or Futurelearn or iversity or "miriada x" or moodle or novoed or openlearning or open2study or plato or spoc or udacity or pingpong or "Massive Open Online Course*" or Mooc or Moocs or e-learn* or elearn* or m-learn* or mlearn* or smartphone* or smart-phone* or iphone* or android* or ipad* or "personal digital assistant*" or "handheld computer*" or "mobile app" or "mobile apps" or "mobile application" or "mobile applications" or webcast* or webinar* or "flipped classroom*" or "serious game*" or "serious gaming" or "patient simulat*" or "virtual patient*" or ((mobile or cell) adj2 phone*))
#6 #5 OR #4 OR #3 OR #2
#7 #6 AND #1
#8 TS=((educat* or teach* or learn* or train* instruct*))
#9 TS=((physician* or doctor* or nurs* or surg* or "health personnel" or "healthcare professional*" or radiolog* or dentist* or pharmacist* or "hospital administrator*" or podiatr* or psycholog* or psychiatr* or

an*esthesi* or clinician* or dermatolog* or “general practioner*” or cardiolog* or oncolog* or rheumatolog* or neurolog* or patholog* or p*ediatric* or physiotherap* or “physical therap*” or “occupational therap*” dieti*ian* or dietetic* or midwi*e* or nutrition* or orthopti* or obstetric* or gyn*ecolog* or orthodont* or urolog*))
#10 #9 AND #8 AND #6
#11 TS=(((psychomotor or procedural or technical) NEARor3 (skill*))) OR TS=(((psychomotor) NEARor3 (performance))
#12 #11 AND #1
#13 #12 OR #10 OR #7
#14 #12 OR #10 OR #7
Refined by: **PUBLICATION YEARS:** (2013 OR 2001 OR 2012 OR 1998 OR 2014 OR 1999 OR 2011 OR 1997 OR 2010 OR 1996 OR 2009 OR 1995 OR 2008 OR 1994 OR 2007 OR 1993 OR 2006 OR 2015 OR 2005 OR 1992 OR 2004 OR 1991 OR 2003 OR 1990 OR 2002 OR 2000)

APPENDIX I C: CHARACTERISTICS OF INCLUDED STUDIES

Alfieri 2012

Methods	• Design: Randomised controlled trial. • Recruitment method: Radiation oncology residents from the three postgraduate radiation oncology programs in Quebec were recruited by extending an invitation to participate in the study during their academic half day • Randomization: Yes, method not described • Speciality: Radiology • Setting: Hospital • Country: Canada
Participants	• Type of participants: Radiation oncology residents. • Inclusion criteria: All PGY-2 to PGY-5 radiation oncology residents were eligible for the study. • Exclusion criteria: 10 residents, PGY-1 residents and fellows were excluded. • No of participants randomised: 36 residents.
Interventions	• Intervention: The web-based module targeted both junior and senior radiation oncology residents; the content was divided into four chapters, each representing different tumour sites in the female genital system: uterus, uterine cervix, vagina, and vulva. Learning objectives were established for each chapter and were subdivided into two sections: (1) normal anatomy, including blood supply, nerve supply, and lymphatic drainage, and (2) staging and practice cases with exercises. • Control: Control group relied on traditional methods to acquire knowledge.
Outcomes	• Logins, pre and post-test knowledge scores. • Intervention group's pre-test and post-test mean scores were 35 % and 52 %, respectively, and those of the control group were 37 % and 42 %, respectively. • The mean improvement in test scores was 17 % ($P < 0.05$) for the intervention group and 5 % (P = not significant) for the control group. • Retrospective pre-test and posttest surveys showed a statistically significant change on all measured module

	objectives.
Notes	• Study aim: The study had two phases, phase 1 reports on the development of the eLearning module, phase 2 evaluates whether the web-based learning module can be used as an adjunct to conventional learning tools and does it enhance knowledge and technical skills of radiation oncology residents in the realm of gynaecologic malignancies. • Pedagogical approach used: Individual eLearning, the learning module included case-based scenarios • Was a learning management system used? No • Journal: International Journal of Radiation Oncology • Year of publication: 2012 • Income status of country: High-income • Source of funding: The development phase of this study was supported by an unrestricted grant from Philips Medical Systems Canada. • Conflict of interest: None

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	36 residents were stratified by residency level and randomised to either the control group or the intervention group, randomisation method not described (pg. e576, evaluation phase, level two: student learning).
Allocation concealment (selection bias)	Unclear risk	No details given to enable judgement.
Blinding of outcome assessment (detection bias)	Unclear risk	No details given to enable judgement.
Incomplete outcome data (attrition bias)	Low risk	No missing outcome data reported.

Selective reporting (reporting bias)	Low risk	Authors reported all outcomes mentioned in the methods section.
Other bias	Unclear risk	Comparison of demographic characteristics of the groups is presented in table 1. Groups similar among the variables compares, however statistical comparison of the groups were not done (pg. e578).

Ali 2013

Methods	• Design: Randomised controlled trial. • Recruitment method: members of the first year family practice medicine resident class at the University of Toronto who had all completed the same standard undergraduate medical curriculum were invited to participate in the project. • Randomization: Yes, method not described. • Speciality: Primary care. • Setting: University • Country: Canada
Participants	• Type of participants: First-year family practice residents • Inclusion criteria: Not stated • Exclusion criteria: Not stated • No of participants randomised: 32 residents
Interventions	• Intervention: Telemedicine group (2 days), for the telemedicine course, 2 advance trauma life support (ATLS) instructors and a coordinator, with all skill station equipment including the TraumaMan surgical skills manikin and 2 cameras, were located at the designated telemedicine group site and 2 instructors were located at the telemedicine transmission port. • Control: Standard ATLS course (2 days), for the standard ATLS course, the usual 7 faculty and course coordinators participated with lectures and skills stations on site. The lecture schedules for both courses were as listed in the ATLS manual, and all lectures for the telemedicine group were delivered by the 2 instructors at the telemedicine transmission port.
Outcomes	• MCQ performance, course feedback, participants assessment of the educational value of the course and

	evaluation of skill station performance by instructors. • Knowledge: measured using MCQs; Skills: assessed by the instructor; Satisfaction: measured using questionnaire • Knowledge scores (MCQ performance results): Intervention: n=16, mean: 85.89, 95% CI: 82.03 to 89.76, estimated SD: 6.7; Control: n=16, mean:89.69, 95% CI: 86.94 to 92.43, estimated SD: 5.2 • Satisfaction: Patient assessment of the educational course: Intervention: n=14, mean: 3.91, SD: 0.30; Control: n=16, mean: 3.67, SD: 0.50. • Overall skill station by instructors: Intervention: n=14, mean: 3.12, SD: 0.5: Control: n=16, mean:3.00, SD: 0.39
Notes	• Study aim: The project assesses the potential of applying telemedicine technology to teaching ATLS by distance learning • Pedagogical approach used: Collaborative learning, ATLS instructors, coordinator and TraumaMan (Surgical simulator) was involved in the training. • Was a learning management system used? No • Journal: Journal of Surgical Education • Year of publication: 2013 • Income status of country: High income • Source of funding: None stated • Conflict of interest: None stated

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Members of the first year family practice medicine resident class at the University of Toronto who had all completed the same standard undergraduate medical curriculum were invited to participate in the project. From the list of potential participants, 32 students were randomly chosen and further randomly assigned to either a standard 2-day ATLS course (control group) or a course involving tele-medicine teaching (telemedicine group) (pg. 259, materials and methods). Randomisation method not described.
Allocation concealment (selection bias)	Unclear risk	No details given to enable judgement.
Blinding of outcome assessment (detection bias)	Unclear risk	No details given to enable judgement.
Incomplete outcome data (attrition bias)	Low risk	No drop outs. Table 4 shows the means and standard deviation (SD) of the percentage scores in the post ATLS test for both groups, with the 95% confidence intervals. In each group there was 1 student that did not reach the 80 % pass mark and they both passed on a remedial written test (pg. 259, results).
Selective reporting (reporting bias)	Low risk	Authors reported all outcomes mentioned in the methods section.
Other bias	Unclear risk	Baseline comparison of the groups not done.

Allison 2005

Methods	• Design: Cluster randomised controlled trial. • Recruitment method: Recruitment occurred in states where the study managed care organization had an active presence and consistently collected chlamydia screening rates. Recruitment first occurred at the office level (Phase 1) and then at the physician level (Phase 2). In Phase 1, all potentially eligible offices were invited to participate via facsimile; an office was designated as "recruited" when one of its physicians declared intent to participate. In Phase 2, an active Internet link to the intervention module was delivered by e-mail to physicians recruited in Phase 1. Physicians were designated as "participating" when they first engaged the Internet intervention. • Randomization: Yes, pseudo random number generator was used. • Speciality: Primary care. • Setting: Primary care • Country: United States.
Participants	• Type of participants: Primary care physicians. • Inclusion criteria: Eligible offices had (1) ≥ 20 patients at risk for chlamydia infection as defined by the NCQA in the Health Plan Employer Data and Information Set (HEDIS) 26; and (2) at least one primary care physician internal medicine, family medicine/general practice, paediatrics) with Internet access. • Exclusion criteria: Not stated. • No of clusters / participants randomised: 191 physician offices, 209 physicians.
Interventions	• Intervention: Multicomponent internet CME (mCME) on women's health. The intervention consisted of four mCME modules, released sequentially every 3 months. The modules emphasized that (1) young, sexually active women are at high risk for asymptomatic infection that may lead to future serious health consequences; (2) recently developed urine-based screening allows diagnosis without a pelvic examination; and (3) infection may be treated easily and effectively. All modules contained printable patient education material. • Control: Flat-text, internet-based CME on women's

	health.
Outcomes	• HEDIS chlamydia screening rates for the pre-intervention (2000) and post-intervention (2002) periods. • Pre-intervention screening rates for the intervention and comparison offices were 18.9 % and 16.2 % (P = 0.135). Post-intervention screening rates for the intervention and comparison offices were 15.5 % and 12.4 %, respectively (P = 0.044, adjusting for baseline performance).
Notes	• Study aim: To test a multicomponent CME (mCME) intervention for increasing chlamydia screening for at-risk women in the managed care setting. • Pedagogical approach used: Individual eLearning, with case-based learning modules, self-instructional materials and performance feedback. • Was a learning management system used? No. • Journal: American Journal of Preventive Medicine. • Year of publication: 2000. • Income status of country: High income. • Source of funding: This project was supported by the Agency for Healthcare Research and Quality (grant HS11124). • Conflict of interest: None.

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	High risk	Primary care offices (n = 191) participating in the study managed care organization were randomised to an intervention or comparison group (Table 1). Physicians in the intervention group received mCME modules and physicians in the comparison group received flat-text, Internet-based CME modules on women's health (pg. 286, methods). Using a pseudo–random number generator, offices were allocated equally to the intervention or comparison group in blocks of six when the physician first logged on to the Internet (pg. 287, allocation to study arm).
Allocation concealment (selection bias)	Unclear risk	No details given to enable judgement.
Blinding of outcome assessment (detection bias)	Unclear risk	No details given to enable judgement.
Incomplete outcome data (attrition bias)	Low risk	Of all eligible offices (n = 978), 325 (33 %) were recruited (Figure 1, Phase I). From the recruited offices, 191 (59 %) participated. No drop outs reported post randomisation (pg. 287, results).
Selective reporting (reporting bias)	Low risk	Authors reported all outcomes mentioned in the methods section.
Other bias	Low risk	Office and physician characteristics did not differ significantly by study group (pg. 287, results). This signifies baseline similarity.

Barthelemy 2017

Methods	• Design: Randomised controlled trial. • Recruitment method: Not stated. • Randomization: Method not stated • Speciality: Emergency medicine • Setting: Hospital • Country: France
Participants	• Type of participants: Emergency department residents • Inclusion criteria: First-year and second-year ED residents. • Exclusion criteria: Not stated. • No of participants randomised:39 residents
Interventions	• Intervention: eLearning for ECG interpretation • Control: Lecture for ECG interpretation
Outcomes	• .Skills: eLearning group (n=19), precourse: 42.1% (34.8-49.4), SD: 15.15Lecture-based group (n=20), precourse: 37.5% (30.7-44.2),SD:14.42,59.5 P=0.42eLearning group (n=19), postcourse: 59.5% (51.8-67.1), SD:15.87Lecture-based group (n=20), postcourse: 51% (42.4-59.6),SD:18.38 P=0.14
Notes	• Study aim: To compare two teaching modalities to improve the ECG interpretation skills of ED residents: e-learning and lecture-based courses. • Pedagogical approach used: Not stated • Was a learning management system (LMS) used? Not stated. • Journal: European Journal of Emergency Medicine. • Year of publication: 2017 • Income status of country: High income • Source of funding: Not stated

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	ED residents were randomly assigned to the e-learning group or the lecture-based course using computer generated random allocation sequence built in R. Pg. 150, participants and methods.
Allocation concealment (selection bias)	Unclear risk	No details given to enable judgement.
Blinding of outcome assessment (detection bias)	Unclear risk	No details given to enable judgement.
Incomplete outcome data (attrition bias)	Low risk	No drop outs reported post randomisation.
Selective reporting (reporting bias)	Unclear risk	Authors reported all outcomes mentioned in the methods section.
Other bias	Unclear risk	Baseline comparison not done

Bell 2000

Methods	• Design: Randomised controlled trial. • Recruitment method: We recruited residency programs in family and internal medicine at four universities. A total of 5 family medicine and 7 internal medicine programs agreed to participate. • Randomization: Yes, method not described. • Speciality: Family and internal medicine. • Setting: University. • Country: United States.
Participants	• Type of participants: Family and internal medicine residents (1st-3rd year residents). • Inclusion criteria: Age 21-80 years, Left ventricular ejection fraction < 0.40, Acute Myocardial infarction (AMI) survived the first three days after an MI. • Exclusion criteria: Concurrent use of ACE inhibitors,

	relative contraindication to the use of an angiotensin-converting-enzyme inhibitor or the need for such an agent to treat symptomatic congestive heart failure or systemic hypertension. • No of participants randomised: 162 residents.
Interventions	• Intervention: Self-Study Acceleration with Graphic Evidence (SAGE), a web-based tutorial system. • Control: Study from printed materials.
Outcomes	• Scores on multiple-choice knowledge tests, score gain per unit of study time, and ratings on a learner satisfaction scale. • Immediate post-test scores on a 20-point scale were similar in the SAGE and control groups (median score, 15.0 compared with 14.0; P > 0.2), but SAGE users spent less time studying (median, 27.0 compared with 38.5 minutes; P < 0.001) and therefore had greater learning efficiency (median score gain, 8.6 compared with 6.7 points per hour; P = 0.04). On a scale of 5 to 20, SAGE users were more satisfied with learning (median rating, 17.0 compared with 15.0; P < 0.001). After 4 to 6 months, knowledge had decreased to the same extent in the SAGE and control groups (median score, 12.0 compared with 11.0; P = 0.12).
Notes	• Study aim: To compare knowledge, learning efficiency, and learner satisfaction produced by self-study of World Wide Web-based and print-based guidelines for care after acute myocardial infarction. • Pedagogical approach used: Individual eLearning, with self-study materials and graphic models. • Was a learning management system used? Yes, web-based learning system, Self-study Acceleration with Graphic Evidence (SAGE). • Journal: Annals of Internal Medicine. • Year of publication: 2000. • Income status of country: High income. • Source of funding: Funded in part by a National Research Service Award (T32 PEI9 (IOl-O9) from the Health Resources and Services Administration of the U.S. Department of Health and Human Services. Additional project support was provided by the University of California. Ltis Angeles. Stein-

	Oppenheimei Fund and by the GTE Foundation through the University of California. Los Angeles, Center for Digital Innovation. Dr. Mangione was partially supported by the Rohert Wood Johnson Foundation as a Generalist Faculty Scholar (award no. 129250). • Conflict of interest: None stated.

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Letters were placed in residents' mailboxes inviting them to attend a 1.25-hour learning session in which they would be randomly assigned to study from computer or printed materials on the care of myocardial infarction (pg. 939, study sample). Randomisation method not described.
Allocation concealment (selection bias)	Unclear risk	No details given to enable judgement.
Blinding of outcome assessment (detection bias)	Unclear risk	No details given to enable judgement.
Incomplete outcome data (attrition bias)	Low risk	A total of 162 residents (30 % of the 541 residents in the 12 training programs) attended a session. Among non-participants, it was not logistically possible to differentiate those who truly declined to participate from those who were unable to participate because of vacations, "away" rotations, or immediate patient care responsibilities. (pg. 941, results). Through randomisation, 79 participants were assigned to the control group and 83 were assigned to the SAGE group (Figure 2). Because no participants used unassigned self-study materials, there was no crossover between groups. Three participants withdrew from the control group, and 1 withdrew from the SAGE group. Of these 4 participants, 1 withdrew because of post-call fatigue and

		3 withdrew because of immediate patient care demands. Therefore, 76 participants in the control group and 82 participants in the SAGE group completed the immediate post-test (pg. 941, results).
Selective reporting (reporting bias)	Low risk	Authors reported all outcomes listed in the methods section.
Other bias	Low risk	Baseline characteristics of participants in the two groups are not compared, however there no difference in pre-test knowledge scores between the groups (table 2, pg. 942).

Bell 2015

Methods	• Design: Randomised controlled trial • Recruitment method: A list of PCPs was compiled through an internet search. Physicians were then sent information about the study through faxes and flyers. Colleagues at clinics in two large health systems made recruitment appeals on our behalf. In Pennsylvania, PCPs were identified via the Pennsylvania Area Health Education Center, which sent personalized letters of invitation, recruitment flyers, and business reply postcards to prospective participants. The Pennsylvania state University (PSU) team sent recruitment materials to PCPs around the state. Across all sites, 121 PCPs were recruited between September 2011 and April 2013 (fig 1) (pg. 335, methods) • Randomization: Yes, method not described • Speciality: Primary care • Setting: University • Country: United States
Participants	• Type of participants: Community physicians • Inclusion criteria: MD or DO, English-speaking, and had Internet and e-mail access • Exclusion criteria: Not stated • No of participants randomised: 155 physicians
Interventions	• Intervention: Six-hour interactive web-based curriculum covering information about genetic testing, risk assessment, practice behaviours, and communication skills about screening for inherited breast cancer

	• Control: Participants in the control group read eight review articles from leading journals and an information sheet extracted from the National Cancer Institute website about the same topic.
Outcomes	• Clinical behaviours: Transcripts of visit discussions were coded for presence or absence of 69 topics relevant to inherited breast cancer. • Intervention physicians were more likely than controls to explore genetic counselling benefits (78.3 % versus 60.7 %, P = 0.048), encourage genetic counselling before testing (38.3 % versus 21.3 %, P = 0.048), ask about a family history of prostate cancer (25.0 % versus 6.6 %, P = 0.006), and report that a positive result indicated an increased risk of prostate cancer for male relatives (20.0 % versus 1.6 %, P = 0.001). • Intervention-group physicians were less likely than controls to ask about Ashkenazi heritage (13.3 % versus 34.4 %, P = 0.01) or to reply that they would get tested when asked, "What would you do?" (33.3 % versus 54.1 %, P = 0.03).
Notes	• Study aim: To evaluate the outcomes of an interactive web-based genetics curriculum versus text curriculum for primary care physicians. • Pedagogical approach used: Individual eLearning, interactive web-based curriculum with clinical patient cases and video vignettes that modelled physician communication. • Was a learning management system used? No. • Journal: Journal of General Internal Medicine • Year of publication: 2015. • Income status of country: High income • Source of funding: This research was supported by National Human Genome Research Institute grant 5-R01-HG005117 (M.S. Wilkes, PI). • Conflict of interest: None

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Each physician was randomly assigned to an intervention group (n = 60) or control group (n = 61) (pg. 336, methods). Randomisation method not described.
Allocation concealment (selection bias)	Unclear risk	No details given to enable judgement.
Blinding of outcome assessment (detection bias)	Unclear risk	No details given to enable judgement.
Incomplete outcome data (attrition bias)	High risk	Out of the participants randomised to intervention (n= 77) and control groups (n = 78), only 60 participants in the intervention and 61 participants in the control group completed the study. (pg. 335, fig 1). High drop-out rate of 22% (N=34)
Selective reporting (reporting bias)	Unclear risk	No details given to enable judgement.
Other bias	Low risk	No difference in physician characteristics by study group at baseline (table 1, pg. 337). Additionally, PCPs were told only that the SP would be used to evaluate the curriculum no mention was made of the clinical condition (breast cancer).” this may increase the performance bias.

Bello 2005

Methods	• Design: Randomised controlled trial • Recruitment method: The student population was recruited from the group of graduate physicians currently enrolled in the 4-year Residency Program in Anesthesiology and Intensive Care Medicine of the Catholic University Medical Center in Rome, Italy. Each resident received a written invitation to take part in the study, with a brief

	explanation of its purpose and methods. Participation was completely voluntary • Randomization: Yes, method not described • Speciality: Anesthesiology and Intensive care Medicine • Setting: University • Country: Italy
Participants	• Type of participants: Residents enrolled in Anesthesiology and Intensive care medicine • Inclusion criteria: Not stated • Exclusion criteria: Not stated • No of participants randomised: 56 residents
Interventions	• Intervention: The online course on airway management was set up using the Blackboard platform, a flexible program specifically designed for computer-based instruction. The platform allows access by teachers and students to all course materials from any computer connected to the Internet. The course could be individually accessed for a period of 36 hours. Students had access to a threaded forum; instructors were available 30 min at each session to clarify additional points with students. • Control: A traditional 5-h course on the principles and practice of airway management, which included lectures, slide projection, and dummy demonstrations. Lectures accompanied by computer projection of slides containing texts and images. The course was taught by four members of the teaching staff of the Department of Anesthesiology and Intensive Care Medicine, each with particular expertise in the field he covered
Outcomes	• Knowledge post-test scores, learner satisfaction • Knowledge gains in Group 2 were slightly, but not significantly, greater compared with Group 1 both in written (P = 0.228) and practical skills (P = 0.376) tests • Semi-quantitative ratings of learner satisfaction were significantly higher in the online group (P = 0.014)
Notes	• Study aim: To compare the effectiveness of traditional and online teaching methods for educating anesthesiology residents in the principles and practice of difficult airway management • Pedagogical approach used: Individual eLearning, which contained self-instructional slides, with video instructions

	provided for each procedure carried out by the instructor on dummies actual patients • Was a learning management system used? Yes, blackboard platform • Journal: Intensive care medicine • Year of publication: 2005 • Income status of country: High income • Source of funding: Not stated • Conflict of interest: None stated

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Two randomly selected groups, each containing 28 physicians enrolled from among residents in Anesthesiology and Intensive Care Medicine in Italy (pg. 547). Randomisation was done using a computer-generated blocked randomisation list stratified by sex and year of residency
Allocation concealment (selection bias)	Unclear risk	No details given to enable judgement
Blinding of outcome assessment (detection bias)	Unclear risk	No details given to enable judgement
Incomplete outcome data (attrition bias)	Low risk	The 56 residents who agreed to take part in the study represented 71 % of the 79 enrolled in the Residency program: 28 of the 41 (68 %) first- or second-year residents (beginners) and 28/38 (74 %) enrolled in the third or fourth year of the program (advanced). No attempt was made to determine the reasons for the other residents' refusal to participate in the study. All 56 participants completed the course (traditional or online) and all baseline and final tests, and all filled out questionnaires on learner satisfaction (pg. 549, results)
Selective reporting	Low risk	All outcomes of interest listed in the methods section have been reported

(reporting bias)		
Other bias	Low risk	Baseline characteristics of the two groups were not compared, however the results of baseline and final evaluations in Groups 1 and 2 are shown in Fig. 1. There were no significant differences between the baseline performances of the two groups on either the written (P = 0.249) or practical-skills test (P = 0.670) (pg. 550, results)

Bernstein 2013

Methods	• Design: Cluster randomised controlled trial • Recruitment method: Not stated • Randomization: Yes, method described • Speciality: Paediatrics • Setting: Hospital • Country: United States
Participants	• Type of participants: Paediatric residents • Inclusion criteria: Pediatric categorical residents from each participating training program were eligible if their continuity practice was enrolled in the Continuity Research Network (CORNET) and their practice site agreed to participate. Within the recruited programs, paediatric resident inclusion criteria included first or second postgraduate year levels of training • Exclusion criteria: Not stated • No of clusters / participants randomised: 27 programs with 208 paediatric residents
Interventions	• Intervention: Bright Futures Oral Health curriculum, the Bright Futures Oral Health curriculum consisted of 7 self-directed modules, each ranging in length from 20 to 35 minutes (Table 1), with each emphasizing specific Bright Futures and oral health concepts. Modules integrate audio streaming and video role-play, case exercises, reflective questions, and resources. Participants were able to complete the modules at any point in a 3- to 6-month period, and they were allowed to save their work and return at a later time. • Control: Active control group, the active control group

	completed a single 1-hour module addressing the identification and prevention of iron deficiency created by the American Academy of Pediatrics on PediaLink (http://pedialink.aap.org). The purpose of the active control group was to provide a standard of comparison for the effectiveness of an online curriculum.
Outcomes	• Knowledge was measured by self-report and multiple-choice questions, respectively. Clinical performance was measured with structured clinical observations, performed by trained faculty, of Bright Futures and oral health performance before and after intervention. • A total of 143 paediatric residents from 27 Continuity Research Network (CORNET) sites participated in the study. At a median of 3 months after intervention, the intervention group demonstrated significant improvement in general Bright Futures confidence (n = 128, F = 6.564, P = .012) and knowledge (n = 102, F = 5.296, P = .023), oral health confidence (n = 123, F = 15.220, P < .001), and clinical performance skills in oral health (n = 96, F = 11.315, P = .001) compared with the control group
Notes	• Study aim: to evaluate the effectiveness of an online health promotion curriculum on paediatric residents' confidence, knowledge, and clinical performance in Bright Futures and oral health practice • Pedagogical approach used: Individual eLearning, modules integrate audio streaming and video role-play, case exercises, reflective questions, and resources • Was a learning management system used? No • Journal: Academic Pediatrics • Year of publication: 2013 • Income status of country: High income • Source of funding: This study was supported by grant 5R40MC05267 from the Health Resources and Services Administration Maternal and Child Health Bureau, with additional support from the Academic Pediatric Association and the Department of Pediatrics at Children's Hospital at Dartmouth • Conflict of interest: None

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	This was a cluster randomised, controlled trial involving CORNET sites stratified into 2 groups on the basis of the number of participating residents (8 or fewer vs more than 8 residents). Sites were then randomised within each group to either the intervention or the active control groups by use of a random number table (pg134, study design).
Allocation concealment (selection bias)	Unclear risk	No details given to enable judgement.
Blinding of outcome assessment (detection bias)	Unclear risk	No details given to enable judgement.
Incomplete outcome data (attrition bias)	Unclear risk	Residents who completed phase 2 of the study did not differ from those who dropped out from phase 1. Dropouts were examined for differences in the demographic variables included in the study: gender, white or not, and resident year. A chi-square analysis revealed no significant difference between those who completed the program and those who dropped out (gender x^2 = .504 P = .521, white x^2 = 2.000 P = .631, resident year x^2 = .157 P = .183) (pg. 137, results).
Selective reporting (reporting bias)	Low risk	Outcome listed in the study protocol (ClinicalTrials.gov (NCT01406366) is presented in the manuscript.
Other bias	Low risk	Baseline characteristics of residents in the intervention and active control groups were comparable by age, gender, race, and resident year at the time of intervention (table 2).

Braido 2012

Methods	• Design: Randomised controlled trial. • Recruitment method: Participants were randomly enrolled to participate in this study at the Local Health Unit No. 3 of Genoa. • Randomization: Yes, method not described. • Speciality: General practice. • Setting: Hospital. • Country: Italy.
Participants	• Type of participants: general practitioners (GPs). • Inclusion criteria: Not stated. • Exclusion criteria: Not stated. • No of participants randomised: 60 GPs.
Interventions	• Intervention: CME / CPD program (five residential events + four short distance-learning refresher courses over one year). • Control: No training.
Outcomes	• The primary end-point of this study was the change in knowledge, which was assessed with the questionnaires administered at the end of each course. The secondary end-points were changes in patient management according to data from the Local Health Unit database. A pharmaco-economic assessment of these changes was carried out performing inter / intra-group comparisons and a cost minimization analysis. • Fourteen general practitioners (46.7 %) in the CME group reached the cut-off of 50 % attendance of the training courses. Knowledge improved significantly after training ($P < 0.001$, correct answers to key questions + 13 %). Training resulted in pharmaceutical cost containment (trained general practitioners + 0.5 % vs controls + 18.8 %) and greater attention to diagnosis and monitoring (increase in spirometry + 63.4 %, $P < 0.01$). • Hospital admissions: There were no significant differences in admissions between intervention and control groups. The rate of hospital episodes. • Re-consultation rates: There were no significant differences between intervention and control groups for reconsultation rates after an index consultation, expressed as reconsultations per 1000 registered patients, for

	respiratory tract infections (median difference (intervention−control) −0.65 (−1.69 to 0.55) at seven days; −1.33 (−2.12 to 0.74) at 14 days; and −2.32 (−4.76 to 1.95) at 31 days.
Notes	• Study aim: To assesses the effectiveness of a one-year continuing medical education / continuing professional development course for general practitioners, regarding the improvement in knowledge of ARIA and GINA guidelines and compliance with them in asthma management. • Pedagogical approach used: Individual eLearning. • Was a learning management system used? Yes, but not described in detail. • Journal: European Annals of Allergy and Clinical Immunology. • Year of publication: 2012. • Income status of country: High income. • Source of funding: The authors thank ARMIA (Associazione Ricerca Malattie Immunologiche e Allergiche), ASPADIRES (Associazione Pazienti Disturbi Respiratori nel Sonno) and FIMMG (Federazione Italiana Medici di Medicina Generale) for supporting the research. • Conflict of interest: None.

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	A group of 60 out of a total of 650 general practitioners (GPs; 9.2%) were randomly enrolled to participate in this study at the Local Health Unit No. 3 of Genoa. Thirty of these GPs were randomly allocated to the CME / CPD program, while the other 30 GPs were assigned to the control (no training) group. (pg. 194, materials and methods). Randomisation method not described.
Allocation concealment (selection bias)	Unclear risk	No details given to enable judgement.

Blinding of outcome assessment (detection bias)	Unclear risk	No details given to enable judgement.
Incomplete outcome data (attrition bias)	High risk	Less than half of the GPs in training completed the full year (46.7 %) and only six (20 %) completed the distance-learning refresher courses. (pg. 198, discussion).
Selective reporting (reporting bias)	Low risk	All relevant outcomes reported.
Other bias	Unclear risk	Baseline comparison was not done.

Butler 2012

Methods	• Design: Cluster Randomised controlled trial • Cluster: General Practices • Recruitment method: General practices approached at random • Randomization: Dynamic block randomisation • Speciality: General practice • Setting: Primary care • Country: United Kingdom
Participants	• Type of participants: General practitioners • Inclusion criteria: General Practices in Wales (2007 & 2008) • Exclusion criteria: Not stated • Clusters / Participants randomised: 68 general practices / 263 clinicians with 480000 patients
Interventions	• Intervention: Stemming the Tide of Antibiotic Resistance (STAR) educational programme. (www.stemmingthetide.org), it's a blended learning program, included reflection on own practice, provision of new research evidence and guidelines, video-rich material presenting novel communication skills based on motivational interviewing, practice in usual clinical contexts, sharing experiences and views on a web form, and participating in a facilitator led, practice based seminar. • Control: The control practices were not exposed to the

	learning programme and provided care as usual
Outcomes	• Total numbers of oral antibiotic items dispensed for all causes per 1000 practice patients in the year after the intervention, adjusted for the previous year's dispensing. Secondary outcomes included reconsultations, admissions to hospital for selected causes, and costs. • The rate of oral antibiotic dispensing (items per 1000 registered patients) decreased by 14.1 in the intervention group but increased by 12.1 in the control group, a net difference of 26.1. This represented a reduction of 4.2% (0.6% to 7.7%) in total oral antibiotic dispensing for all age groups and all conditions in the year after the intervention relative to the control practices. • There were no significant differences between intervention and control practices in the number of admissions to hospital or in reconsultations for a respiratory tract infection within seven days of an index consultation • The mean cost of the programme was £2923 (€3491, $4572) per practice (SD £1187). There was a 5.5 % reduction in the cost of dispensed antibiotics in the intervention group compared with the control group (− 0.4 % to 11.4 %), equivalent to a reduction of about £830 a year for an average intervention practice
Notes	• Study aim: To evaluate the effectiveness and costs of a multifaceted flexible educational programme aimed at reducing antibiotic dispensing at the practice level in primary care • Pedagogical approach used: Facilitated learning, the intervention incorporated a blended learning experience for the participants with reflection on own practice, provision of new research evidence and guidelines, video-rich material presenting novel communication skills based on motivational interviewing, practice in usual clinical contexts, sharing experiences and views on a web form, and participating in a facilitator led, practice based seminar • Was a learning management system used? No • Journal: British Medical Journal • Year of publication: 2012 • Income status of country: High income • Source of funding: This study was funded by the UK Medical Research Council (G0500956).

	• Conflict of interest: None stated

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	General practice was considered as the unit for randomisation and general practices were randomised to intervention or control (usual care). Dynamic block randomisation took place once all practices were recruited and all participating clinicians had provided written consent. Dynamic block allocation was used (pg2, methods, para3).
Allocation concealment (selection bias)	Low risk	Clinicians and researchers were blinded to group allocation until after randomisation (pg3, ln2).
Blinding of outcome assessment (detection bias)	Unclear risk	Outcome assessors were not blinded, it is unclear if this constitutes a clear risk of bias.
Incomplete outcome data (attrition bias)	Low risk	Two practices, one in each group, withdrew after randomisation but were included in the intention to treat analyses. In the intervention practices that agreed to participate, 127 of the 139 clinicians completed the programme. Of the 124 clinicians in the control practices, 117 participated (pg4, para2).
Selective reporting (reporting bias)	Low risk	The outcomes listed in pre-registered study protocol (ISRCTN63355948) were unchanged.
Other bias	Low risk	Antibiotic dispensing rates were measured at baseline and follow-up, results are presented in table 2 (pg9).

Butzlaff 2004

Methods	• Design: Randomised controlled trial • Recruitment method: Screening questionnaire • Randomization: Block randomisation • Speciality: General practice • Setting: Primary care • Country: Germany
Participants	• Type of participants: General practitioners • Inclusion criteria: Should be available and have access to a PC with a CD-ROM drive or PC with Internet access • Exclusion criteria: Not stated • No of participants randomised: 72 general practitioners.
Interventions	• Intervention: Clinical practice guidelines via the Internet or CD-ROM (n = 38). • Control: No intervention (self-directed learning) • Note: 4.2% of the participants did not have internet access. (intervention: 5.3%, control: 2.9%)
Outcomes	• The primary outcome for the first successful step towards implementation was the increase of individual medical knowledge regarding four clinical topics covered by web- and evidence-based guidelines. Usage of guidelines, quality rating and motives to use or not to use available guidelines were secondary outcomes. • There was no significant knowledge increase in the intervention group; median difference (n = 35), controls = Median: 0 [25th and 75th percentile (- 1) - 2], Intervention = Median=0 [25th and 75th percentile (- 1) - 2], (P = 0.69). • Twenty-two (58 %) GPs of the intervention group had used the guidelines.
Notes	• Study aim: to study a potential knowledge increase among German GPs after implementation of web- and evidence-based guidelines and to identify and analyse potential barriers to individual professional learning with computerized guidelines • Pedagogical approach used: Individual eLearning, online self-instructional materials • Was a learning management system used? No • Journal: Family Practice • Year of publication: 2004

	• Income status of country: High income • Source of funding: Not mentioned • Conflict of interest: None stated

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Allocation numbers were associated with intervention and control groups by use of a computer-generated allocation schedule. To protect against unintended individual knowledge transfer between intervention and controls, participants were block-randomized with regard to single or group practice (pg184, para8). Randomisation method not described in detail
Allocation concealment (selection bias)	Unclear risk	No details given to enable judgement
Blinding of outcome assessment (detection bias)	Unclear risk	No details given to enable judgement
Incomplete outcome data (attrition bias)	Low risk	Intention to treat was used to analyse knowledge gain, table 3 (pg. 185, para9)
Selective reporting (reporting bias)	Unclear risk	Unable to find any trial registration or published protocol and primary/secondary outcomes not mentioned in the methods section to check reporting bias
Other bias	Low risk	Baseline comparison of characteristics are presented in table 1 (pg. 185)

Cabrera-Muffly 2015

Methods	• Design: Randomised controlled trial. • Recruitment method: residents enrolled in 3 otolaryngology residency programs • Randomization: Yes. Method not described. • Speciality: Otolaryngology • Setting: Hospital • Country: USA
Participants	• Type of participants: Otolaryngology residents • Inclusion criteria: Not stated • Exclusion criteria: Not stated • No of participants randomised: 37
Interventions	• Intervention: Residents were randomised into 2 groups, one with access to the educational modules and the other with no access. Online modules were created for supplemental otolaryngology resident education. Videos were produced using Microsoft Windows Paint as the background for the images, a Wacom Bamboo tablet (Intuos) to allow for drawing and writing on the background, HyperCam 2 software to record the video, and a micro-phone to record sound. The six videos covered laryngology topics, including laryngeal anatomy, benign laryngeal lesions, benign laryngeal, neoplasms, vocal cord immobility, congenital laryngeal lesions, and airway stenosis. Two videos discussed audiology topics, while 2 discussed general head and neck anatomy. • Controls: No intervention (Self-directed learning)
Outcomes	• Outcomes reported: Knowledge was assessed through exams performance. Learner Satisfaction was self-reported through questionnaire. The study reported "significant improvements in the experimental arm vs the control arm in 3 of the subspecialty sections (facial plastic surgery, otology, and pediatric otolaryngology), overall mixed results. • otolaryngology training examination (OTE), Otology: Intervention: OTE scores among residents with access to modules: mean difference: 7, SD: 20.9; n=18; Control: OTE scores among residents with access to modules: mean difference: 4, SD: 28.7; n=19. Mean difference and SD

	estimated from OTE scores from 2012 and 2013.
Notes	• Study aim: To assess whether otolaryngology residents at multiple institutions used online video modules to supplement their studying for the Otolaryngology Training Exam, whether the modules had any effect on their Otolaryngology Training Examination Scores, and to obtain survey feedback about the modules. • Pedagogical approach used: Individual eLearning with short videos and supplemental blogs. • Was a learning management system used? No • Journal: JAMA Otolaryngology - Head Neck Surgery, Year of publication: 2015 • Income status of country: High Income • Source of funding: Not mentioned. Conflict of interest: None.

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Randomisation method not described.
Allocation concealment (selection bias)	Unclear risk	Insufficient information to make a judgement.
Blinding of outcome assessment (detection bias)	Unclear risk	Insufficient information to make a judgement.
Incomplete outcome data (attrition bias)	Unclear risk	Of the 18 residents who had access, there was a 22% response rate. Those who responded reported they had watched a mean of 66% of the available lectures.
Selective reporting (reporting bias)	Low risk	All relevant outcomes mentioned in the methods section were reported.
Other bias	Unclear risk	Baseline comparison within the group is reported; between groups comparison is not done.

Chan 1999

Methods	• Design: Randomised controlled trial. • Recruitment method: Promotional pamphlets. • Randomization: Not described • Speciality: Family medicine. • Setting: Primary care. • Country: Canada.
Participants	• Type of participants: Family physicians • Inclusion criteria: Family physicians from northern Ontario practices and across Canada interested in Geriatric psychiatry • Exclusion criteria: Not stated. • No of participants randomised: 23 physicians
Interventions	• Intervention: Intervention had internet + small group interaction, the study group (n = 11) group spent two months discussing the topic of depression in the elderly with the help of a facilitator and two geriatric psychiatrists. • Control: The control group had internet without small group interaction. The participants (n = 12), were given similar educational resources via the internet but without the benefit of the small-group interaction.
Outcomes	• Knowledge • No significant difference in knowledge between the intervention groups.
Notes	• Study aim: To determine feasibility and the effectiveness of a problem-based small group learning (PBSGL) intervention conducted by the internet. • Pedagogical approach used: Individual learning • Was a learning management system used? No. • Journal: MD computing • Year of publication: 1999 • Income status of country: High income • Source of funding: None declared • Conflict of interest: None stated.

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Physicians who completed the pretest MCQs before the deadline were randomly allocated to a study and a control group (pg. 56, results). Randomisation method not described.
Allocation concealment (selection bias)	Unclear risk	No details given to enable judgement.
Blinding of outcome assessment (detection bias)	Unclear risk	No details given to enable judgement.
Incomplete outcome data (attrition bias)	High risk	23 physicians who agreed to participate in the study, and were randomised to a study (n = 11) and to a control group (n = 12). Prior to the posttest assessment at two months, four subjects withdrew (three from the study group and one from the control group). One participant moved to the United States during the study, one was too busy to continue and two other participants lost their internet service providers. Nineteen physicians (83 %) completed both assessments, the characteristics are summarised in table 1.
Selective reporting (reporting bias)	Unclear risk	No details given to enable judgement.
Other bias	Low risk	Comparison of participants characteristics are presented in table 1. No difference in the compared characteristics. Although there was no statistically significant difference between the two groups in terms of key characteristics, the control group was older and had been in practice longer and their percentage of geriatric work was also greater (pg. 56, results).

Chang 2014

Methods	• Design: Randomized controlled Solomon four-group study. • Recruitment method: Participants were enrolled in a rolling fashion from tertiary-care children's hospitals across United States. • Randomization: stratified block randomisation was done using a Solomon four group design through a random number generator (http://www.random.org). • Speciality: Paediatrics, Emergency medicine, Family medicine. • Setting: Hospital. • Country: United States.
Participants	• Type of participants: Participants included medical students and residents from paediatrics, emergency medicine and family medicine. • Inclusion criteria: Eligible participants included any resident or fourth-year medical student rotating through the ED for a minimum of 2 weeks. • Exclusion criteria: Not stated. • No of participants randomised: 458 participants.
Interventions	• Intervention: The experimental arms received an asynchronous eLearning curriculum consisting of nine Web-based, interactive, peer-reviewed Flash/HTML5 modules. • Control: Traditional/self-directed learning
Outcomes	• Knowledge improvement. • A total of 256 of 458 participants completed all study elements; 104 had access to asynchronous e-learning modules, and 152 were controls who used the current education standards. No pretest sensitization was found (P = 0.75). • Use of asynchronous eLearning modules was associated with an improvement in posttest scores (P < 0.001), from a mean score of 18.45 (95% confidence interval [CI] = 17.92 to 18.98) to 21.30 (95% CI = 20.69 to 21.91), a large effect (partial g2 = 0.19). Posttest scores correlated with ITE scores (r2 = 0.14, P < 0.001) among paediatric residents.

Notes	• Study aim: We hypothesized that a single multi-center e-learning curriculum was feasible and could universally improve medical knowledge among many different types of residents and students in the pediatric emergency department (ED). • Pedagogical approach used: Individual eLearning, self-instructional materials which included photos, diagrams, patient videos, audio clips with voice-over accompaniment. • Was a learning management system (LMS) used? Yes, Moodle Learning Management System. • Journal: Academic Emergency Medcine. • Year of publication: 2014. • Income status of country: High income. • Source of funding: Not stated. • Conflict of interest: None.

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Stratified block randomisation assigned each participant to one of four groups using a Solomon four-group design through a random number generator (http://www.random.org), stratified by specialty. That is, paediatric residents were block randomised within their specialty, EM residents were randomised separately, and so forth. Each institution randomised independently from each other. This design had two experimental groups and two control groups and is summarized in Figure 1 (pg. 914, study protocol).
Allocation concealment (selection bias)	Unclear risk	No details given to enable judgement.
Blinding of outcome assessment (detection bias)	Unclear risk	No details given to enable judgement.

Incomplete outcome data (attrition bias)	High risk	Intent-to-treat analysis was not possible as withdrawn participants contributed little analysable data (pg. 914, data analysis). Among 506 eligible trainees, 458 enrolled, and 48 declined, most citing lack of time as the primary reason. Out of 458 participants across the four institutions, 256 completed all parts of the study. The full CONSORT diagram is shown in Figure 2. The majority of enrolled trainees were residents in general pediatrics or medicine-pediatrics (n = 173), followed by EM (n = 41), family medicine (n = 22), and fourth-year medical students (n = 20). Our sample represented a spectrum of fourth-year medical students to PGY-4 residents. A large dropout rate of 44 % was noted. There was a higher withdrawal rate due to incompletion of study materials among participants randomised to use modules than those without modules (P < 0.001). EM residents were excluded more than any other group (P = 0.04), but otherwise no demographic differences were found between the analysed and the withdrawn trainees (P > 0.18). Table 1 summarizes comparisons between withdrawn and analysed participants (pg. 915, results).
Selective reporting (reporting bias)	Unclear risk	No details given to enable judgement.
Other bias	High risk	Table 1 shows the baseline characteristics of the analysed and withdrawn participants in the four groups, evidence of statistical difference between the groups (pg. 916).

Chenkin 2008

Methods	• Design: Randomized controlled non-inferiority trial. • Recruitment method: Junior emergency medicine residents and emergency physicians at the University of Toronto were invited to participate. • Randomization: Yes, randomisation was carried using computer generated random numbers. • Speciality: Emergency medicine.

	• Setting: Hospital. • Country: Canada.
Participants	• Type of participants: Emergency physicians and emergency medicine residents. • Inclusion criteria: Eligible participants must have completed an introductory ultrasound course and must have had no previous training on ultrasound-guided vascular access training. • Exclusion criteria: Not stated. • No of participants randomised: 21 emergency medicine physicians/residents.
Interventions	• Participating staff emergency physicians (EPs) and junior emergency medicine (EM) residents with no Ultrasound-guided Vascular Access Training (UGVA) experience completed a precourse test and were randomized to either a: • Intervention: Web-based group, the web-based group was provided access to the training website and instructed to spend approximately 1 hour reviewing the material. • Control: Didactic group, the didactic group attended an hour classroom lecture that covered the same material as found on the website.
Outcomes	• Procedural skills were assessed using Objective structured clinical examination (OSCE) score and written examination. • There were no significant differences in mean OSCE scores (absolute difference = -2.8 %; 95% confidence interval [CI] = -9.3 % to 3.8 %), P=0.39 or written test scores (absolute difference = -1.4 %; 95% CI = -7.8 % to 5.0 %) between the Web group and the didactic group, P=0.65. • 100% of those in the intervention group (n=11) found the course to be useful, 80% in the control group found the course to be useful (n=8). P=0.21
Notes	• Study aim: We hypothesized that a single multi-center e-learning curriculum was feasible and could universally improve medical knowledge among many different types of residents and students in the pediatric emergency department (ED). • Pedagogical approach used: Individual eLearning, self-

	instructional materials which included photos, diagrams, patient videos, audio clips with voice-over accompaniment. • Was a learning management system (LMS) used? Yes, Moodle. • Journal: Academic Emergency Medcine. • Year of publication: 2008. • Income status of country: High income. • Source of funding: This study was supported by a research grant from the Canadian Association of Emergency Physicians and a Fellowship for Studies in Education from the Royal College of Physicians and Surgeons of Canada. • Conflict of interest: None stated.

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Participants were randomised by a computer-generated random number sequence into either a web-based learning group or a didactic group (pg. 950, study protocol, ln 2).
Allocation concealment (selection bias)	Unclear risk	No details given to enable judgement.
Blinding of outcome assessment (detection bias)	Low risk	The examiners for the OSCE were physicians with expertise in the technique and who were blinded to the participants training group (pg. 950, measurements, ln 10).
Incomplete outcome data (attrition bias)	Low risk	All 124 staff EPs and 13 junior residents in the EM residency training program at the University of Toronto were invited to participate in the study. The first 22 respondents to the study invitation were included in the study (Figure 1). One participant subsequently withdrew, leaving 21 participants that completed the study (11 residents, 10 staff physicians) (pg. 951, results).

Selective reporting (reporting bias)	Unclear risk	No details given to enable judgement.
Other bias	Low risk	The baseline demographics were similar between the two groups (Table 1). No difference in studies characteristics between the two groups (pg. 952).

Chung 2004

Methods	• Design: Randomised controlled trial. • Recruitment method: Physicians from urban, academic tertiary care hospitals were recruited. • Randomization: Block randomisation. • Speciality: General practice. • Setting: Community hospitals. • Country: United States.
Participants	• Type of participants: Emergency medicine physicians, paediatric emergency medicine attending physicians, paediatric emergency medicine fellows, and fourth-year emergency medicine residents. • Inclusion criteria: As above. • Exclusion criteria: Not stated. • No of participants randomised: 63 emergency medicine physicians.
Interventions	• Interventions: A bioterrorism educational Web site was created by a panel of bioterrorism experts, consisting of physicians with expertise in emergency medicine, paediatric emergency medicine, pediatrics, infectious disease, medical toxicology, and medical informatics. The Web site contained published articles on specific biological agents, textbooks on bioterrorism, clinical practice guidelines for suspected respiratory and cutaneous illness due to biological warfare, links to related bioterrorism web sites, and a decision support tool that provided a differential diagnosis of biological diseases based on the physician's input of symptoms of a real or hypothetical patient. In addition, case scenarios of diseases caused by biological warfare agents were e-mailed to the web intervention group weekly for three weeks. • Controls: Participants in the control group did not receive

	information about the bioterrorism educational web site.
Outcomes	• Self-reported knowledge scores of the concepts of bioterrorism, pre-test, one and six month posttest using MCQ (34 items). • There was no difference in mean ± standard deviation (SD) pretest scores between Web intervention (45 % ± 10 %) and control (44 % ± 10 %) groups (mean difference: 1.9 %; 95% confidence interval [CI] = - 6.7 % to 2.9 %). • There was no significant difference between pre- and posttest scores among groups at one month (Web intervention 48 % ±10 % vs control 45 % ± 10 %; mean difference: 3.3 %; 95% CI = - 8.5 % to 2.0 %) and six months (Web intervention 51 % ± 8 % vs control 47 % ± 9 % ; mean difference: 3.8 %; 95% CI = - 8.8 % to 1.2 %). • More than 60 % of physicians cited media reports as their primary source of information on bio terrorism and believed that their knowledge of bioterrorism was limited after one month.
Notes	• Study aim: To determine whether aWeb-based educational intervention improves emergency physicians' knowledge about bioterrorism and to survey physicians' knowledge and sources of information on bioterrorism. • Pedagogical approach used: Individual eLearning, self-instructional materials with case scenarios (passive learning). • Was a learning management system (LMS) used? No. • Journal: Academic Emergency Medicine. • Year of publication: 2004. • Income status of country: High income. • Source of funding: None declared. • Conflict of interest: None stated.

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Block randomisation was used (pg144, study protocol, ln10) but method not described.
Allocation concealment (selection bias)	Low risk	Sealed envelopes were used to conceal allocation (pg144, study protocol, ln13).
Blinding of outcome assessment (detection bias)	Unclear risk	Not mentioned.
Incomplete outcome data (attrition bias)	Low risk	Of the 31 physicians assigned to the web intervention group, at 1 month, 7 physicians did not assess the educational intervention, 7 physicians declined to continue participation. Thirty two physicians were assigned to the control group (no further educational intervention) and at 6 months, 2 physicians declined participation in the web intervention group and 3 physicians declined to continue participation in the control group. Intention to treat was used to analyse knowledge, figure 2 (pg. 145, results, para2).
Selective reporting (reporting bias)	Unclear risk	Unable to find any trial registration or published protocol.
Other bias	Low risk	Baseline differences were tested. Twenty-nine participants were female. Scores did not significantly differ between the control group and the Web intervention group at the pretest, posttest and six month follow-up (pg. 145, results).

Claxton 2011

Methods	• Design: Randomised controlled study. • Recruitment method: Internal medicine interns from the University of Pittsburg were recruited. • Randomization: Yes, method no described. • Speciality: Internal medicine. • Setting: University, Medical college. • Country: United States.
Participants	• Type of participants: Internal medicine interns. • Inclusion criteria: Not stated. • Exclusion criteria: Not stated. • No of participants randomised: 82 internal medicine interns.
Interventions	• Intervention: Educational impact of weekly Fast Facts and Concept (FFAC) e-mails (32 weekly emails), the intervention group received 32 weekly emails • Control: Participants in the control group did not get FFAC e-mails.
Outcomes	• Medical knowledge measured by pre-post comparison of scores assessed through 24 multiple choice questions, preparedness on skills assessed using 4-point Likert scale and satisfaction based on ranking of education quality. • Post-test knowledge score for the Intervention: Mean: 15.7, SD: 1.9, n=41Control: Mean:14.2, SD: 2.5, n=41SD was estimated from the median and range. • Preparedness in symptom management skills (converting between opioids, differentiating types of pain, treating nausea) improved in the intervention group more than the control group (P = 0.04, 0.01, and 0.02, respectively) • There were no differences in preparedness in communication skills or satisfaction between the control and intervention groups.
Notes	• Study aim: To assess the educational impact of weekly Fast Facts and Concept (FFAC) e-mails on residents' knowledge of palliative care topics, self-reported preparedness in palliative care skills, and satisfaction with palliative care education. • Pedagogical approach used: Individual eLearning. • Was a learning management system (LMS) used? No.

	• Journal: Journal of Palliative Medicine. • Year of publication: 2011. • Income status of country: High income. • Source of funding: Not stated. • Conflict of interest: None stated.

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Interns in each of these categories were randomised to either the control or intervention group (pg476, participants, ln6). Randomisation method not described.
Allocation concealment (selection bias)	Unclear risk	No details given to enable judgement.
Blinding of outcome assessment (detection bias)	Unclear risk	No details given to enable judgement.
Incomplete outcome data (attrition bias)	High risk	Response rate for pre-test evaluation was 100 % and 70 % for posttest (pg477, para1, ln5). No mention of intention to treat analysis in the manuscript.
Selective reporting (reporting bias)	Unclear risk	Unable to find any trial registration or published protocol. No details given to enable judgement.
Other bias	Low risk	Baseline comparison of characteristics was presented in table 2. The intervention group's overall pretest preparedness score was significantly lower than the control group score (p=0.001)

Connolly 2014

Methods	• Design: Randomised controlled study. • Recruitment method: Participants were recruited from the Sydney Children's Hospitals Network through an online assessment (pg394, recruitment). • Randomization: Yes, randomisation sequence was generated using a Computerised random number generator. • Speciality: Paediatrics. • Setting: Children's Hospital. • Country: Australia.
Participants	• Type of participants: Resident medical officers in paediatric training. • Inclusion criteria: Not stated. • Exclusion criteria: Not stated. • No of participants randomised: 56 paediatric trainees.
Interventions	• Intervention: Beyond Milestones, an interactive teaching resource for online use. The teaching segments show children during free play and in interaction with the expert developmental paediatricians (CC) and their caregiver. CC demonstrates how to elicit key skills in language, fine motor, gross motor, cognition/problem solving and social domains. • Control: No teaching.
Outcomes	• The major outcome measures were attitudes, knowledge and usefulness (pg394). • Compared with the control group, the teaching group reported higher confidence in their developmental assessment skills at post-A (mean difference = 0.56; t (44) = - 2.170; P = 0.035) and higher satisfaction with instruction received at post-A (mean difference = 1.24; t (44) = -4.503; P < 0.0001) and post-B (mean difference = 0.90; t (43) = - 3.031; P = 0.004). • The teaching group scored higher on markers pre-to post-A (mean difference z-score = 0.405; P = 0.033), and compared to the control group, at post-A (mean difference z-score = 1.078; P < 0.0001) and post-B (mean difference z-score = 0.730; P = 0.005). • The Teaching group scored higher on observational expertise pre- to post-A (mean difference z-score = 0.521;

	P = 0.002) and pre- to post-B (mean difference z-score = 0.452; P = 0.022), and compared to the Control group, at post-A (mean difference Z-score = 1.243; P < 0.0001) and post-B (mean difference z-score = 1.075; P < 0.0001). • Teaching participants valued the video and expert commentary and reported improvement in confidence and understanding and acquiring a more structured approach.
Notes	• Study aim: The study aimed to create and evaluate the educational effectiveness of a digital resource instructing paediatric trainees in a systematic approach to critical and quality observation of normal child development. • Pedagogical approach used: Individual eLearning, interactive teaching resource with video instructions. • Was a learning management system (LMS) used? No. • Year of publication: 2014. • Journal: Journal of Paediatrics and Child Health. • Income status of country: High income. • Source of funding: None declared. • Conflict of interest: None.

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	The allocation to group sequence was generated using a Computerised random number generator (pg394, design).
Allocation concealment (selection bias)	Unclear risk	No details given to enable judgement.
Blinding of outcome assessment (detection bias)	Low risk	Coders and data entry were blinded to group and, when possible, to time point (pre- or post-teaching) (pg. 395).
Incomplete outcome data (attrition bias)	High risk	Eleven participants failed to complete the study (20 % attrition: Teaching group (7), Control group (4) because of sickness (1), holiday (1), lack of time (2), technical problems (2) and no response to follow-up contact (5). No mention of intension to treat analysis in the manuscript (pg. 395, loss to follow-up).
Selective reporting (reporting bias)	Low risk	Authors have reported all pertinent outcomes mentioned in the methods section.
Other bias	Low risk	Pg. 395, there were no significant differences between groups for gender (P = 0.975), age (P = 0.530), years of experience (P = 0.978), position (P = 1.000) and baseline knowledge of markers of development (P = 0.478) and observational expertise (P = 0.711)

Conroy 2015

Methods	• Design: Randomised controlled trial. • Recruitment method: Eligible trainees were recruited through email and by advertising the trial on the Alder Hey Children's Hospital intranet and in workplaces. Invitations to participate were also included in induction packs for new doctors. • Randomization: Random allocation sequence was generated by computer by an independent statistician and

	was stratified by specialty training level. • Speciality: Pediatrics • Setting: Hospital • Country: UK
Participants	• Type of participants: Specialist trainees in paediatrics • Inclusion criteria: Eligible participants were specialist trainees in paediatrics (ST level 1 and above) • Exclusion criteria: Trainees who had previously received formal training in causality assessment or had obtained a professional qualification in clinical pharmacology or pharmacy were excluded • No of participants randomised: 57
Interventions	• Intervention: An interactive, web-based, e-learning package, the Liverpool ADR Causality Assessmente-learning Package (LACAeP), was designed to improve causality assessment using the Liverpool Causality Assessment Tool (LCAT). • Controls: No intervention
Outcomes	• Outcomes reported: Learners correct classifications of adverse drug reactions assessed using LCAT tool and satisfaction assessed through assessment questionnaires. • Correct classification: Intervention: n=29, mean: 9.22, 95% CI: 7.96-10.48; Control: n=28, mean: 7.88, 95% CI: 6.76-9.00. • User Satisfaction on LCAT (All accessed): 76% easy to use, 74% reported using it on their role, 68% would recommend to others. E-Learning Package (Intervention Group only): 78% Useful, 72% Learned something, 92% could use it in practice, 61% Unlikely to suggest to others.
Notes	• Study aim: This study aimed to (1) get feedback on usability and usefulness on theLACAeP, identify areas for improvement and development, and generate data on effect size to informal larger scale study; and (2) test the usability and usefulness of the LCAT. • Pedagogical approach used: Individual eLearning with interactive bespoke learning activities that require the user to interact with the software in order to continue, and will offer instructive feedback. • Was a learning management system used? No

	• Journal: International Journal of Pharmacy Practice • Year of publication: 2015 • Income status of country: High Income • Source of funding: the NIHR provided funding for the ADRIC (adverse drug reactions in children programme grant) and the Merseyside and Cheshire Health Innovation and Education Cluster (HIEC) funded the development of the educational tool. • Conflict of interest: None.

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Random allocation sequence was generated by computer by an independent statistician and was stratified by specialty training level.(pg. 449, methods)
Allocation concealment (selection bias)	Unclear risk	Independent statistician for allocation sequence generation mentioned, concealment not mentioned.
Blinding of outcome assessment (detection bias)	Low risk	Data analysts were kept blinded to the allocation until after the analyses were finalised
Incomplete outcome data (attrition bias)	Low risk	Sixty participants provided consent during the recruitment phase; three were found to be ineligible upon screening; one had a pharmacology PhD, one had pharmaceutical industry experience, and the ST level was unknown for the third.
Selective reporting (reporting bias)	Low risk	Satisfaction data not reported for control group. The control had no intervention hence nothing to be (dis)satisfied with.
Other bias	High risk	Baseline differences were not compared. The study had high dropout rates, 38% in the intervention arm and 39% in the control arm.

Cullinan 2017

Methods	• Design: Randomised controlled trial. • Recruitment method: Non-consultant hospital doctors (NCHDs) of all grades (i.e. house officers [interns], senior house officers [SHOs]. • Randomization: A Computerised random number generator was used to allocate participants to control or intervention groups in a 1:1 ratio, pg. 369) • Speciality: Multispeciality • Setting: Hospital • Country: Ireland
Participants	• Type of participants: Non-consultant hospital doctors from different departments and registrars. • Inclusion criteria: Non-consultant hospital doctors and registrars. • Exclusion criteria: Pharmacy degree, history of working in the pharmaceutical industry and/or working as a consultant doctor. • No of participants randomised: 146 doctors
Interventions	• Intervention: Online module on geriatric pharmacotherapy • Controls: No intervention
Outcomes	• Knowledge, 4-week MCQ, Intervention group: 15.36, SD: 2.91; Control group: 10.71, SD: 3.01; 95% Confidence interval of the difference: 3.44 to 5.84, P<0.0001
Notes	• Study aim: To determine if an online module, focused on geriatric pharmacotherapy, improves doctors' prescribing knowledge, as well as prescribing confidence, as applied to older patients. • Pedagogical approach used: Individual eLearning with interactive case module • Was a learning management system used? Not stated • Journal: Drugs Aging • Year of publication: 2017 • Income status of country: High income • Source of funding: This work was supported by the SENATOR project which has received funding from the European Union Seventh Framework Programme.

	• Conflict of interest: None

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	A Computerised random number generator was used to allocate participants to control or intervention groups in a 1:1 ratio, pg. 369)
Allocation concealment (selection bias)	Low risk	The researcher marking the assessments and performing the analysis was blinded to the allocation group of the participants during this process, pg. 369, data analysis.
Blinding of outcome assessment (detection bias)	Unclear risk	Not stated.
Incomplete outcome data (attrition bias)	Low risk	64 out of 76 participants in the intervention completed the study, while 63 out of 70 completed the study in the control group. Attrition rate was similar in both groups and the reasons for attrition was provided in pg. 370, fig 1.
Selective reporting (reporting bias)	Low risk	The trials were registered with United Stated NIH, the study all reported outcomes stated in the protocol.
Other bias	Low risk	Baseline characteristics of the two groups reported in table 2, the two groups were similar.

Curtis 2007

Methods	• Design: Randomised controlled trial. • Recruitment method: Participants were recruited using printed materials mailed via a certified commercial carrier, broadcast faxes, and direct e-mails. • Randomization: Yes, block randomisation was used (pg. 592, intervention and control modules). • Speciality: Primary care • Setting: University, Hospital.

	• Country: United States.
Participants	• Type of participants: Physicians. • Inclusion criteria: Not stated. • Exclusion criteria: Not stated. • No of participants randomised: 153 physicians (949 patients)
Interventions	• Intervention: Web-based Glucocorticoid-induced osteoporosis (GIOP) intervention. The intervention focused on GIOP management and incorporated case-based continuing medical education and personalised audit and feedback of GIOP management compared with that of 10 % of study physicians. • Control: In the control arm of the study, the 3 modules were text-based traditional continuing medical education modules focused on chronic illnesses other than osteoporosis (non-adherence in chronic disease, clinical prediction rules, and pain, opioids, and the law), and no audit or feedback was provided.
Outcomes	• Primary outcomes were the proportion of the long-term glucocorticoid users of each physician in the 1 year following the intervention that underwent BMD testing and received prescription osteoporosis medication (i.e., bisphosphonate's, estrogens, calcitonin, raloxifene hydrochloride, and teriparatide). Combined end point of BMD testing or osteoporosis medication prescribing (or both) during this period was also examined. • Intent-to-treat analyses showed that 78 intervention physicians (472 patients) vs 75 control physicians (477 patients) had similar rates of BMD testing (19 % vs 21 %, P = .48; rate difference, − 2 %; 95% confidence interval [CI], − 8 % to 4 %) and osteoporosis medication prescribing (32 % vs 29 %, P = .34; rate difference, 3 %; 95% CI, − 3 % to 9 %). • Among 45 physicians completing all modules (343 patients), intervention physicians had numerically but not significantly higher rates of BMD testing (26 % vs 16 %, P = .04; rate difference, 10 %; 95% CI, 1 % - 20 %) and bisphosphonate prescribing (24 % vs 17 %, P = .09; rate difference, 7 %; 95% CI, − 1 % to 16 %) or met a combined end point of BMD testing or osteoporosis medication prescribing (54 % vs 44 %, P = .07; rate

	difference, 10 %; 95% CI, − 1 % to 21 %) compared with control physicians.
Notes	• Study aim: RCT is aimed to increase bone mineral density (BMD) testing and osteoporosis medication prescribing among patients receiving long term glucocorticoid therapy. • Pedagogical approach used: Individual eLearning, interactive instructional materials with case-based modules of clinical scenarios. • Was a learning management system (LMS) used? No. • Journal: Archives of Internal Medicine. • Year of publication: 2007. • Income status of country: High income. • Source of funding: This study was supported by grant HS10389 from the Agency for Healthcare Research and Quality and by grants P60 AR48095 and AR47512 from the National Institutes of Health. • Conflict of interest: None stated.

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	A physician was considered a study participant and was randomised to the intervention group or the control group when he or she first logged on to the study Web site. Block randomisation was used to balance the number of intervention vs control physicians randomised over time (pg. 592, intervention and control modules).
Allocation concealment (selection bias)	Unclear risk	No details given to enable judgement.
Blinding of outcome assessment (detection bias)	Unclear risk	No details given to enable judgement.

Incomplete outcome data (attrition bias)	Low risk	Twenty-seven (34.6 %) of 78 physicians participating in the GIOP course completed all 3 modules compared with 18 (24.0 %) of 75 physicians in the control group (P = .15). Intention to treat and per protocol analysis results have been presented in Table 2 (pg. 593, results, para 2). Attrition rate was
Selective reporting (reporting bias)	Low risk	Authors have reported all pertinent outcomes mentioned in the methods section.
Other bias	Low risk	Baseline characteristics are statistically compared and results presented in table 1 (pg. 593, para 3). To verify that randomization had achieved a successful balance between the study groups, we evaluated the baseline performance of the primary end points between July 1, 2001, and June 30, 2003 (before the intervention) and found no significant differences in the rates of BMD testing or osteoporosis treatment prescribing between intervention and control physicians (data not shown) (pg. 593, para 3).

Daetwyler 2010

Methods	• Design: Randomised controlled trial. • Recruitment method: Volunteer participations were randomised based on baseline interview scores. • Randomization: Yes, randomised using excel based random number generator. • Speciality: General Medicine. • Setting: University, Medical College. • Country: United States.
Participants	• Type of participants: Interns. • Inclusion criteria: Interns from Drexel University College of Medicine (DUCOM) who volunteered to participate in the study. • Exclusion criteria: Not stated. • No of participants randomised: 55 interns.
Interventions	• Intervention: The eLearning tool "doc.com", a collection of 41 media-rich online modules for teaching and

	learning of the knowledge aspects of medical communication skills. Interns were randomised into three groups: • Intervention I: Interns in one intervention group were asked to read the doc.com module on BBN and answer the MCQs after completing the module. • Intervention II: Interns in the second intervention group were asked to read the doc.com module, answer the MCQs, and participate in a second WebEncounter exercise, in which they were required to tell an SP the diagnosis of metastatic ovarian cancer with a poor prognosis. Interns received feedback from the SP as described above. • Controls III: Control subjects did not experience any intervention.
Outcomes	• Performance of behavioural checklist. • Number correct behaviours scored by SPs between "Doc.com+Web OSCE group" and "Control group" (Final - baseline) • Doc.com+Web OSCE group, n=16, mean difference:27, SD: 21; Control group, n=19, mean difference: 8, SD: 27
Notes	• Study aim: To describe two specific methodologies for teaching physician-patient communication skills developed at our institution and pilot test them for effectiveness. • Pedagogical approach used: Individual eLearning, interactive media rich online modules. • Was a learning management system (LMS) used? No. • Journal: Medical Teacher. • Year of publication: 2010. • Income status of country: High income. • Source of funding: None. • Conflict of interest: None reported.

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	We randomised interns into three groups, based on their baseline interview scores, blocking by performance score using the random number generator in Excel. However, the realities of interns' schedules precluded strict randomisation and several interns in each group needed to switch groups before the educational interventions (pg. 387, phase 2 two educational interventions).
Allocation concealment (selection bias)	Unclear risk	No details given to enable judgement.
Blinding of outcome assessment (detection bias)	Unclear risk	No details given to enable judgement.
Incomplete outcome data (attrition bias)	High risk	18 residents being assigned to each of the three study groups. Of the 18 residents initially assigned to the intervention group, only 77.7% (14/18) did the second standardized patient interview (pg. 388, results). Given the small sample size and preliminary nature of this study, we did not analyse the data with an intention to treat model (pg. 387, statistical methods).
Selective reporting (reporting bias)	High risk	At the end of the module, interns completed multiple choice questions (MCQs) demonstrating their understanding of the module" was not reported.
Other bias	Unclear risk	Table 3 shows the scores at baseline for the three groups; however the baseline group characteristics are not compared (p388).

Dayton 2000

Methods	• Design: Randomised controlled trial. • Recruitment method: Not stated. • Randomization: Yes, method not described. • Speciality: Internal medicine. • Setting: Hospital. • Country: United States.
Participants	• Type of participants: General internal medicine residents. • Inclusion criteria: Not stated. • Exclusion criteria: Not stated. • No of participants randomised: 29 residents.
Interventions	• Intervention: Decision support system (DSS) was developed to guide physicians in applying the American Thoracic Society (ATS) and Centers for Disease Control (CDC) guidelines based on Purified protein derivative (PPD) reactivity. The intervention group (Group A), assessed the decision support system (DSS) tool on a T1 line over the WWW using a Netscape 4 browser. • Control: Group B (controls) were allowed to use a guideline card.
Outcomes	• Practice or behavior change: Guideline compliance and concordance • Group A correctly used the therapy in 92/96 possible cases (95.8 %) and group B in only 77/136 (56.6 %), $P < 0.001$.
Notes	• Study aim: Effect of computer-based DSS compared with traditional paper-based reference sources to assist physicians in deciding on tuberculosis preventive therapy over the Internet. • Pedagogical approach used: Individual eLearning, online module with patient scenarios. • Was a learning management system (LMS) used? No. • Journal: Medical Decision Making. • Year of publication: 2000. • Income status of country: High income. • Source of funding: Funded in part by an educational grant from Glaxo-Welcome pharmaceutical. • Conflict of interest: Not stated.

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Residents were randomly assigned to a computer-based group (group A, n = 12), and a written-resource-based group (group B, n=17) (pg. 3, para 3, ln 6). Randomisation method not described.
Allocation concealment (selection bias)	Unclear risk	No details given to enable judgement.
Blinding of outcome assessment (detection bias)	Unclear risk	No details given to enable judgement.
Incomplete outcome data (attrition bias)	Unclear risk	No details given to enable judgement.
Selective reporting (reporting bias)	Unclear risk	No details given to enable judgement.
Other bias	Unclear risk	Baseline comparison not mentioned.

Dolan 2015

Methods	• Design: Randomised controlled trial. • Recruitment method: The 52 junior (second-year) and senior (third-year) residents in the continuity clinic at Brigham and Women's Hospital, a large urban academic institution, were all invited to participate. • Randomization: Yes, Computerized random number allocation sequence. • Speciality: General internal medicine • Setting: Hospital • Country: USA
Participants	• Type of participants: internal medicine resident physicians • Inclusion criteria: Not stated.

	• Exclusion criteria: Not stated. • No of participants randomised: 50
Interventions	• Intervention: An adaptive, longitudinal, online formative self-assessment curriculum delivered via multiple-choice questions • Control: a standard curriculum in bone health care
Outcomes	• Outcomes Reported: Knowledge, Skills, Patient outcomes • Knowledge: Residents correctly answering questions on bone mineral testing Intervention = n=21, 15/21, 73%Control= n=20, 13/20, 66%, P=0.04. • Skills: Treatment rates for high risk fragility fractures, Intervention: 57/75, 76%; Control: 47/80, 59%, P=0.03 • Patient outcome: Proportion of female patients appropriated screened for osteoporosis: Intervention: patient screened n=227, Appropriate screening: 216 (95.2%); Control: patients screening n=231, inappropriate screening: 206 (89.2%), P=0.02
Notes	• Study aim: Determine if the intervention would improve resident physicians' knowledge, and change their behavior regarding prevention of fragility fractures in women. • Pedagogical approach used: Individual eLearning of an adaptive, longitudinal, online formative self-assessment curriculum delivered via multiple-choice questions • Was a learning management system (LMS) used? No • Journal: Journal of Graduate Medical Education • Year of publication: 2015 • Income status of country: High Income • Source of funding: No specific source of funding mentioned • Conflict of interest: None.

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Computerized random number allocation sequence. (pg. 378, results)
Allocation concealment (selection bias)	Unclear risk	No details given to enable judgement.
Blinding of outcome assessment (detection bias)	Unclear risk	No details given to enable judgement.
Incomplete outcome data (attrition bias)	Low risk	(pg. 379) 80 and 88% completed the knowledge survey.
Selective reporting (reporting bias)	Low risk	Authors have reported all pertinent outcomes mentioned in the methods section.
Other bias	Low risk	No baseline differences, limitation were reported.

Edrich 2016

Methods	• Design: Randomised controlled trial. • Recruitment method: Not stated. • Randomization: Block randomisation was done (pg. 2, methods) • Speciality: Anaesthesiology and Emergency medicine • Setting: Hospital. • Country: United States, Austria and Germany.
Participants	• Type of participants: Anesthesia physicians • Inclusion criteria: Any resident, fellow, or staff physician in the departments of anesthesia or EM. Anesthesia physicians. • Exclusion criteria: Anesthesia physicians who had received any formal training in LUS were excluded • No of participants randomised: 138
Interventions	• Web-based group: received online access to instructional videos on Lung Ultrasound (LUS) training. • Group Class: received class room teaching (45 minutes) followed by hands-on practice (20 minutes) on Lung Ultrasound (LUS) • Control: No training group (self-directed learning)
Outcomes	• MCQ Tests for detection of pneumothorax • Practical test, the examiner prompted the subject to perform LUS on the examiners chest
Notes	• Study aim: The study hypothesized that Web-based training would not be inferior to “traditional” classroom-based training beyond a non-inferiority limit of 10% and that both would be superior to no training • Pedagogical approach used: Individual eLearning • Was a learning management system (LMS) used? No. • Journal: Anesthesia & Analgesia • Year of publication: 2016. • Income status of country: High income. • Source of funding: The research was funded internally. • Conflict of interest: None.

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Randomised in blocks of 7 with a ratio of 3:3:1. (pg. 2, methods)
Allocation concealment (selection bias)	Unclear risk	No details given to enable judgement.
Blinding of outcome assessment (detection bias)	Low risk	The stored images and clips from the practical tests were evaluated in a blinded fashion by the 3 reviewers." (p.126)
Incomplete outcome data (attrition bias)	Low risk	3 subjects were excluded because of unavailability of the subject for the posttest. Another 5 subjects did not complete the retention test as planned.(pg. 126, results)
Selective reporting (reporting bias)	Low risk	Authors reported all outcomes mentioned in the methods section.
Other bias	Unclear risk	Baseline performance of groups Web, class, and control did not differ significantly in the pretest. The limitations of the study include unequal recruitment of anaesthesiologists among the centers.

Enders 2006

Methods	• Design: Random Controlled Trial. • Recruitment method: Students consented to enroll in the trial (pg. 10, study participation). • Randomization: Yes, method not described. • Speciality: Public health. • Setting: University. • Country: United States.
Participants	• Type of participants: Public health graduates. • Inclusion criteria: All students were eligible, but were enrolled in the study only after providing written informed consent. • Exclusion criteria: Not stated. • No of participants randomised: 265
Interventions	• Internet learning group (online, n = 100). • Cooperative learning group (In person, n = 69). • Controls: No intervention (n = 96).
Outcomes	• Statistical knowledge, Mathematical skill. • Statistical knowledge: Intervention: n=100, mean: 4.3, SD: 1.9, Control: n=69, mean:4.3, SD: 1.8 • Mathematical skills: Intervention: n=100, mean: 4.3, SD: 1.2, Control: n=96, mean:4.4, SD: 1.0
Notes	• Study aim: Implementation and evaluation of the addition of innovative instructional methods to an existing didactic course sequence in introductory biostatistics for non-statisticians. The present study was designed to evaluate cooperative learning and internet learning within a randomised setting, and to compare the relative merits of cooperative and internet learning to each other and to a control group. • Pedagogical approach used: Individual eLearning, online modules. • Was a learning management system (LMS) used? No. • Journal: Statistics Educational Research Journal. • Year of publication: 2006. • Income status of country: High income. • Source of funding: No details given. • Conflict of interest: None stated.

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	The study design was a randomisation among consenting students to one of three groups: cooperative learning (in person), Internet-based learning (online), and control (see Figure 1 for a schema of the study design and participation, pg. 8). Randomisation method not described.
Allocation concealment (selection bias)	Unclear risk	No details given to enable judgement.
Blinding of outcome assessment (detection bias)	Unclear risk	No details given to enable judgement.
Incomplete outcome data (attrition bias)	High risk	A total of 376 students registered in the course; (pg. 12, para 3). By the third study session, **51%** of the students in the two intervention groups had dropped out
Selective reporting (reporting bias)	Low risk	Assessments were based on student performance as measured by four course examination scores (pg. 8, methods). The pertinent outcomes were reported.
Other bias	Low risk	Table 1, shows the comparison of baseline characteristics (pg. 11). As expected by

		randomization, all three groups were fairly comparable with respect to pre-study characteristics, with no statistically significant differences (pg. 10).

Epstein 2011

Methods	• Design: Cluster Random Controlled Trial. • Recruitment method: Practices satisfying the study's eligibility criteria were recruited in August and September 2009. • Randomization: Yes, Matched practices were assigned through simple random allocation to the intervention group that received the intervention immediately or to a control group that would receive the intervention after a 6-month period (Table 2). Randomization was performed by a researcher who was not familiar with the identity of the practices, by using a random number generator. • Speciality: Pediatrics. • Setting: Hospital. • Country: United States.
Participants	• Type of participants: Community-based paediatricians. • Inclusion criteria: Practice served primarily children and the practice was composed of >= 3 physicians who provided ADHD-related care. • Exclusion criteria: the practice as a whole served primarily adults (n = 9) or the practice included less than 3 physicians (n = 30). • No of participants randomised: 49.
Interventions	• Intervention: Intervention used in this study included four 1-hour training sessions conducted with remote, Internet-based, conferencing software. Intervention group received the intervention immediately after randomisation. Two 60-minute didactic sessions were conducted by a practicing, community-based, primary care physician (Dr Lichtenstein), focusing on the evidence base for the AAP guideline recommendations. The first didactic focused on ADHD assessment, and the second focused on ADHD treatment. The didactic sessions were attended by all

	paediatricians in the practice and a practice-identified ADHD champion. Each didactic session was followed by a 60-minute workshop, led by a quality improvement consultant, that focused on 3 main goals, that is, (1) modifying office flow, (2) learning to perform tests of change, and (3) training on the ADHD Internet portal. • Controls: Control group received the intervention after a 6-month period.
Outcomes	Several behavioral change outcomes were reported, we report only "use of parent rating of ADHD during assessment at 6 months", the mean difference between baseline and 6 months assessment. Intervention: n=, mean: 42.0, SD: 25.9, Control: n=, mean: 18.1, SD: 33.1, t=2.21, P=0.03, Cohen's d=0.69.
Notes	• Study aim: To determine the effectiveness of a quality improvement program to improve pediatricians' adherence to existing, evidence-based, attention-deficit/hyperactivity disorder (ADHD) practice guidelines. • Pedagogical approach used: Facilitated, internet-based training using conferencing software, didactic sessions conducted by primary care physician and workshops. • Was a learning management system (LMS) used? No. • Journal: Pediatrics. • Year of publication: 2011. • Income status of country: High income. • Source of funding: Funding for this study was provided by National Institutes of Health grants 21MH082714 and K24MH064478. In addition, this publication was supported by Institutional Clinical and Translational Science Award UL1RR026314. • Conflict of interest: None stated.

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Each pair of matched practices was assigned through simple random allocation to the intervention group that received the intervention immediately or to a control

		group that would receive the intervention after a 6-month period (Table 2). Randomization was performed by a researcher who was not familiar with the identity of the practices, by using a random number generator (pg. 1203, study design, ln 7).
Allocation concealment (selection bias)	Unclear risk	No details given to enable judgement.
Blinding of outcome assessment (detection bias)	High risk	It was impossible to keep chart reviewers blinded to treatment condition because of the need to query the Internet portal, pg. 1207, discussion.
Incomplete outcome data (attrition bias)	Low risk	An intent-to-treat analysis was performed to analyse changes in practice behaviours from baseline to 6 months after the intervention across the intervention and control groups, by using t tests (pg. 1205, statistical analysis, ln 4).
Selective reporting (reporting bias)	Low risk	This trial has been registered at www.clinicaltrials.gov (identifier NCT01056016). The original goal of the proposed study is to modify the ADHD Collaborative intervention to make it transportable and then evaluate this version in terms of effectiveness, consumer satisfaction, and costs. Effectiveness as measured by rate of American Academy of Pediatrics-recommended ADHD care practices, consumer ratings were reported, while cost is not reported in this paper.
Other bias	Unclear risk	Table 2, shows baseline assessment for the scores, table 1 shows practice characteristics, baseline comparisons of the groups were not done.

Estrada 2011

Methods	• Design: Cluster Random Controlled Trial. • Recruitment method: Physicians were recruited online. • Randomization: Yes, physicians provided informed consent online and were randomised to the intervention or control arms using block randomisation. • Speciality: Primary care. • Setting: Hospital.

	• Country: United States.
Participants	• Type of participants: Primary care physicians. • Inclusion criteria: General and internal medicine physicians located in rural areas of 11 Southeastern USA (Alabama, Arkansas, Florida, Georgia, Kentucky, Mississippi, Missouri, North Carolina, South Carolina, Tennessee and West Virginia). • Exclusion criteria: Not stated. • No of clusters / participants randomised: 205 practices with 95 physicians and their 1182 patients.
Interventions	• Intervention: Multi-component interactive intervention including Web-based continuing medical education, performance feedback and quality improvement tools. Website included a formative evaluation and focused on helping physicians to achieve A1C, BP and LDL control in their diabetic patients. The Website included case-based learning, personalized audit and feedback, and tools designed to facilitate the provision of high-quality care. Intervention arm physicians received e-mail reminders every 1–3 weeks about Website updates. E-mails were tailored for participants who had not completed specific sections of the Website. • Controls: The control Website contained: (i) links to diabetes practice guidelines and patient education materials; (ii) a list of educational conferences on general medical topics (updated monthly); (iii) an area to track and view their CME credit; and (iv) a link to an external medical blog. Physicians in the control group did not receive performance feedback reports or electronic communications.
Outcomes	• The primary outcomes were measures of ‘acceptable’ and ‘optimal’ diabetes control. Acceptable control was the proportion of patients with A1C <= 9 %, BP < 140 / 90 mmHg and LDL 130 mg/dl. • The proportion of patients with A1C <= 9 % acceptable A1C control (9%) was similar at baseline and follow-up in both trial arms [control, adjusted odds ratio (AOR): 0.94; 95% confidence interval (CI): 0.61, 1.47; intervention, AOR: 1.16 (95% CI: 0.80, 1.69)]. • Similarly, [BP control arm, AOR: 1.19 (95% CI: 0.89,

	1.58), P=0.24; BP intervention arm, AOR:1.06 (95% CI: 0.82, 1.38), P=0.66] and • [LDL control arm, OR: 1.08 (95% CI: 0.69, 1.69), P=0.74; LDL intervention arm, AOR: 1.16 (95% CI: 0.78, 1.73), P=0.46]
Notes	• Study aim: To determine the effectiveness of a provider-based education and implementation intervention for improving diabetes control. • Pedagogical approach used: Individual eLearning, web-based multi-component interactive intervention, website included case-based learning, personalized audit and feedback. • Was a learning management system (LMS) used? No. • Journal: International Journal of Quality in Health Care. • Year of publication: 2011. • Income status of country: High income. • Source of funding: Awards by the National Institute of Diabetes and Digestive and Kidney Diseases (NIDDK). • Conflict of interest: None stated.

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Physicians provided informed consent online and were randomised to the intervention or control arms using block randomisation (pg. 683, methods, para 2). Randomisation method not described.
Allocation concealment (selection bias)	Low risk	Block size of four was concealed to the investigators and statistician (pg. 683, methods, para 2, ln 6).
Blinding of outcome assessment (detection bias)	Low risk	Data abstraction was performed by trained personnel on blinded records sent to the study center (or abstracted on site) (pg. 683, data sources).
Incomplete outcome data (attrition bias)	Low risk	In the statistical analysis, it's reported that intention-to-treat principle analysis was used. Figure 1, 48 and 47 practices which provided baseline and follow up data for the intervention group and control groups

		were analysed.
Selective reporting (reporting bias)	High risk	The Rural Diabetes Online Care (R-DOC) study was a cluster-randomised trial (Clinical Trials.gov identifier: NCT00403091). Primary outcomes such as A1c, blood Pressure, lipids mentioned in the study record are reported in the study. However some secondary outcomes listed in the study report such as eye screening, foot exam, kidney disease monitored, dietary or exercise advice, smoking cessation advice are not reported in the study.
Other bias	Unclear risk	Table 1 shows the baseline characteristics of patients, physician characteristics not reported. The non-random sampling of physicians may have introduced selection bias. Second, physicians were asked to provide records of consecutively seen patients, and while we were unable to monitor compliance with this request, the wide range of A1c, BP and LDL values suggests that not only well-controlled patients were selected, but poorly-controlled patients as well. About 10 or 15 records did not represent the physician's diabetes patients in general. The high attrition may have introduced biases.

Farah 2012

Methods	• Design: Randomised Controlled Trial. • Recruitment method: Participants were invited via intra-hospital email and advertisement flyers. • Randomization: Participants were randomised to either intervention group (immediate access to IA) or control group (delayed access to IA); a JavaScript (Oracle Corporation, Redwood Shores, CA, USA) program was used for randomisation, which determined allocation on a random 50/50 basis. (pg. 634, randomisation and study design). • Speciality: Internal medicine • Setting: Hospital. • Country: Australia.
Participants	• Type of participants: Participants were doctors apart of the hospital network. • Inclusion criteria: Participants who gave consent were recruited. Eligible participants were doctors who were part of the hospital network. • Exclusion criteria: Not stated. • No of participants randomised: 45 doctors.
Interventions	• Intervention: Immediate access to information and decision aids (IA). IA is a website based on the latest evidence that explored the effectiveness of prostate cancer screening. It has 3 sections, first provided baseline information about Prostate Specific Antigen (PSA) tests, part 2 summarized information from two large trials that addressed effectiveness of PSA/DRE testing in reducing prostate cancer mortality. Part 3 provided a summary of the screening benefits and the number needed to screen and treat. • Controls: Delayed access to IA.
Outcomes	• Increase in knowledge, time to compete screening. • Doctors spent a mean time of 4:04 (95% confidence interval: 0.53–7.52) reading and completing the IA. • Those who read IA were more knowledgeable (mean score out of 9, 7.45 versus 5.75, $P < 0.0001$), potential harms and current literature findings were better recognized, as well as having a better understanding of

	what is meant by the term screening. • Eighty-two per cent found that IA helped them understand prostate cancer screening, and 73 % found it easy to understand.
Notes	• Study aim: The objectives of this study were to evaluate the effectiveness of an information aid (IA) on doctor's knowledge about the strengths and limitations of prostate-specific antigen/digital rectal examination (PSA / DRE) testing, and to help doctors make better and more informed decisions about prostate cancer screening • Pedagogical approach used: Individual eLearning, self-instructional website. • Was a learning management system (LMS) used? No. • Journal: Australia New Zealand Journal of Surgery. • Year of publication: 2012. • Income status of country: High income. • Source of funding: Not available. • Conflict of interest: None stated.

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	A JavaScript (Oracle Corporation, Redwood Shores, CA, USA) program was used for randomisation, which determined allocation on a random 50 / 50 basis (pg. 634, randomisation and study design).
Allocation concealment (selection bias)	Low risk	There was no restriction on allocation or any either allocation sequence used. Allocation was concealed from the investigators. The program written to allocate participants was written by the authors and is available upon request (pg. 634, randomisation and study design, ln 5).
Blinding of outcome assessment (detection bias)	Unclear risk	No details given to enable judgement.

Incomplete outcome data (attrition bias)	Low risk	All analyses were conducted on an intention to treat basis (pg. 635, analysis).
Selective reporting (reporting bias)	Low risk	All pertinent outcomes mentioned in the methods section have been reported.
Other bias	Unclear risk	Baseline knowledge of PSA screening was compared but not tested statistically, table 1 (pg. 634).

Feng 2013

Methods	• Design: Cluster Random Controlled Trial. • Recruitment method: Primary care physicians (internal and family medicine) were recruited from 5 health systems in California. • Randomization: Physicians were randomised to 1 of 3 study arms. Randomization method not described. • Speciality: Primary care • Setting: Hospital. • Country: USA.
Participants	• Type of participants: Primary care physicians (internal and family medicine). • Inclusion criteria: Physicians from university-affiliated community-based practices (2 sites), staff model health maintenance organizations (2 sites), and a private practice network (1 site) who consented to take part in the study were included. • Exclusion criteria: Not stated. • No of participants randomised: 120 physicians.
Interventions	• Intervention: Immediate access to information and decision aids (IA). IA is a website based on the latest evidence that explored the effectiveness of prostate cancer screening. It has 3 sections, first provided baseline information about Prostate Specific Antigen (PSA) tests, part 2 summarized information from two large trials that addressed effectiveness of PSA/DRE testing in reducing prostate cancer mortality. Part 3 provided a summary of the screening benefits and the number needed to screen and treat.

	• Controls: Delayed access to IA.
Outcomes	• Authors analysed physician behaviours around screening: (1) engagement after prompting, (2) degree of shared decision making, and (3) final recommendations for prostate cancer screening. • Intervention physicians showed somewhat more shared decision making behaviours (intervention 14 items vs control 11 items, P < .05), were more likely to mention no screening as an option (intervention 63 % vs control 26 %, P < .05), to encourage patients to consider different screening options (intervention 62 % vs control 39 %, P < .05) and seeking input from others (intervention 25 % vs control 7 %, P < .05).
Notes	• Study aim: to explore physician behaviors during an unannounced standardized patient encounter that was part of a randomized controlled trial to educate physicians using a prostate cancer screening, interactive, Web-based module. • Pedagogical approach used: Individual eLearning, self-instructional interactive web module, also included interactive roulette wheels, illustrative video vignettes. • Was a learning management system (LMS) used? No. • Journal: Annals of Family Medicine. • Year of publication: 2013. • Income status of country: High income. • Source of funding: This work was supported by the Centers for Disease Control and Prevention grant RO1PH000019. • Conflict of interest: None.

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Physicians were randomised to 1 of 3 study arms, with interventions. Method not described (pg. 316, experimental design, ln 4).
Allocation concealment	Unclear risk	No details given to enable judgement.

(selection bias)		
Blinding of outcome assessment (detection bias)	Unclear risk	No details given to enable judgement.
Incomplete outcome data (attrition bias)	Low risk	To assess the impact of actual intervention participation on physician behaviours, we performed an as-treated analysis, comparing the behaviours of physicians who participated and those who did not participate in the intervention (pg. 317, analysis).
Selective reporting (reporting bias)	Low risk	Protocol (NCT 00207649) is available and all pertinent outcomes were reported:
Other bias	Unclear risk	Baseline characteristics not compared by groups.

Ferguson 2015

Methods	• Design: Randomised Controlled Trial • Recruitment method: Cardiothoracic residents were contacted through e-mail using addresses provided by the Thoracic Surgery Directors' Association, and were provided $50 in remuneration (pg. 235, materials and methods) • Randomization: Yes, method not described • Speciality: Cardiothoracic surgery • Setting: University • Country: USA
Participants	• Type of participants: Cardiothoracic surgery residents • Inclusion criteria: Not stated • Exclusion criteria: Not stated. • No of participants randomised: 41
Interventions	• Intervention: Online short course on frailty (experimental group) • Controls: No training (control group
Outcomes	• Knowledge • Fraility questions answered correctly, Intervention: n=20,

	93.7%; Control: n=21, 75.2%, P<0.001
Notes	• Study aim: The study assessed the influence of a frailty education module on surgical residents' estimates of lobectomy risk. • Pedagogical approach used: Individual eLearning • Was a learning management system (LMS) used? No • Journal: Annals of Thoracic Surgery • Year of publication: 2015 • Income status of country: High income. • Source of funding: This study was supported in part by the Eugenia Dallas Fund for Thoracic Surgery Research. The REDCap project (UL1 RR024999) at the University of Chicago and funded by the Biological Sciences Division and by the Institute for Translational Medicine. • Conflict of interest: Not stated.

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Yes, method not described.
Allocation concealment (selection bias)	Unclear risk	No details given to enable judgement.
Blinding of outcome assessment (detection bias)	Unclear risk	No details given to enable judgement.
Incomplete outcome data (attrition bias)	Low risk	Of those who completed the training 20 subjects were randomly assigned to the experimental group, and 21 subjects were in the control group, no drop outs have been reported. (pg. 236, results)
Selective reporting (reporting bias)	Low risk	All results mentioned in methods are reported.

Other bias	High risk	The number of resident participants was relatively small, and the study had limited statistical power (pg. 240, discussion). There was a significantly a larger percentage of women in the experimental group.

Fordis 2005

Methods	• Design: Randomised Controlled Trial. • Recruitment method: Recruitment took place between November 2001 and January 2002 using letters, presentations, and conferences at the practice sites. • Randomization: Randomization of participants to the live CME or online CME group, stratified by clinic type (public or private), was done using a pseudo random number generator. • Speciality: Primary care. • Setting: Hospital. • Country: United States.
Participants	• Type of participants: Primary care physicians. • Inclusion criteria: Participants were 97 primary care physicians drawn from 21 practice sites in Houston, Texas, including 7 community health centers and 14 private group practices. • Exclusion criteria: Physicians were excluded if they were unwilling or unable to participate in either randomly assigned educational program. • No of participants randomised: 103 physicians
Interventions	• Intervention: Online CME group had mutiformat didactic presentations, application exercises with cases with scripted interactivity. It has tools which provided quick desk reference, guideline summary and risk calculator. Learning was reinforced with access to experts by email, interactive case discussions with faculty via web conferencing. • Internet-based CME intervention that could be completed in multiple sessions over 2 weeks. • Controls: The live CME group had live didactic presentations with question and answer session and discussion. It had application exercises which included interactive case discussions with faculty and enabling

	tools. The group had access to experts by phone and email.
Outcomes	• Knowledge: Online CME group (n=44) scored slightly higher than the live CME group (n=49) when averaged across all 3 testing occasions (4.8% additional items correct, 95% confidence interval [CI], 0.6%-9.0%; partial ω2= 0.01; P= .03). • Appropriate screening for dyslipidaemia: Online CME: n=20, mean difference: -0.1, 95% CI:-2.9 to 2.6; Live CME: 20, mean difference: -3.3, 95% CI:-5.9 to -0.7; Lecture group: n=, mean difference: -0.8, 95% CI:-3.5 to 1.8. • Patients Appropriately Treated for Online CME group: n=17, mean difference: 5.0, 95% CI: 1.0 to 9.1; Live CME group: n=19, mean difference: -1.1, 95% CI: -4.9 to 2.7; Control group; n=18, mean difference: 1.2, 95% CI: -2.8 to 5.1. • Satisfaction: Online CME: n= 52, satisfaction: 94%; Live CME: n=51, Satisfaction: 100%
Notes	• Study aim: To determine if Internet-based CME can produce changes comparable to those produced via live, small-group, interactive CME with respect to physician knowledge and behaviors that have an impact on patient care. • Pedagogical approach used: Individual eLearning, interactive cases, access to presentations and mail contact with the faculty members. • Was a learning management system (LMS) used? Yes. • Journal: Journal of American Medical Association. • Year of publication: 2005. • Income status of country: High income. • Source of funding: This study was supported by a grant from AstraZeneca Pharmaceuticals. • Conflict of interest: None stated.

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	High risk	Randomization of participants to the live CME or online CME group, stratified by clinic type (public or private), was done using a pseudo random number generator (pg. 1045, para 1).
Allocation concealment (selection bias)	Unclear risk	No details given to enable judgement.
Blinding of outcome assessment (detection bias)	Low risk	The data analyst was blinded to the identification of participants (pg. 1045, para 1).
Incomplete outcome data (attrition bias)	Low risk	Analysis was based on intention to treat (pg. 1047, analysis, para 3).
Selective reporting (reporting bias)	Low risk	Knowledge tests, activity evaluation, and outcomes survey (pg. 1046, data collection); authors have reported all pertinent outcomes.
Other bias	Low risk	Comparison of baseline characteristics are presented in table 2 (pg. 1048) Because gains in knowledge were similar for both groups over time, it is reasonable to consider the possibility that cross-contamination occurred within those practices housing physicians in both study arms. However, because the live CME workshops primarily occurred before the beginning of the online CME interventions, and the pretest and post-test 1 measure for the live CME group were collected during the workshop, cross-contamination could not have affected the pre-intervention to post-intervention gains for the live CME group. Payment of honoraria for completing data collection instruments could potentially have influenced study results, giving individuals a greater incentive to participate.

Franchi 2016

Methods	• Design: Cluster randomised controlled trial • Recruitment method: A convenience sample of ten internal medicine and ten geriatric wards of Italian hospitals were selected (pg. 54, methods). • Randomization: All physicians received a personal user identification code and a password to access the e-learning platform, which provided access only to the ward assigned by randomization to e-learning. (pg. 55, methods) • Speciality: Internal medicine and Geriatrics • Setting: Hospital • Country: Italy
Participants	• Type of participants: Geriatric and internal medicine wards • Inclusion criteria: All patients aged 75 years or over consecutively admitted to the participating wards were eligible. • Exclusion criteria: Exclusion criteria were consent refusal or estimated life expectancy of less than6months. • No of participants randomised: 20 hospital wards
Interventions	• Intervention: Interactive web-based platform E-learning to improve drug prescription • Area 1: main concepts of CGA (Module A). • Area 2: general geriatric pharmacology notions (Module B). • Area 3: prescription appropriateness and related issues in older adults: (a) assessment and management of patients exposed to polypharmacy (Module C); (b) criteria and tools for the revision and evaluation of prescription appropriateness in older people, such as Beers Criteria, Screening Tool of Older Person's Prescriptions (STOPP), Assessing Care of the Vulnerable Elderly (ACOVE), Inappropriate Prescribing in the Elderly Tool (IPET) and the Medication Appropriateness Index (MAI) (Module D); (c) criteria and tools to evaluate potential drug–drug interactions (Module E). • Controls: eLearning refresher on the basic notions of geriatric pharmacology
Outcomes	• The primary outcome of the study was whether or not

	there was a reduction in the prescriptions at hospital discharge of PIMs. • Secondary outcomes were whether or not at discharge there was a reduction of prescription of potential DDIs (PDDIs) or potentially severe DDIs, and to evaluate the clinical impact of the integrated e-learning intervention on the length of hospital stay, mortality and incidence of any re-hospitalization during the 12-month follow-up period.
Notes	• Study aim: to evaluate the effect of an e-learning educational program meant to foster the quality of drug prescription in hospitalized elderly patients. • Pedagogical approach used: Individual eLearning • Was a learning management system (LMS) used? No • Journal: British Journal of Clinical Pharmacology • Year of publication: 2016 • Income status of country: High income • Source of funding: Not stated. • Conflict of interest: None stated.

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	The 20 hospital wards were centrally randomized to the intervention (n = 10) or control arm (n = 10). All physicians received a personal user identification code and a password (pg. 55, Randomisation). No randomization method was mentioned.
Allocation concealment (selection bias)	Low risk	All physicians received a personal user identification code and a password (pg. 55, Randomisation)
Blinding of outcome assessment (detection bias)	Low risk	All investigators involved in data collection were blinded to arm allocation. (pg. 55, blinding)
Incomplete outcome data	Low risk	Figure 1 provides the flow chart of the study. Ninety per cent of the clinicians involved in the study completed the e-

(attrition bias)		learning program. (pg. 56, study flow chart). Even though the study had high loss to follow-up, intention to treat analysis was used.
Selective reporting (reporting bias)	Low risk	All results mentioned in methods are reported.
Other bias	High risk	There were no between-arm statistically significant differences pertaining to socio-demographic variables, risk factor and clinical variables, except for the number of diagnoses (P < 0.0001), CIRS comorbidity index (P < 0.0001) and CIRS severity index (P < 0.0001) both at admission and discharge. (pg. 58).

Gerbert 2002

Methods	• Design: Random allocation only. • Recruitment method: Members of the society of general internal medicine were invited to participate in the study. • Randomization: Yes, participants were randomly assigned to either an intervention group or a control group (pg. 8, study procedures). • Speciality: Primary care. • Setting: University. • Country: United States.
Participants	• Type of participants: Primary care physicians. • Inclusion criteria: Physicians were invited to participate if they 1) were practicing primary care, 2) had access to the Internet and a computer with adequate resolution to view the program's digitised images, and 3) had not participated in a previous study using the same images. • Exclusion criteria: Not stated. • No of participants randomised: 46 physicians.
Interventions	• Intervention: Skin cancer triage tutorial, the tutorial had 7 modules, those were registration, pretest, pretest score with individualised feedback, skin cancer instruction, posttest 1, posttest 2 and exit survey. • Control: no intervention.

Outcomes	• Diagnosis and evaluation planning of malignant melanoma, basal cell carcinoma, squamous cell carcinoma, actinic keratosis, seborrheic keratosis and nevus and overall diagnosis and evaluation planning. • The intervention group scores significantly higher than the control group in nine of the 14 outcome measures; this improvement was maintained for five of the nine outcomes.
Notes	• Study aim: To determine the efficacy of an Internet-based skin cancer triage intervention for physicians. • Pedagogical approach used: Individual eLearning, with feedback. • Was a learning management system (LMS) used? No. • Journal: Journal of Cancer Education. • Year of publication: 2002. • Income status of country: High income. • Source of funding: Not stated. • Conflict of interest: None stated.

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Participants were randomly assigned to either an intervention group or control group and completed the testing sequence (pg. 8, study procedures). Randomisation method was not described.
Allocation concealment (selection bias)	Unclear risk	No details given to enable judgement.
Blinding of outcome assessment (detection bias)	Unclear risk	No details given to enable judgement.

Incomplete outcome data (attrition bias)	High risk	Of those enrolled, 149 began the tutorial, 71 completed the program through posttest 1, and 46-27 of 39 in the intervention group and 19 of the 32 in the control group completed the entire program through the exit survey (pg. 8, results).
Selective reporting (reporting bias)	Unclear risk	No details given to enable judgement.
Other bias	High risk	Baseline comparison of the intervention groups are presented in table 2 (pg. 9, characteristics of the study population). Results, pg. 8, greater proportion of intervention group participants had their primary employment in medical schools.

Girgis 2009

Methods	• Design: Randomized controlled trial. • Recruitment method: All medical and radiation oncologists from six tertiary care hospitals in six Australian cities which incorporated oncology outpatient clinics were invited to participate in the study (pg. 457, methods). • Randomization: Yes, oncologists were individually randomised immediately after consenting to participate and completing their baseline data collection. Randomization within group was undertaken using Microsoft Excel. • Speciality: Oncologists. • Setting: Hospitals. • Country: Australia.
Participants	• Type of participants: Medical and radiation oncologists. • Inclusion criteria: Participating doctors were eligible if they were (1) attending the oncology clinic for their first

	consultation with one of the participating oncologists, (2) aged 18 years or older, (3) able to understand English sufficiently to complete questionnaires and telephone interviews, and (4) not visibly distressed at the time of recruitment. • Exclusion criteria: The study eligibility criteria necessitated the exclusion of patients who were too distressed or unwell to participate, or who were not sufficiently fluent in the English language to complete the surveys. • No of participants randomised: 29 oncologists
Interventions	• Intervention: Consultation skills training (CST) program, the CST consisted of a 1.5-day face-to-face workshop incorporating presentation of principles, a DVD modelling ideal behaviour and role-play practice, and four 1.5 hour monthly video conferences. • Control: Usual care.
Outcomes	• Quality of life was assessed using the 30-item EORTC Core Quality of Life Questionnaire (EORTC QLQ-C30), however this paper only reports results from the emotional functioning sub-scale of EORTC QLQ-C30. Anxiety and depression were assessed using 14-item Hospital Anxiety and Depression Scale (HADS); patients perceived needs were measured using a sub-set of 24 of 59 items in the Supportive Care Needs Survey (SCNS). • Despite high patient functioning at baseline, anxiety significantly improved at 1-week follow-up in the CST group, compared to the control group. There were no statistically significant differences in emotional functioning, depression or unmet supportive care need between the groups. • QoL scores were similar at baseline and improved for both groups at 3 months, with no significant post-intervention difference between the groups. • Baseline mean anxiety scores were within the ‘‘normal’’ range for both study groups, with no significant between-group differences at baseline, 1 week or at 3 months. Whilst mean anxiety scores reduced over the 3-month period for both groups, larger changes were observed in the intervention group compared to the control group. Furthermore, the differences in change scores were statistically significant only in the intervention group, from

	baseline to 1-week follow-up (P =0.021), and did not reach statistical significance at the 5% level for the 3-month follow-up (P = 0.077) • Baseline mean depression scores were within the ‘‘normal’’ range for both study groups, with no significant between-group differences at baseline, 1 week or at 3 months. Whilst mean depression scores reduced between the baseline and 3-month period for both groups, the observed differences in depression scores between groups were not statistically significant. • Greater reduction in average psychological needs over time in the intervention group compared to those in the control group (from 44 to 25 in the intervention group, compared to 39 – 27 in the control group from baseline to 3 months follow-up), although the change was not statistically significant between groups (P = 0.084).
Notes	• Study aim: To evaluate whether a consultation skills training (CST) program with oncologists and trainees would improve skills in detecting and responding to patient distress, thereby improving their patients' emotional functioning and reducing psychological distress. • Pedagogical approach used: Collaborative eLearning, face-face workshop, video-conference, role-plays, training DVD. • Was a learning management system (LMS) used? No. • Journal: Patient Education and Counseling. • Year of publication: 2009. • Income status of country: High income. • Source of funding: Not stated. • Conflict of interest: None stated.

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Randomization within group was undertaken using Microsoft Excel (pg. 458, randomisation).
Allocation concealment	Unclear risk	No details given to enable judgement.

(selection bias)		
Blinding of outcome assessment (detection bias)	Unclear risk	No details given to enable judgement.
Incomplete outcome data (attrition bias)	Low risk	Drop-out occurred as a result of active withdrawal (n = 81 or 12 % of original sample) or loss to follow-up (n = 37 or 6 %) and was not significantly different between the treatment and control groups (pg. 459, results)
Selective reporting (reporting bias)	Low risk	All pertinent outcomes reported.
Other bias	High risk	Comparison of demographic and personal disease characteristics between treatment and control patient groups at baseline are presented in table 1 (pg. 459). Patient characteristics were well balanced between the two groups, although there was a significantly larger proportion of patients in the control group having undergone treatment in the past month (P = 0.03) and a larger proportion of patients in the intervention group with a type of cancer not specified in the list (pg. 460). Compared with national data (proportion of all new cancer cases, 2001), the study participants were of similar age, but over-represented breast cancer cases and under-represented prostate and colorectal cancer cases. This was expected as a majority of our patients (62 %) were females.

Gold 2004

Methods	• Design: Randomized controlled trial. • Recruitment method: Thoracic Surgery Residents matriculating in 2002 were invited to participate in the trial. • Randomization: Yes, method not described. • Speciality: Thoracic surgery. • Setting: Hospital.

	• Country: United States.
Participants	• Type of participants: Thoracic surgery residents. • Inclusion criteria: Not stated. • Inclusion criteria: Not stated. • No of participants randomised: 138 residents.
Interventions	• Intervention: Prerequisite Curriculum (PRC), contains 75 segments organized with textbook and case-based navigational systems. CD-ROM internet hybrid curriculum. • Control: Curriculum outline.
Outcomes	• Knowledge, usage and ease of usage of the novel internet hybrid surgery curriculum. After TS residency matriculation, the self-evaluated knowledge and performance satisfaction scores were superior among PRC users in all categories. Simultaneous TS faculty evaluations of the same resident groups demonstrated smaller, but significant group differences. **Resident assessment:** • Resident knowledge assessment: (Surveys returned, PRC n = 46, -PRC n = 32) • Overall knowledge, PRC: 3.46, -PRC: 2.93, P < 0.05 • Teaching knowledge, PRC: 3.45, -PRC: 2.90, P< 0.05 • Application of knowledge, PRC: 3.42, -PRC: 2.87, P < Comfort, satisfaction, confidence, interest communication, study habits, organisation, etc. : PRC: 3.43, -PRC: 2.87, P < 0.05 **Faculty assessment:** • Resident knowledge assessment: (Surveys returned, PRC, n = 125, -PRC, n = 125)Overall knowledge, PRC: 3.65, -PRC: 3.54, P < 0.05 • Teaching of knowledge, PRC: 3.48, -PRC: 3.56 • Application of knowledge, PRC: 3.62, -PRC: 3.55, P < 0.05 • Comfort, satisfaction, confidence, interest, communication, study habits, organization, etc.: PRC: 3.84, -PRC: 3.76

	Most residents (55 / 69) responded to the written pre-matriculation surveys and indicated they used the PRC (43 / 55), averaging 1.45 hours weekly. Web-based tracking revealed that 47 / 69 actually used the PRC. Sessions averaged 23.3 minutes with an average of 148 sessions over the pre-matriculation year. The PRC was rated as easy to use (8.3 / 10), a valuable study guide (7.7 / 10), and superior to traditional texts and journals for pre-residency preparation (7.9 / 10).
Notes	• Study aim: prospective randomized trial testing resident acceptance and educational impact of a unique web-based curriculum system on pre-matriculated TS residents. • Pedagogical approach used: Individual eLearning, multimedia content. • Was a learning management system (LMS) used? No. • Journal: Annals of Surgery. • Year of publication: 2004. • Income status of country: High income. • Source of funding: This project has been supported in part by unrestricted educational grants from Ethicon Endosurgery Inc. (Cincinnati, OH), and by Edwards Lifesciences, LLC (Irvine, CA). • Conflict of interest: None stated.

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Residents to sign an informed consent allowing them to be prospectively randomised into one of 2 groups, those receiving the full CD-ROM Internet hybrid curriculum and those receiving only an outline of the content of the curriculum, appropriate references, but no educational content (pg. 502, implementation). Randomisation method not descried.
Allocation concealment (selection bias)	Unclear risk	No details given to enable judgement.
Blinding of outcome assessment	Unclear risk	No details given to enable judgement.

(detection bias)		
Incomplete outcome data (attrition bias)	Unclear risk	No details given to enable judgement.
Selective reporting (reporting bias)	Low risk	Table 5 shows the outcomes (pg. 502); of these "segment critique response analysis is not reported in the manuscript. However, the outcome is not an outcome of review interest; hence the risk of bias is low.
Other bias	High risk	Baseline comparison was not done between the groups. This study is limited by low usage of the curriculum materials (pg. 505, limitations, ln1). The educational outcome assessment tools that were used do not mirror the content that was delivered, nor do they separate the outcomes of a highly motivated learner from a less motivated learner (pg. 505, limitations, ln16). Further evaluation is of little potential for better comparative data, as the teaching tool will become more widely available and will likely be “shared” among residents and program directors. There is no way to accurately measure the amount of sharing that occurred prior to and following the matriculation date described in this prospective randomised study, thus contaminating the 2 groups (pg. 505, limitations, ln 28).

Grover 2010

Methods	• Design: Randomized controlled trial. • Recruitment method: Residents in 3 internal medicine residency programs (Brigham and Women’s Hospital [BWH], Massachusetts General Hospital [MGH], and North Shore Medical Center [NSMC]) were invited to participate in the study. • Randomization: Yes, Participants were stratified by level of training. Subjects were then randomized using a random number generator to 1 of 4 groups (pg. 549, study design). • Speciality: Internal medicine. • Setting: Hospital. • Country: United States.

Participants	• Type of participants: Internal medicine residents. • Inclusion criteria: Not stated. • Exclusion criteria: Not stated. • No of participants randomised: 210 residents.
Interventions	• Participants were stratified by level of training. Subjects were then randomised using a random number generator to 1 of 4 groups granting access to the video and associated text for (1) both CVL and AL procedures, (2) CVL but not AL, (3) AL but not CVL, or (4) neither procedure (Figure, pg. 550). • Intervention 1: Central venous line curriculum (CVL) and intervention. • Intervention 2: Arterial line curriculum and intervention. • Control 1: Central venous line control group. • Control 2: Arterial line control group.
Outcomes	• Difference in test scores between test 1 and test 2. • Baseline mean test scores were 62 % and 58 % in the CVL and AL tests, respectively. • Sixty-five residents completed all 3 CVL tests, and 85 residents completed all 3 AL tests. Access to the web-based procedure education was associated with a significant improvement in scores for both the CVL test (effect size, d = 0.25, P = 0.01) and AL test (d = 0.52, P = 0.001).
Notes	• Study aim: to evaluate the impact of a web-based education program on medical residents' knowledge of 2 advanced medical procedures. • Pedagogical approach used: Individual eLearning, text and procedure videos. • Was a learning management system (LMS) used? No. • Journal: Journal of Graduate Medical Education. • Year of publication: 2010. • Income status of country: High income. • Source of funding: Not stated. • Conflict of interest: None stated.

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Participants were stratified by level of training. Subjects were then randomized using a random number generator to 1 of 4 groups granting access to the video and associated text for (1) both CVL and AL procedures, (2) CVL but not AL, (3) AL but not CVL, or (4) neither procedure (pg. 549).
Allocation concealment (selection bias)	Unclear risk	No details given to enable judgement.
Blinding of outcome assessment (detection bias)	Unclear risk	No details given to enable judgement.
Incomplete outcome data (attrition bias)	Unclear risk	No details given to enable judgement.
Selective reporting (reporting bias)	Low risk	The primary outcome measure was the difference in test scores between test 1 and test 2 on each of the 2 procedural knowledge tests (AL and CVL), comparing participants who had access to the educational material to those residents who did not. Secondary outcomes included (1) the difference in self-reported complications between residents with access to the web-based procedural curriculum and those without access and (2) acceptability of the web-based educational program. (pg. 550). All pertinent outcomes were reported (pg. 551).
Other bias	Low risk	There were no significant differences between baseline scores by gender, residency track, training program, or year of training (pg. 551). Table 3, shows mean test scores at baseline and following the performance of the next 2 procedures (pg. 552). Though the study was powered to anticipate a low completion rate, the majority of participants completed only a single procedure report. The low number of second-procedure reports may be attributed

		to the low number of overall procedures performed by internal medicine residents, with vascular access increasingly obtained by emergency room staff and with residents spending limited continuous time in critical care units as a consequence of duty hour restrictions. Open-label trials can be subject to residual confounding that persists despite appropriate randomisation. These differences may account for the low completion / large dropout rate in this study. Residents in both arms of the study across study sites were likely to have received additional bedside and/or didactic teaching that was not part of this study. Although there were no differences in our results by study site, we cannot rule out residual confounding due to site differences in procedural training.

Gyorki 2013

Methods	• Design: Randomized controlled trial. • Recruitment method: Participants in the Clinical Oncology Society of Australia weekend seminar, titled 'Everything you need to know about breast cancer', were invited to participate in the study. Participation in both the weekend seminar and the study was voluntary, with attendees having to opt in to the programme. • Randomization: Yes, Participants were randomised to either the SE group or a control group (using the Research Randomizer software, version 3.0, http://www.randomizer.org). • Speciality: Oncology. • Setting: Hospital. • Country: Australia.
Participants	• Type of participants: Residents in general surgery, medical oncology and radiation oncology. • Inclusion criteria: Not stated. • Exclusion criteria: Not stated. • No of participants randomised: 97 residents.
Interventions	• Intervention: Online spaced education, the spaced

	education item includes a bank of 34 case scenarios, each with associated multiple-choice questions. Questions were related to all aspects of breast cancer therapy including surgery, chemotherapy, endocrine therapy, radiation oncology, supportive care and cancer genetics. The SE group received three case scenarios by email every 2 days. Immediate feedback was given after an answer was submitted. If a question was answered correctly, it would be repeated after a 20-day interval and if answered incorrectly, after an 8-day interval. When a question was answered correctly on two successive occasions, the question became retired. The course was completed after 80% of questions were retired. The emailing of participants was fully automated using publicly available online software (http://www.app.qstream.com). • Control: All participants in the control group received the bank of SE questions after completing the post-test.
Outcomes	• The post-test consisted of 22 questions. Thirteen questions were matched to questions covering a similar topic in the SE question bank and nine questions were unmatched, covering an aspect of the seminar that was not covered in the SE programme. • The residents randomised to the SE group had a significantly higher post-test score than the control group (72 versus 67 %, P = 0.03) (Fig. 2). This difference applied only to the questions that were 'matched' to the SE programme (74 versus 69 %, P = 0.02) and not to the unmatched questions (68 versus 65 %, P = 0.14). The highest scores (76 %) were seen in the subgroup of participants who had completed all questions but were not significantly better than the remainder of the SE group (P = 0.3).
Notes	• Study aim: This study was performed to assess whether an SE programme would improve the impact of a didactic seminar. • Pedagogical approach used: Individual eLearning, case-scenarios by email with feedback. • Was a learning management system (LMS) used? No. • Journal: Australia New Zealand Journal of Surgery. • Year of publication: 2013. • Income status of country: High income. • Source of funding: Not stated.

	• Conflict of interest: None stated.

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Participants were randomised to either the SE group or a control group (using the Research Randomizer software, version 3.0, http://www.randomizer.org) (pg. 478, study design and organization).
Allocation concealment (selection bias)	Unclear risk	No details given to enable judgement.
Blinding of outcome assessment (detection bias)	Unclear risk	No details given to enable judgement.
Incomplete outcome data (attrition bias)	High risk	Of the 49 residents randomised to the SE group, only 43 % completed the SE programme (pg. 489, results, ln 7). A greater proportion of the control group completed the post-test compared with the SE group (65 versus 57 %) (pg. 479, results, ln 14).
Selective reporting (reporting bias)	Low risk	All pertinent outcomes were reported.
Other bias	Unclear risk	Baseline comparison was not done.

Hadley 2010

Methods	• Design: Cluster Randomized controlled trial. • Recruitment method: The West Midlands Deanery leads the training programmes for all foundation-year doctors in the region. Approval was obtained from the Deanery, who granted us permission to undertake the trial. All of the hospitals in the region who were responsible for

	postgraduate medical education were recruited for the trial. • Randomization: The teaching hospitals were randomised by means of computer programme into two groups. • Speciality: Oncology. • Setting: Hospital. • Country: Australia.
Participants	• Type of participants: Foundation year two doctors (interns). • Inclusion criteria: All consenting foundation-year doctors from West Midlands Deanery. • Exclusion criteria: Not stated. • No of participants randomised: 7 Clusters involving 237 trainees.
Interventions	• Intervention: Group 1 received e-learning EBM teaching program (four clusters, 122 participants). • Control: Group 2 received standard classroom-based standalone EBM teaching sessions of equivalent content (three clusters, 115 participants).
Outcomes	• Knowledge gain and change in knowledge. • The total number of postgraduate trainees who completed the course was 88 in the intervention group and 72 in the control group. After adjusting for baseline knowledge, there was no difference in the amount of improvement in knowledge of EBM between the two groups. The adjusted post course difference between the intervention group and the control group was only 0.1 scoring points (95% CI −1.2 – 1.4).
Notes	• Study aim: To evaluate the educational effectiveness of a clinically integrated e-learning course for teaching basic evidence-based medicine (EBM) among postgraduate medical trainees compared to a traditional lecture-based course of equivalent content. • Pedagogical approach used: Individual eLearning, web-based self-instructed materials. • Was a learning management system (LMS) used? No. • Journal: Journal of the Royal Society of Medicine. • Year of publication: 2010. • Income status of country: High income. • Source of funding: Not stated.

	• Conflict of interest: None stated.

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	The teaching hospitals were randomised by means of computer programme into two groups: Group 1 – received the e-learning EBM teaching programme (experimental intervention) (four clusters, 122 participants); and Group2–received standard classroom-based standalone EBM teaching sessions of equivalent content (control group) (pg. 289, randomisation).
Allocation concealment (selection bias)	Low risk	The study mentions allocation concealment, pg. 292, comparison with other studies, "Concerning randomisation we ensured allocation concealment".
Blinding of outcome assessment (detection bias)	Unclear risk	No details given to enable judgement.
Incomplete outcome data (attrition bias)	Low risk	A total of 91 postgraduate trainees completed the pre course MCQs in the e-learning (intervention) group and 79 in the standard classroom teaching (control) group (pg. 291, results). Analyses were done in an intention-to-treat basis (pg. 290, analysis).
Selective reporting (reporting bias)	Low risk	All pertinent outcomes were reported.
Other bias	Unclear risk	Table 2 shows overall baseline knowledge scores and scores by teaching module for the two arms of the trial (pg. 291, results). The baseline comparison between the groups not done. Trainees in both groups showed high baseline knowledge for all modules prior to the EBM teaching and this left little margin for improvement in the post course scores, this may be due to previous training undertaken in the deanery.

Harris 2002

Methods	• Design: Randomized controlled trial. • Recruitment method: Kansas physicians who had not received more than 1 hour of CME instruction in DV during the prior year and who responded to an invitation to participate in a study of on-line DV education sent by the Johnson/Wyandotte Counties (Kansas) Medical Society were recruited. • Randomization: Yes, method not described. • Speciality: Family medicine. • Setting: Hospital. • Country: United States.
Participants	• Type of participants: Physicians. • Inclusion criteria: Physicians practicing in Kansan and who had not received more than 1 hour of CME instruction in DV during the prior year and who responded to an invitation to participate in a study of on-line DV education sent by the Johnson / Wyandotte Counties (Kansas) Medical Society. • Exclusion criteria: Not stated. • No of participants randomised: 99 physicians.
Interventions	• Intervention: Interactive, case based Domestic Violence education program targeted to physicians caring for DV patients. • Control: No intervention.
Outcomes	• Program effectiveness as measured by validated pretest / posttest instrument. • + 17.8 % mean change in confidence (self-efficacy) for physicians who took the Deprogram versus a -.6 % change for physicians who did not take the program. We also found improvements in other important areas associated with poor management of DV patients. These changes were similar or greater in magnitude to those reported by others who have used the same survey tool to evaluate an intensive, multi-hour classroom approach to DV education. User satisfaction with the online program was high. • A key item of the on-line DV program was an explanation of mandatory abuse reporting laws for healthcare providers. One question in the DV knowledge domain was "How much do you feel you know about your legal

	reporting requirements for DV?" Mean changes in scores for this question showed a 39.4 % increase for the intervention group versus a 5.1 % decrease for the control group (P < .005).
Notes	• Study aim: to develop an on-line DV education program that could achieve improvements in physician confidence and attitudes in managing DV patients comparable to classroom-based courses. • Pedagogical approach used: Individual eLearning, with case series and interactive case-based scenarios. • Was a learning management system (LMS) used? No. • Journal: Family Medicine. • Year of publication: 2002. • Income status of country: High income. • Source of funding: This work was supported by grant 1R43-MH62233 from the US National Institute of Mental Health (NIMH). The opinions and assertions contained herein represent those of the authors and not the NIMH. • Conflict of interest: None stated.

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Participating physicians who met the eligibility criteria were randomly assigned to either the intervention or control group (pg. 289, study design). Randomisation method not described.
Allocation concealment (selection bias)	Unclear risk	No details given to enable judgement.
Blinding of outcome assessment (detection bias)	Unclear risk	No details given to enable judgement.
Incomplete outcome data	High risk	Sixty-five (66 %) of the 99 eligible physicians completed both the pretest and posttest survey. Figure 1 shows the drop

(attrition bias)		outs in the study.
Selective reporting (reporting bias)	Low risk	The specific objectives of the on-line DV program were to (1) increase physicians' ability to recognize victims of DV by increasing their use of office-based screening tools, (2) improve physicians' knowledge of risk assessment techniques, (3) improve medical record documentation of recognized cases of DV, (4) increase physicians' self-efficacy in managing DV victims, and (5) increase physicians' self-efficacy in managing DV perpetrators (pg. 288, methods), pertinent outcomes were reported in the results section.
Other bias	Low risk	Demographic and other baseline characteristics were evenly balanced between the intervention (28 physicians) and control (37 physicians) groups (Table 2) (pg. 290, results). Study subjects were predominantly male (70%) and white, non-Hispanic (81%). Demographic and other baseline characteristics were evenly balanced between the intervention (28 physicians) and control (37 physicians) groups (Table 2).

Hearty 2013

Methods	• Design: Randomized controlled trial. • Recruitment method: Orthopaedic surgery residents were recruited from the four participation academic institutions. • Randomization: Yes, the randomisation was completed by a coin flip (pg. e126 (2)). • Speciality: Orthopaedic surgery. • Setting: Hospital. • Country: United States.
Participants	• Type of participants: Orthopaedic surgery residents. • Inclusion criteria: The residents were naive to a closed reduction and percutaneous pinning of a paediatric supracondylar humeral fracture and had not completed a paediatric orthopaedic rotation, with the exception of one fourth-year resident who completed a paediatric rotation but had never participated in a supracondylar humeral

	fracture case. • Exclusion criteria: Residents were excluded if they had completed a closed reduction and percutaneous pinning supracondylar case prior to collecting data. • No of participants randomised: 28 residents.
Interventions	• Intervention: The test group was given instructions and access to the web-based computer enhanced visual learning [CEVL]; CEVL training module and was provided with the procedure preparedness test after completion of the e-learning module. • Control: The control group was given the procedure preparedness test without access to the CEVL training module. After each control group subject submitted a completed test, he or she completed the e-learning module as well.
Outcomes	• Usefulness of the module and their comfort in the operating room after the CEVL e-learning training • The test group scored significantly better ($P < 0.001$) and demonstrated competence on the test compared with the control group; the mean correct test score (and standard deviation) was 90.9 % ± 6.8 % for the test group and 73.5 % ± 6.4 % for the control group. All residents surveyed (n = 27) agreed that the module is a useful supplement to traditional methods for case preparation and twenty-two of twenty-seven residents agreed that it reduced their anxiety during the case and improved their attention to surgical detail. **Preparedness testing:** The test group scored significantly higher ($p < 0.001$) than the control group; the correct mean test score (and standard deviation) was 90.9 % ± 6.8 % for the test group and 73.5 % ± 6.4 % for the control group (Fig. 2). The test group scored significantly higher than the control group for each PGY class as well (Table I).
Notes	• Study aim: The study hypothesized that e-learning could increase resident knowledge acquisition for case preparation in the operating room. • Pedagogical approach used: Individual eLearning, web-based module with multimedia. • Was a learning management system (LMS) used? No. • Journal: The Journal of Bone & Joint Surgery America. • Year of publication: 2013. • Income status of country: High income.

	• Source of funding: This project was funded internally by a department grant and there was no external funding. Funds were used to pay for implementation and management of the module. • Conflict of interest: None stated.

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	The subjects were randomised into one of two groups, a control group or a test group. The randomisation was completed by a coin flip (pg. e (126(2)).
Allocation concealment (selection bias)	Unclear risk	No details given to enable judgement.
Blinding of outcome assessment (detection bias)	Unclear risk	No details given to enable judgement.
Incomplete outcome data (attrition bias)	Low risk	Twenty-eight subjects (fourteen per group) completed the project. All subjects randomised completed the study (pg. e126 (4), results).
Selective reporting (reporting bias)	Low risk	All pertinent outcomes listed in the methods reported.
Other bias	High risk	Baseline characteristics were compared only for post-graduate year. All residents were considered naive prior to enrolment but may have had differing levels of knowledge regarding supracondylar humeral fractures from conferences, previous discussions with other residents and attending surgeons, and other past learning experiences. In addition, the survey completed by the residents and attending surgeons was not validated and reliability not tested. And lastly, this study did not compare surgical performance with and without the module.

Hemmati 2013

Methods	• Design: Quazi randomised trial. • Recruitment method: A convenience sample of general physician trainees was selected from Kermanshah University of medical sciences and health services. • Randomization: The selected trainees were randomly assigned to experimental and control groups (pg. 257, methods). • Speciality: General physician. • Setting: Hospital. • Country: United States.
Participants	• Type of participants: General physician trainees. • Inclusion criteria: Not stated. • Exclusion criteria: Not stated. • No of participants randomised: 80 trainees.
Interventions	• Intervention: Internet based learning (IBL), a program was designed based on the newest curriculum guidelines and deployed on a learning management system (LMS). The internet based CME was power point presentation that incorporated photography, video, text, narrative and animation which permitted some interaction with the material. The Internet based CME started with a brief explanation on how to navigate the course. Then it was organized into three sections: section I presented the objectives and utility of the instruction. Section II was organized on an explanation of the CPR algorithm. And section III was a simple simulation which included examples and Scenario-based with feedback and a review of course material. This section presents realistic scenarios portrayed through video footage, photographs and animations alongside essential text. The pre- and post-test results were automatically uploaded to the learning management system of university into a protected account, to be accessed by the researcher and module leaders responsible for CPR testing. • Control: Traditional classroom lecture (TCL), a full time professor with considerable experience in the subject and whose teaching skills are recognized

	throughout the university presented the lecture. This professor was blinded about the other program. The professor had 6 hours to lecture using the content developed for the Internet Based CME material only in terms of text and photography
Outcomes	• Knowledge was measured by an instructor-developed 20 item multiple-choice test based on articles published in journals and books, as well as on content specialist teaching experience. Post course satisfaction survey was done using a 15 evaluative statements rated along the questions based on a fire-point Likert scale. • Participants in the TCL group reported an overall mean pre-knowledge score of 68.5 ± 5.68 and a post-knowledge score of 83.12 ± 5.84. Participants in the IBL group reported an overall mean pre-knowledge score of 67.87 ± 5.41 and a post-knowledge score of 85.5 ± 5.16. A paired samples t-test analyses indicated a significant pre to post-knowledge increase ($p \leq 0.001$) for both program group at the $P < 0.05$ probability level. There was no significant difference in pre and post-knowledge assessment results between the two groups ($P > 0.05$). • The satisfaction ratings suggest respondents were very satisfied with the IBL format. An independent t-test analysis indicated that participants in the IBL format reported significantly higher mean ratings for this format (62.5 ± 2.32) than TCL format (54.6 ± 2.18) ($P = .001$). The mean time for Internet based CME group was 145 minutes ranging from 125 minutes to 182 minutes. The time required for IBL included pretest, provide educational content to the participants until the end of learning, and post-tests performed by each participant with self-pace learning. While the time required for the traditional classroom lecture based on the written CME course design was 6 hours.
Notes	• Study aim: The purpose of this study was to compare the satisfaction and effectiveness of Internet-based learning (IBL) and traditional classroom lecture (TCL) for continuing medical education (CME) programs by comparing final resuscitation exam

	results of physicians who received the newest cardiopulmonary resuscitation (CPR) curriculum guidelines training either by traditional or by an Internet-based CME. • Pedagogical approach used: Individual eLearning, web-based module. • Was a learning management system (LMS) used? Yes, name not described. • Journal: Turkish Online Journal of Distance Education. • Year of publication: 2013. • Income status of country: Upper - Middle income. • Source of funding: Not stated. • Conflict of interest: None.

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	The participants enrolling in the program by the calling of Kermanshah university of medical sciences and health services (convenience sampling) and then randomly assigned to experimental (n = 40) and control (n = 40) in two groups (pg. 257, methods). Randomisation method not described.
Allocation concealment (selection bias)	Unclear risk	The participants enrolling in the program by the calling of Kermanshah university of medical sciences and health services (convenience sampling) and then randomly assigned to experimental (n = 40) and control (n = 40) in two groups and were unaware that two teaching methods were compared during the programs (pg. 257, participants). No allocation concealment was mentioned.
Blinding of outcome assessment (detection bias)	Unclear risk	No details given to enable judgement.
Incomplete outcome data (attrition bias)	Low risk	No drop out from the study.

Selective reporting (reporting bias)	Low risk	All pertinent outcomes reported.
Other bias	Low risk	Demographic information statistic for each group is provided in table 1. There was no significant difference in variables included gender, age, years of experience, marital status, and the ability to use computers between the two groups (pg. 259).

Houwink 2014

Methods	• Design: Randomized controlled trial. • Recruitment method: General practitioners (GPs) working full time or part time in family practice were eligible for inclusion in the study. • Randomization: For sampling and random assignment of participants to the intervention and control group, a pseudo random number generator was used for which the operator was not otherwise involved in the intervention or data analysis (pg. 311, study participants, ln 12). • Speciality: General practice. • Setting: Hospital. • Country: Netherlands.
Participants	• Type of participants: General practitioners. • Inclusion criteria: General practitioners (GPs) working full time or part time in family practice were eligible for inclusion in the study. • Exclusion criteria: Not stated. • No of participants randomised: 80 GPs.
Interventions	• Intervention: Online genetic module, it provided access to didactic presentations, clinical genetic cancer consultations in daily practice; interactive cases on breast cancer due to BRCA mutations and on colon cancer (e.g. Lynch syndrome) due to APC / mismatch-repair gene mutations, and enabling tools such as information about regional possibilities for referral and consultation. • Control: No intervention.

Outcomes	• Knowledge, satisfaction, time spent and applicability. • Satisfaction with the module was high, with the three item's scores in the range 4.1 – 4.3 (5-point scale) and a global score of 7.9 (10-point scale). Knowledge gains posttest and at retention test were 0.055 ($P < 0.05$) and 0.079 ($P < 0.01$), respectively, with moderate effect sizes (0.27 and 0.31, respectively). The participants appreciated applicability in daily practice of knowledge aspects (item scores 3.3 – 3.8, five-point scale), but scores on self-reported identification of disease, referral to a specialist and knowledge about the possibilities/limitations of genetic testing were near neutral (2.7 – 2.8, five-point scale).
Notes	• Study aim: We designed a Genetics e-learning Continuing Professional Development (CPD) module aimed at improving general practitioners' (GPs') knowledge about oncogenetics, and we conducted a randomized controlled trial to evaluate the outcomes at the first two levels of the Kirkpatrick framework(satisfaction, learning and behavior). • Pedagogical approach used: Individual eLearning, web-based module with options to monitor participant's progress, test and survey completion. • Was a learning management system (LMS) used? No. • Journal: European Journal of Human Genetics. • Year of publication: 2014. • Income status of country: High income. • Source of funding: This study is part of the research programs of the Centre for Society and the Life Sciences and the Centre of Medical Systems Biology in The Netherlands, funded by the Netherlands Genomics Initiative. • Conflict of interest: None.

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	For sampling and random assignment of participants to the intervention and control group, a pseudo random number generator was used for which the operator was not otherwise involved in the intervention or data analysis. The results of the randomisation were communicated to the NHG but not to the researchers (pg. 311, study participants)
Allocation concealment (selection bias)	Unclear risk	No details given to enable judgement.
Blinding of outcome assessment (detection bias)	Unclear risk	No details given to enable judgement.
Incomplete outcome data (attrition bias)	High risk	Of the total of 80 participating physicians (40 intervention group and 40 control group), 44 (20 intervention, 24 control group) completed all the learning activities, knowledge tests and questionnaires (Figure 1). Thirty-six participants were lost to follow-up; 22 did not participate because of time limitation or illness, and 14 did not respond to requests for information (pg. 313, results).
Selective reporting (reporting bias)	Low risk	All pertinent outcomes listed in the methods section reported.
Other bias	Low risk	There were no significant differences between intervention and control group in age, gender, years of experience in primary care, type of practice and practice situation (pg. 313).

Houwink 2015

Methods	• Design: Randomized controlled trial. • Recruitment method: The GPs who had previously participated in the accompanying evaluation studies and were enrolled (pg. 5, participants). • Randomization: Randomisation method not described. • Speciality: General practice. • Setting: Hospital. • Country: Netherlands.
Participants	• Type of participants: General practitioners. • Inclusion criteria: General practitioners (GPs) working full time or part time in family practice were eligible for inclusion in the study. • Exclusion criteria: Not stated. • No of participants randomised: 168 GPs.
Interventions	• Intervention: G-eCPD online oncogenetics training. • Control: Live module.
Outcomes	• An online questionnaire on self-reported genetic competencies and changes in referral behaviour • Referral rates from GPs to clinical genetics centers and • Satisfaction questionnaire and • Visitor count analytics of supportive genetics website.
Notes	• Study aim: The study investigates long-term increase in genetic consultation skills (1-year follow-up) and interest in and satisfaction with a supportive website on genetics among GPs. • Pedagogical approach used: Individual eLearning, web-based module with options to monitor participants' progress, test and survey completion. • Was a learning management system (LMS) used? No. • Journal: PLoS ONE • Year of publication: 2015 • Income status of country: High income. • Source of funding: This study is part of the research programs of the Centre for Society and the Life Sciences and the Centre of Medical Systems Biology

	in The Netherlands, funded by the Netherlands Genomics Initiative. • Conflict of interest: None.

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Randomization done, method not described.
Allocation concealment (selection bias)	Unclear risk	No details given to enable judgement.
Blinding of outcome assessment (detection bias)	Unclear risk	No details given to enable judgement.
Incomplete outcome data (attrition bias)	High risk	Participation rates were 52% [G-eCPD] and 57% [live training]. (pg. 11, strengths and limitations)
Selective reporting (reporting bias)	Low risk	All pertinent outcomes listed in the methods section reported.
Other bias	Low risk	Baseline comparison not done, voluntary participation by interested GPs may have caused selection bias. (pg. 11, strengths and limitations)

Hugenholtz 2008

Methods	• Design: Randomized controlled trial. • Recruitment method: Participants were recruited from a series of four mental health care meetings conducted in 2006. • Randomization: Occupational Physicians' were randomly assigned to four different groups in order of arrival at the meeting, by means of a four-block randomisation system. • Speciality: Occupational health. • Setting: Hospital.

	• Country: Netherlands.
Participants	• Type of participants: Occupational Physicians. • Inclusion criteria: Not stated. • Exclusion criteria: Not stated. • No of participants randomised: 74 OPs.
Interventions	• Intervention 1: e-learning based teaching, Group A. • Intervention 2: e-learning based teaching, Group B. • Control 1: Lecture based teaching, Group C. • Control 2: Lecture based teaching, Group D.
Outcomes	• Knowledge was tested through 30 true/false questions and three open-ended ones. • As the baseline scores of both knowledge tests X and Y (mean 52.9, SD 9.2 and mean 51.5, SD 8.1, respectively) did not differ significantly. Two versions of the test, version X and Y, each containing different questions from the pool were generated. The use of the knowledge tests was counterbalanced: one e-learning group completed test X before finishing the e-learning module and test Y after finishing. The other e-learning group completed test Y before the e-learning module and test X after finishing it. The same procedure was used in the two lecture-based learning groups. • Although the scores of the based Group C 55.0 (10.0) X 63.8 (7.3) Y Group D 49.7 (7.4) Y 64.9 (10.5) X four groups differed at baseline, they differed not significantly within each teaching approach as well as between the two teaching approaches. Both learning approaches significantly enhanced OPs' knowledge on mental health care issues. The mean score for the e-learning approach was 52.1 (SD 8.4) at baseline and 65.1 (SD 9.6) at post-test ($P < 0.05$). For the lecture-based approach, the mean score was 52.3 (SD 9.0) at baseline and 64.3 (SD 9.0) at post-test ($P < 0.05$). The improvement in knowledge did not differ significantly between these groups.
Notes	• Study aim: To evaluate the effect of e-learning on knowledge on mental health issues as compared to lecture-based learning in a CME programme for OPs. • Pedagogical approach used: Individual eLearning,

	self-directed web-based module. • Was a learning management system (LMS) used? No. • Journal: Occupational Medicine. • Year of publication: 2008. • Income status of country: High income. • Source of funding: Not stated. • Conflict of interest: None.

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Occupational Physicians' were randomly assigned to four different groups in order of arrival at the meeting, by means of a four-block randomisation system. Randomisation method not described.
Allocation concealment (selection bias)	Unclear risk	No details given to enable judgement.
Blinding of outcome assessment (detection bias)	Unclear risk	No details given to enable judgement.
Incomplete outcome data (attrition bias)	Low risk	No evidence of attrition, only two OPs in the lecture-based group was excluded because they arrived too late (pg. 371, results).
Selective reporting (reporting bias)	Low risk	All pertinent outcomes reported.
Other bias	Unclear risk	The baseline characteristics of the OPs are described in Table 1. Only the years of experience as an OP differed significantly between both groups. As the baseline scores of both knowledge tests X and Y (mean 52.9, SD 9.2 and mean 51.5, SD 8.1, respectively) did not differ significantly (pg. 371, results).

Hymowitz 2007

Methods	• Design: Random allocation only (Cluster). • Recruitment method: All first, second, and third-year residents in each participating residency-training program (n = 2069 during the four years of training) were invited to take part in program training activities. • Randomization: Yes, sixteen paediatric residency-training sites in New York and New Jersey were recruited and assigned randomly (coin toss) to special or standard training conditions (pg. 3). • Speciality: Paediatrics. • Setting: Hospital. • Country: United States.
Participants	• Type of participants: First, second and third-year paediatric residents. • Inclusion criteria: Not stated. • Exclusion criteria: Not stated. • No of clusters / participants randomised: 16 paediatric residency training programs involving 2069 residents.
Interventions	• Intervention: Special training, Solutions for Smoking served as the main teaching tool for the special training condition. The website provided didactic material on Environmental Tobacco Smoke (ETS), tobacco use, prevention, and cessation, as well as intervention and interviewing strategies derived from the “5 A's” model of tobacco intervention (ask about tobacco, advise change, assess readiness for change, assist behavior change, and arrange follow-up), the Trans theoretical Model of Behavior Change, motivational interviewing, and pharmacological and behavioral approaches to smoking cessation. The CD-ROM contained audiovisual vignettes that modelled clinical encounters between doctors and patients / parents. • Control: Standard training, standard training residents received background reading material, attended the seminar series, and utilized standard educational and behavior change materials to facilitate intervention with patients and parents in continuity clinic. They

	did not have access to Solutions for Smoking, companion intervention material, or clinic mobilization and the vignettes were not shown in the seminars.
Outcomes	The percent of residents in special training, but of not those in standard training, who provided assistance for modifying environmental tobacco smoke, preventing use, and helping patients and parents stop smoking increased significantly from baseline to year 4 of training, as did the percent who felt prepared to address tobacco. Performance on the OSCEs was consistent with survey outcomes, as special training residents' revealed mastery of key interviewing and intervention skills. **Program participation:** About 70 % of the residents in special training reported that they reviewed Solutions for Smoking in year 4, an increase from year 2 (60 %). More residents viewed the audio / visual vignettes (> 90 %) at years 2 and 4. About 60 % of the residents in standard training reported reading some or all of the background material in years 2 and 4 of training. **Beliefs about effectiveness of intervention:** The residents in special training rated the efficacy of each intervention significantly higher at Year 4 than residents in standard training (Table 4) (pg. 6). **Tobacco intervention** **Environmental tobacco smoke (ETS)** • Percent of residents who assisted parents to create a smoke-free household and to protect children from ETS increased significantly for special training, but not for standard training (table 5, pg. 17). • The difference in the percentages of residents in each group at year 4 who helped parents modify ETS exposure approached statistical significance (60.6 % for special training vs. 41.7 % for standard training; F = 4.7, p = .052), while the difference in the use of material on how to modify ETS exposure was significant (58.6 % for special training vs. 37.5 % for standard training; F = 7.1, P = .021) (pg. 6). **Prevention** • Fewer residents addressed tobacco advertising or

	engaged in role-playing, although the increase from baseline for the latter was statistically significant for special training. • Special training residents also revealed a significant increase in provide material on smoking (tobacco use) prevention, although the absolute magnitude of endorsement (35.5 %) was modest. • The percentage of special training residents that indicated that they felt prepared or very prepared to encourage a young person not to start smoking (or using other forms of tobacco) increased significantly from baseline (51.4 %) to year 4 of training (75.2 %), and the increase also was apparent at year 2 (80 %) (Table 6). For standard training residents, the changes from baseline were not significant.
Notes	• Study aim: To evaluate the effect of e-learning on knowledge on mental health issues as compared to lecture-based learning in a CME programme for OPs. • Pedagogical approach used: Facilitated eLearning, website provided didactic materials as well audio visual vignettes and seminars • Was a learning management system (LMS) used? No. • Journal: Preventive Medicine. • Year of publication: 2007. • Income status of country: High income. • Source of funding: The conduct of the Pediatric Residency Training on Tobacco Project was supported, in part, by NICHHD/NIH grant # RO1 HD40683 to Drs. Norman Hymowitz, Joseph Schwab, and Christopher Keith Haddock. • Conflict of interest: None stated.

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Paediatric training sites were randomised, sixteen paediatric residency-training sites in New York and New Jersey were recruited and assigned randomly (coin toss) to special or standard training conditions.

Allocation concealment (selection bias)	Unclear risk	No details given to enable judgement.
Blinding of outcome assessment (detection bias)	Unclear risk	No details given to enable judgement.
Incomplete outcome data (attrition bias)	Unclear risk	No details given to enable judgement.
Selective reporting (reporting bias)	Low risk	All pertinent outcomes were reported.
Other bias	Unclear risk	Residents in each condition were similar in age and gender, with little variation over time (Table 2). Baseline comparison of characteristics for standard training and special training are presented in table 2, statistical comparison was done only within the two groups not between them (pg. 14).

Kerfoot 2007

Methods	• Design: Randomised Controlled Trial. • Recruitment method: Urology residents were recruited via e-mail announcement in May 2005. Participation was voluntary. • Randomization: Yes, after being stratified by gender and urological training year residents were randomised at a single time point to 1 of 2 intervention arms (fig. 1, pg. 1483). • Speciality: Urology. • Setting: Hospital. • Country: United States.
Participants	• Type of participants: Urology residents. • Inclusion criteria: All urology residents in the United States and Canada who would be taking the November 2005 AUA Urology ISE were eligible to enroll in the study. • Exclusion criteria: Participants who did not agree to participate were excluded. • No of participants randomised: 537 urology residents.

Interventions	• Intervention 1: Cohort 1, Bolus education, for intervention cohort 1 (bolus education) a PDF file of the educational materials (the 96 selected SASP study questions) was distributed to residents as an e-mail attachment in study week 1. • Intervention 2: Cohort 2, Spaced education, for intervention cohort 2 (spaced education) residents received daily (Monday to Saturday) e-mails starting on study week 1, each containing 1 or 2 of the 96 SASP study questions. • The educational material sent to both cohorts was identical. In cohort 2 no more than 2 self-assessment study program (SASP) questions were presented in a single e-mail. Study questions were repeated in an expanding spaced pattern with cycled reviews at 1 week (7 days) and 3 weeks (mean 22.5 days) after the initial presentation of the material. As a result, there was a 3-week ramp up period to build up to the cycled repetitions, a 21-week steady-state period and a 3-week ramp-down period.
Outcomes	• 537 randomised residents, were randomised into 5 outcome cohorts and their outcomes were assessed by online test at different time points, cohort 1 (1 - 2 weeks), cohort 2 (3 - 4 weeks), cohort 3 (5 - 6 weeks), cohort 4 (9 - 10 weeks) and cohort 5 (13 - 14 weeks). • Of 537 participants 400 (74 %) completed the online staggered tests and 515 (96 %) completed the In-Service Examination. Residents in the spaced education cohort demonstrated significantly greater online test scores than those in the bolus cohort (ANOVA P = 0.001). One-way ANOVA with trend analysis revealed that online test scores for the spaced education cohort remained stable with no significant differences with time, while test scores in the bolus cohort demonstrated a significant linear decrease (P = 0.007). The specific learning gains attributable to Spaced Education were robust when controlling for use of the study materials but they did not generalize to higher scores on the In-Service Examination. • Follow-up at 2 years: Residents in the spaced education cohort had significantly greater test scores than residents in the bolus cohort (mean ± SD 70.2 %

	± 9.0 % vs 66.8 % ± 10.6 %, effect size 0.35, P = 0.03).
Notes	• Study aim: We investigated whether an online educational program based on spacing effect principles could significantly improve the acquisition and retention of medical knowledge. • Pedagogical approach used: Individual eLearning, email delivery of learning content. • Was a learning management system (LMS) used? No. • Journal: Journal of Urology. • Year of publication: 2007. • Income status of country: High income. • Source of funding: Supported by grants from the American Urological Association, Linthicum, Maryland and Pellegrino Foundations, Boston, Massachusetts; and by the Research Career Development Award Program of the Veterans Affairs Health Services Research and Development Service; American Urological Association Foundation, Linthicum, Maryland; and Astellas Pharma US, Inc. • Conflict of interest: None stated.

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	After being stratified by gender and urological training year residents were randomised at a single time point to 1 of 2 intervention arms (fig. 1, pg. 1482). Randomisation method not described.
Allocation concealment (selection bias)	Unclear risk	No details given to enable judgement.
Blinding of outcome assessment (detection bias)	Unclear risk	No details given to enable judgement.
Incomplete outcome	High risk	Loss to follow up is shown in figure 1, no mention of intention to treat in the

data (attrition bias)		analysis.
Selective reporting (reporting bias)	Low risk	All pertinent outcomes reported.
Other bias	Low risk	Characteristics of participants randomised to intervention cohorts, table 1 (pg. 1484) show no difference. There were no significant differences in the background characteristics between the intervention and outcome cohorts (tables 1 and 2).

Kerfoot 2014

Methods	• Design: Randomised Controlled Trial. • Recruitment method: Participants were recruited via e-mail. • Randomization: PCPs were stratified by hospital and block randomised (block size = 4) into 2 cohorts (Figure 1) (pg. 469). • Speciality: Primary care. • Setting: Hospital. • Country: United States.
Participants	• Type of participants: Primary care practitioners (PCPs). • Inclusion criteria: PCPs with ≥ half-time clinical effort were eligible to enroll. • Exclusion criteria: Patients were excluded if they had visits with clinicians from both intervention and control cohorts. • No of participants randomised: 111 PCP's
Interventions	• SE clinicians were enrolled in the game, whereas control clinicians received identical educational content in an online posting. SE game clinicians were e-mailed 1 question every 3 days. Adaptive game mechanics resent questions in 12 or 24 days if answered incorrectly or correctly, respectively. Clinicians retired questions by answering each correctly twice consecutively. Posting of relative performance among peers fostered competition.

Outcomes	• Primary outcome measure was time to BP target (< 140 / 90 mmHg). • The SE game was completed by 87 % of clinicians (48 / 55), whereas 84 % of control clinicians (47 / 56) read the online posting. In multivariable analysis of 17 866 hypertensive periods among 14 336 patients, the hazard ratio for time to BP target in the SE game cohort was 1.043 (95% confidence interval, 1.007 – 1.081; P = 0.018). The number of hypertensive episodes needed to treat to normalize one additional patient's BP was 67.8. The number of clinicians needed to teach to achieve this was 0.43.
Notes	• Study aim: The study investigated whether an online spaced-education (SE) game among primary care clinicians can decrease time to BP target among their hypertensive patients. • Pedagogical approach used: Individual eLearning, spaced education game structured in a question-explanation format, email delivery of questions with clinical scenarios. • Was a learning management system (LMS) used? No. • Journal: Circulation: Cardiovascular Quality and Outcomes. • Year of publication: 2014. • Income status of country: High income. • Source of funding: This study was supported in part by the American Urological Association (Linthicum, MD), the American Urological Association Foundation (Linthicum, MD), Astellas Pharma US, Inc., and the United States Agency for Healthcare Research and Quality. • Conflict of interest: None.

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	PCPs were stratified by hospital and block randomised (block size=4) into 2 cohorts (Figure 1) (pg. 469). Randomisation method not described.

Allocation concealment (selection bias)	Unclear risk	No details given to enable judgement.
Blinding of outcome assessment (detection bias)	Unclear risk	No details given to enable judgement.
Incomplete outcome data (attrition bias)	Low risk	All participants completed the pretest at enrolment, and 95 % (52 / 55) and 93 % (52 / 56) of SE game and control group clinicians completed the posttest, respectively (Figure 1). Mean pretest scores were similar for both cohorts: 58 % (SD, 15) and 60 % (17) for SE game and control clinicians, respectively (P = 0.44) (pg. 470, results). Less than 5% drop out rate.
Selective reporting (reporting bias)	Low risk	All pertinent outcomes reported.
Other bias	Low risk	Participants' baseline demographic characteristics were similar between randomised cohorts (Table 1) (pg. 471, results). The recruitment of 37 % of eligible PCPs and its restriction to northeastern VA hospitals where practice patterns may differ from other regions. Although we worked to assess all meaningful covariates in our analyses, some meaningful covariates may not have been assessed, and thus, the analyses may not fully account for the clustering of data within providers. The intervention cohort received more frequent e-mail notifications compared with the control group; we cannot exclude that these e-mail reminders rather than their content generated the improved hypertension outcomes in our study (pg. 473, discussion).

Koppe 2016

Methods	• Design: Random allocation only • Recruitment method: Participation was voluntary (pg. 2, sample/setting) • Randomization: Yes, method not described • Speciality: Primary care • Setting: University • Country: Australia
Participants	• Type of participants: General practitioners and General practice registrars • Inclusion criteria: Not stated • Exclusion criteria: Not stated • No of participants randomised: 14 GPs and 12 GP registrars
Interventions	• Intervention: Balient groups were delivered over 8-9 fortnightly online sessions via WebEx • Control: Received no intervention
Outcomes	• Psychological Medicine Inventory (PMI) • Warr's Work-Related Affect Scale (WWAS) • Professional isolation scale (PIS)
Notes	• Study aim: To evaluate online Balint groups for rural doctors and determine effect size for a full-scale trial. • Pedagogical approach used: Collaborative learning • Was a learning management system (LMS) used? No • Journal: The Australasian Journal of Rural Health • Year of publication: 2016 • Income status of country: High income • Source of funding: Not stated • Conflict of interest: None stated.

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Random allocation, randomisation method not described.
Allocation concealment (selection bias)	Unclear risk	No details given to enable judgement.
Blinding of outcome assessment (detection bias)	Unclear risk	No details given to enable judgement.
Incomplete outcome data (attrition bias)	Low risk	One control group GP, two control group registrars and two intervention group registrars dropped out. (pg. 4, results)
Selective reporting (reporting bias)	Low risk	All results mentioned in methods are reported.
Other bias	High risk	However, baseline comparison not done, study limitations include the small sample (<30), the inability to blind participants to the intervention and the possibility of social desirability response bias (pg. 5, discussion)

Kronick 2003

Methods	• Design: Randomised Controlled Trial. • Recruitment method: a survey was mailed to the 489 rural physicians on the Ontario Medical Association's Rural and Isolated Physician mailing list for postal codes in southwestern Ontario. Eligible physicians were identified from the survey. • Randomization: Yes, method not described. • Speciality: Physicians. • Setting: University. • Country: Canada.
Participants	• Type of participants: Physicians. • Inclusion criteria: Physicians were eligible to participate in the study if they practiced in a rural community (defined as a population of 15 000 or

	less) in southwestern Ontario, had a computer with Internet access, completed the initial questionnaire, and agreed to participate in the study. • Exclusion criteria: Not stated. • No of participants randomised: 81 physicians.
Interventions	• Intervention: A 2-day workshop for four rural southwestern Ontario community hospital librarians covering Chatham, Sarnia, Owen Sound, and Huron-Perth was given at UWO .Intervention physicians received an extensive reference binder, 6 months of on-line access to current medical databases, borrowing privileges at the UWO library, a university e-mail account, and a service delivering journal articles and other documents to their offices. The UWO library mounted a special website for their use with evidence-based links and practice guidelines. Immediately after the training, intervention group physicians completed an end-of-training feedback form to measure the effectiveness of the instructional session. The librarians also filled out a physician contact report for each visit. • Control: Control physicians received neither training nor access to the UWO library system. Three months after the educational intervention, questionnaires were sent to all control and intervention physicians to measure changes in comfort level and frequency with which they consulted electronic medical resources to address patient-related problems.
Outcomes	• Frequency of access and comfort with on-line medical information were compared after intervention with baseline data. • At follow up, the intervention group showed a significant improvement over the control group in their frequency of accessing the World Wide Web to address patient-related questions (P = .009), in their comfort level in using on-line databases (P = .032), and in their frequency of accessing on-line databases (P = .044).
Notes	• Study aim: To assess the change in frequency and methods with which a pilot group of rural physicians consulted on-line medical resources before and after

	an educational intervention. • Pedagogical approach used: Individual eLearning, training sessions on EBM and provision of access to medical databases. • Was a learning management system (LMS) used? No. • Journal: Canadian Family Physician. • Year of publication: 2003. • Income status of country: High income. • Source of funding: This study was supported by a grant from the Ontario Medical Association's CME Program for Rural and Isolated Physicians and additional financial support from Associated Medical Services Inc. We thank the four rural librarians, Jill Campbell, Margaret Campbell, Elyse Pike, and Linda Wilcox, for their contributions to this study; Penny Westmacott for her technical assistance; and Larry Stitt for his statistical expertise. • Conflict of interest: None.

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Eligible physicians were then randomly allocated to either the educational intervention or the control group (pg. 313). Randomisation method not described.
Allocation concealment (selection bias)	Unclear risk	No details given to enable judgement.
Blinding of outcome assessment (detection bias)	Unclear risk	No details given to enable judgement.
Incomplete outcome data (attrition bias)	High risk	Eleven of the intervention physicians did not complete the study because they were unable to schedule the librarians' visit. (pg. 314, results), no mention of intention to treat analysis.
Selective reporting (reporting bias)	Low risk	All listed outcomes in the methods section were reported.

Other bias	Low risk	Table 1 gives demographic characteristics and importance of computer training at the time of enrolment. There were no major differences between the two groups including their rating of the importance of training. The control group saw more barriers; there were more specialists in the intervention group.

Kulier 2009

Methods	• Design: Cluster randomised controlled trial. • Recruitment method: Not stated. • Randomization: Yes, random allocation sequence was generated by computer. • Speciality: Obstetrics and Gynaecology. • Setting: University. • Country: United Kingdom.
Participants	• Type of participants: Postgraduate trainees in six obstetrics and gynaecology departments. • Inclusion criteria: Participants were obstetrics and gynaecology trainees in clinical teaching hospitals who did not rotate between clusters during the study period. • Exclusion criteria: Not stated. • No of clusters / participants randomised: There were six clusters involving teaching of 61 postgraduate trainees (28 in the intervention and 33 in the control group).
Interventions	• Intervention: The clinically integrated e-learning course consisted of five modules, each comprising self-directed e-learning components and clinically related activities, under the guidance of a facilitator (table 1). The curriculum http://www.ebm-unity.org. • Control: In the control group, the material covered in the e-learning module was presented by a tutor during classical lecture-based teaching sessions over the same time period. The tutors presented from the same power point slides used in the intervention group.
Outcomes	• Outcomes (knowledge gain and change in attitude towards EBM) were compared between the clinically

	integrated e-learning course (intervention) and the traditional lecture based course (control). Change from pre- to post-intervention scores was measured using a validated questionnaire assessing knowledge (primary outcome) and attitudes (secondary outcome). • The intervention group achieved slightly higher scores for knowledge gain compared to the control, but these results were not statistically significant (difference in knowledge gain: 3.5 points, 95% CI -2.7 to 9.8, p = 0.27). The attitudinal changes were similar for both groups.
Notes	• Study aim: To evaluate the educational effects of a clinically integrated e-learning course for teaching basic evidence-based medicine (EBM) among postgraduates compared to a traditional lecture-based course of equivalent content. • Pedagogical approach used: Individual eLearning, with self-directed eLearning components. • Was a learning management system (LMS) used? No. • Journal: BMC Medical Education. • Year of publication: 2009. • Income status of country: High income. • Source of funding: Not stated. • Conflict of interest: None.

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Random allocation sequence was generated by computer to either intervention or control group and was stratified by country (pg. 3, methods).
Allocation concealment (selection bias)	Unclear risk	No details given to enable judgement.
Blinding of outcome assessment (detection	Unclear risk	No details given to enable judgement.

bias)		
Incomplete outcome data (attrition bias)	Low risk	6 trainees dropped out of the study from the intervention group and 3 from the control group, figure 1, pg. 4. analysis has been done as per protocol basis.
Selective reporting (reporting bias)	Low risk	Outcomes listed in the trial registration (ACTRN12609000022268) were presented in the manuscript.
Other bias	Low risk	Baseline comparison of demographic characteristics between the intervention groups are not presented, however baseline knowledge score were similar between the intervention, mean ± SD (43.3 ± 8.4) and control groups (43.3 ± 4.9), P = 0.27 (figure 2, pg. 5). The modest sample size may have contributed to a limitation in statistical power to detect a small improvement in knowledge between the groups.

Kulier 2012

Methods	• Design: Cluster randomised controlled trial. • Recruitment method: Using their local knowledge the lead country investigators approached heads of potentially eligible clinical obstetrics and gynaecology training units to identify clusters. • Randomization: Yes, randomisation was done using computer generated random numbers. • Speciality: Obstetrics and Gynaecology. • Setting: University. • Country: Argentina, Brazil, Democratic Republic of the Congo, India, Philippines, South Africa, Thailand.
Participants	• Type of participants: Postgraduate trainees in six obstetrics and gynaecology departments. • Inclusion criteria: To be eligible, the unit had to be delivering EBM courses, defined as opportunities to learn about the techniques of EBM and its application in clinical practice, in the unit's residency program. • Exclusion criteria: Not stated. • No of clusters / participants randomised: 60 clusters (204 participants).

Interventions	• Intervention: Clinically integrated elearning course, the course combined e-learning of EBM principles with a specialist library provided in various languages. The eLearning modules for experimental intervention consisted of 5 recorded video sessions in which basic EBM knowledge was delivered by a speaker. Questions arising in clinical practice prompted trainees to study these questions. The knowledge acquired through e-learning was blended with face-to-face teaching and learning with a clinical trainer. The clinical questions were addressed in formative assignments and signed off by trainers. • Control: Standard teaching.
Outcomes	• Primary outcomes were change in EBM knowledge (score range, 0 - 62) and skills (score range, 0 - 14). • The experimental group had higher mean scores in knowledge (38.1 [95% CI, 36.7 to 39.4] in the control group vs 43.1 [95% CI, 42.0 to 44.1] in the experimental group; adjusted difference, 4.9 [95% CI, 2.9 to 6.8]; P =.001) and skills (8.3 [95% CI, 7.9 to 8.7] vs 9.1 [95% CI, 8.7 to 9.4]; adjusted difference, 0.7 [95% CI, 0.1 to 1.3]; P = .02).
Notes	• Study aim: To evaluate the effects of a clinically integrated e-learning EBM course incorporating the World Health Organization (WHO) Reproductive Health Library (RHL) on knowledge, skills, and educational environment compared with traditional EBM teaching. • Pedagogical approach used: Facilitated learning, with self-directed eLearning modules and clinical trainers. • Was a learning management system (LMS) used? No. • Journal: Journal of American Medical Association. • Year of publication: 2012. • Income status of country: High income. • Source of funding: This trial was funded by the UNDP/UNFPA/WHO/World Bank Special Programme of Research, Development and Research Training in Human Reproduction, Department of Reproductive Health and Research, World Health Organization. The initial development and piloting of the e-learning course was funded by the European Union Leonardo da Vinci Vocational Training Action

	Programme (project grant UK/ 05/B/F/PP-162_349). • Conflict of interest: None.

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	The WHO statistical support unit randomised the clusters, stratified by country, by means of computer-generated random numbers into 2 groups: group 1 received the clinically integrated e-learning EBM teaching package (experimental intervention) (31 clusters, 123 participants); group 2 received a self-directed EBM teaching package (control intervention) (29 clusters, 81 participants) (pg. 2219, methods, ln 49).
Allocation concealment (selection bias)	Low risk	Facilitators and participants were informed that an educational evaluation was being conducted within their institutions but were not given any details of the trial to minimize the risk of biases arising from knowledge of group allocation (pg. 2219, ln 64).
Blinding of outcome assessment (detection bias)	Unclear risk	No details given to enable judgement.
Incomplete outcome data (attrition bias)	High risk	Of the 60 clinical training units approached and initially randomised, 14 later dropped out (7 in each group) (FIGURE1). Three clusters in each group declined participation after randomization. The rest either did not respond to further participation and training requests or none of their trainees completed the trial. Of the remaining clusters, 24 (123 trainees) were in the clinically integrated e-learning group and 22 (81 trainees) in the control group. 25 trainees that dropped out in the clinically integrated e-learning group and 13 in the control group.

		Statistical analysis states that the authors used mixed-effects models which allow the inclusion of all available data, consistent with the intention-to-treat approach (pg. 2221, statistical analysis, ln 29).
Selective reporting (reporting bias)	Low risk	Outcomes listed in the trial registration (ACTRN12609000198224) were presented in the manuscript.
Other bias	High risk	Cluster RCTs are not without limitations. Clusters are usually randomised all at once rather than one at a time and entire clusters may drop out after randomisation. In this study, there was loss of clusters attributable to technical difficulties, such as interrupted or limited Internet connection; irregular library or computer access; unwillingness to participate; and lack of protected time for the participants to take part because of service load, all of which have implications for generalisability of our findings. (pg2224, ln 9). Since a priori adjustments anticipating loss of clusters was not done, the study power has been reduced and thus the possibility of type II error (pg. 2224, ln 10).

Kutob 2009

Methods	• Design: Randomised controlled trial. • Recruitment method: Participants were recruited from a random sample of resident members of the American Academy of Family Physicians; potential participants were sent a letter in January 2004 inviting them to participate in the study. • Randomization: Yes, method not described. • Speciality: Family medicine. • Setting: University. • Country: United States.
Participants	• Type of participants: Family medicine residents. • Inclusion criteria: Only first-, second-, or third-year family medicine residents were eligible to participate.

	• Exclusion criteria: Not stated. • No of participants randomised: 122 residents.
Interventions	• Intervention: a case-based, interactive Internet program, Delivering Culturally Effective Care, to teach cultural competence skills to physicians. The course was designed to focus on one common medical condition—type-2 diabetes. Mexican-American Culturally effective diabetes care, assessed by cultural competence assessment tool (CCAT) patients were the prototype patient population for the course, but specific knowledge of Mexican culture was neither the primary feature nor the primary goal. To assess the course, we developed a cultural competence self-assessment tool and use the tool to assess changes in cultural competence of a national sample of family medicine residents in a randomized controlled trial (RCT). • Control: No intervention, subjects in the control group completed only the posttest during the same time period.
Outcomes	• The primary outcome was measured by changes in score on the Cultural Competence Assessment Tool (CCAT), a new self-assessment tool developed for this study. • Total CCAT score increased significantly after the completion of the Internet course for 58 residents in the experimental group (83.55 before the course, 192.09 after the course) but did not change for the 64 residents in the control group (177.58 at baseline, 177.84 at end of study). • On multivariate analysis, the only significant predictor of total CCAT score change was having taken the online course.
Notes	• Study aim: The study developed and tested a skills-focused, Internet-based course on cultural competence in the context of type 2 diabetes and tested its effectiveness. • Pedagogical approach used: Individual eLearning, with case-based interactive internet program. • Was a learning management system (LMS) used? No. • Journal: Journal of American Medical Association.

	• Year of publication: 2009. • Income status of country: High income. • Source of funding: This work was funded by the National Institutes of Health, National Institute of Diabetes and Digestive and Kidney Diseases (No. 5R42DK062569). • Conflict of interest: None stated.

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	High risk	Participants were then alternately assigned to treatment or control groups, but method was not described (pg. 171).
Allocation concealment (selection bias)	Unclear risk	No details given to enable judgement.
Blinding of outcome assessment (detection bias)	Unclear risk	No details given to enable judgement.
Incomplete outcome data (attrition bias)	Unclear risk	No details given to enable judgement.
Selective reporting (reporting bias)	Low risk	All pertinent outcomes were reported.
Other bias	Low risk	Although total CCAT score was not significantly different between the two groups at baseline (P=.225), scores on one subscale score ("Cultural Knowledge") were different. The control group reported less "Cultural Knowledge" than those in the experimental group (pg. 171, results, ln 11). This was explained by a difference in the items pertaining to Hispanic patients, with those in the control group reporting significantly less knowledge than those in the experimental group (P=.016) (pg. 171, results, ln 11). The study was limited to

		family medicine residents. In the survey cited above, family medicine respondents were less likely to report a lack of preparedness to deal with several aspects of cross-cultural patient care than residents from other specialties. Although the study adjusted for prior cultural competence training with a multivariate analysis, family medicine residents may have already been "primed" to be more open to the subject matter. A further limitation was the self-reported nature of the CCAT.

Le 2010

Methods	• Design: Randomised controlled trial. • Recruitment method: The investigators used word-of-mouth, informal contacts, and a broadcast e-mail to the physician membership of the Kentucky Chapter of the American Association of Pediatrics to recruit a convenience sample. • Randomization: Yes, method not described. • Speciality: Paediatrics • Setting: Hospital. • Country: United States.
Participants	• Type of participants: Paediatricians. • Inclusion criteria: Participants had to be board-eligible paediatrician involved in direct primary care for children, have access to a Windows or Macintosh computer with either a CD-ROM drive or Internet access, have access to a telephone for teleconference calls, and be willing to take part in the DALI educational seminar if randomised to the treatment group. • Exclusion criteria: Not stated. • No of participants randomised: 20 paediatricians.
Interventions	• A distance learning program for paediatric asthma consisting of Web- (Distributed Asthma Learning Initiative, DALI) or CD-ROM–based multimedia learning modules and two teleconference calls.

	• The intervention group received two teleconferences, access to a Web site with six interactive multimedia learning modules, and a CD-ROM with the same learning modules to be used when Internet access was not available. 5 paediatricians (>20%) received training via the CD-ROM. • Control group did not receive the intervention.
Outcomes	• Outcome Measures were learner satisfaction, change in physician asthma knowledge, attitudes, and treatment behavior at 1 to 4 months (short term) and 6 to 8 months (long term). • The study reported guidelines score, guideline recommendations and questionnaire test score; we have reported overall guidelines score. Intervention: n=15, MD: 4.75, SD: 3.28; Control: n=9, MD: 2.88, SD: 2.03. • Fifteen domains of attitude were measured, however no difference was found for 14 of these. We report "Patients with daily asthma symptoms should be prescribed an ICS". Intervention: n=15, MD: 0.3, SD: 0.5; Control: n=9, MD:-0.2, SD: 1.6. • The study presents two behavioural outcomes, we report one of these "considering the total number of your patients with persistent asthma, for what percentage of these patients did you prescribe an ICS" Intervention: n=15, MD: 6.9, SD: 15.3; Control: n=9, MD: 10.5, SD: 15.7. • Satisfaction scores was reported for the intervention group only, hence not presented in the data analysis.
Notes	• Study aim: To assess provider acceptability of a distance learning program for pediatric asthma and pilot test its effects on physician knowledge, attitudes and treatment practices. • Pedagogical approach used: Facilitated eLearning, teleconferences with pediatric asthma expert and a physician, access to website with multimedia learning modules and CD-ROM. • Was a learning management system (LMS) used? No. • Journal: Journal of Asthma. • Year of publication: 2010. • Income status of country: High income. • Source of funding: This study is supported by a grant

	from the National Institutes of Health, Enhancing Pediatric Asthma Management (HL-070771). We also thank Indigene Inc., for their assistance in developing the learning modules. • Conflict of interest: None.

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	High risk	We matched participants from the same practice into pairs. Within each pair, we randomised one participant to the control group and the other to the intervention group. Although this allowed for potential contamination of control subjects, it allowed us to control for the wide variety of practice settings that may affect physician utilization of the program and variation in practice resources for asthma care. Unmatched participants were randomised to the control group or the intervention group. (pg. 246, randomisation). Randomisation method not described.
Allocation concealment (selection bias)	Unclear risk	No details given to enable judgement.
Blinding of outcome assessment (detection bias)	Unclear risk	No details given to enable judgement.
Incomplete outcome data (attrition bias)	High risk	After randomisation, four participants withdrew from the study and one physician withdrew from the study after completing part of the program (pg. 247, figure 1, results).
Selective reporting (reporting bias)	Low risk	All pertinent outcomes were reported.
Other bias	High risk	The demographic characteristics for the control and intervention groups were generally similar (Table 1). However,

		there were significant group differences for the number of asthma patients seen per week as well as in the distribution of types of insurance coverage of the patients (P < .05) (pg. 247, ln 7). The sample size was small, and the study was not powered to see differences in learner outcomes. The participants were a convenience sample and not necessarily representative of all practicing primary care providers. Nevertheless, they were likely to be similar to other clinicians who would avail themselves of Internet-based CME and who would be open to participation in practice-based research. Finally, there may be a 'ceiling effect' as the self-reported rates for prescribing ICS for persistent asthma were high at baseline, leaving less room for improvement.

Lee 2015

Methods	• Design: Random allocation only • Recruitment method: Volunteer participation with written informed consent. • Randomization: Yes, block randomisation was done, method not described. • Speciality: Family medicine • Setting: University. • Country: United States
Participants	• Type of participants: Third-year family medicine clerk-ship students • Inclusion criteria: Not stated • Exclusion criteria: Not stated • No of participants randomised: 119 students
Interventions	• Intervention: Intervention group received online cultural competency and PACT training added to their standard curriculum • Control: Control group received the standard curriculum only
Outcomes	• Skills: response to "Problem-Affect-Concern-

	Treatment" (PACT) questions
Notes	• Study aim: to evaluate whether an online cross-cultural communication module could increase student use of cross-cultural communication questions that assess the patient's definition of the problem, the way the problem affects their life, their concerns about the problem, and what the treatment should be (PACT). • Pedagogical approach used: Individual learning • Was a learning management system (LMS) used? No • Journal: Family medicine • Year of publication: 2015 • Income status of country: High income • Source of funding: Tufts Health Care Institute provided funding to support the development of the online learning module dis-cussed in this paper. The collaborative evaluation was partially funded through HRSA grant D54HP23297 (Christopher P. Morley, PI/PD). • Conflict of interest: None stated.

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Faculty blinded to block randomization scored students on the number of PACT questions (PACT score, range: 0–4) asked during a non-graded communication-focused Standardized Patient Exercise (SPE) conducted in the final week of the FM clerkship, method of randomisation was not mentioned. (pg. 2, methods)
Allocation concealment (selection bias)	Unclear risk	No details given to enable judgement.
Blinding of outcome assessment (detection bias)	Low risk	Faculty blinded to block randomization scored students on the number of PACT questions (PACT score, range: 0–4) asked during a non-graded communication-focused Standardized Patient Exercise (SPE) conducted in

		the final week of the FM clerkship. (pg. 2, methods)
Incomplete outcome data (attrition bias)	Low risk	Six students had incomplete data collection, leaving a total of 119 students (60 intervention and 59 control group) contributing data to this study. (pg. 303, results)
Selective reporting (reporting bias)	Low risk	All pertinent outcomes were reported.
Other bias	High risk	Baseline comparison of groups not reported. More questions were asked in the intervention group, compared to control group. (2.48 vs 2.1, P=0.049).Table 1, pg. 304.

Legare 2012

Methods	• Design: Cluster Randomised controlled trial. • Recruitment method: Not stated. • Randomization: Yes, randomisation was done using Internet-based software. • Speciality: Family medicine. • Setting: University. • Country: Canada.
Participants	• Type of participants: Family physician. • Inclusion criteria: All family physicians, including physician teachers and residents, who provided care in the walk-in clinics of the 12 family practice teaching units. • Exclusion criteria: We excluded physicians who had participated in the DECISION+ pilot trial13 or who did not expect to practice in the teaching unit during the trial period. • No of clusters / participants randomised: 12 Family practice teaching units / 181 patients who consulted 77 physicians.
Interventions	• Intervention: DECISION+2, a 2-hour interactive seminar about shared decision making. • Control: Physicians in the control group were asked to provide usual care. To avoid contamination bias, access to the online tutorial was denied to participants

	in the control group during the trial.
Outcomes	• The primary outcome was the proportion of patients who decided to use antibiotics immediately after consultation. • We compared outcomes among 181 patients who consulted 77 physicians in 5 family practice teaching units in the DECISION+2 groups, and 178 patients who consulted 72 physicians in 4 family practice teaching units in the control group. • The percentage of patients who decided to use antibiotics after consultation was 52.2 % in the control group and 27.2 % in the DECISION+2 group (absolute difference 25.0%, adjusted relative risk 0.48, 95% confidence interval 0.34 – 0.68). • DECISION+2 was associated with patients taking a more active role in decision-making ($Z = 3.9$, $p < 0.001$). Patient outcomes 2 weeks after consultation were similar in both groups.
Notes	• Study aim: The study evaluated the effect of DECISION+2, a shared decision-making training program, on the percentage of patients who decided to take antibiotics after consultation with a physician or resident. • Pedagogical approach used: Facilitated eLearning, facilitated online tutorial, interactive workshop. • Was a learning management system (LMS) used? No. • Journal: Canadian Medical Association Journal. • Year of publication: 2012. • Income status of country: High income. • Source of funding: This study was funded by a grant from the Conseil du médicament du Québec / Fonds de la recherche en santé du Québec. The funding organization had no role in the conception or design, conduct, analysis, interpretation or reporting of the study and no access to the data. None of the investigators received any financial compensation. • Conflict of interest: None.

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	A biostatistician used Internet-based software to simultaneously randomise all 12 family practice teaching units to either the intervention group (DECISION+2) or control group (pg. E728, randomisation).
Allocation concealment (selection bias)	Unclear risk	No details given to enable judgement.
Blinding of outcome assessment (detection bias)	Low risk	Statistical analysis was performed by a statistician who was unaware of the teaching unit allocations (pg. E729, statistical analysis).
Incomplete outcome data (attrition bias)	Low risk	In the DECISION+2 group, 11 of the 189 eligible physicians who were not available during the first phase of patient recruitment were recruited (completed the baseline questionnaire) after DECISION+2 training began and therefore were not included in the final analysis. In the control group, 9 of the 144 eligible physicians who were not available during the first phase of patient recruitment were recruited (completed the baseline questionnaire) In total, 9 of the 12 randomised family practice teaching units participated in the study (Figure 1) (pg. E730, results).
Selective reporting (reporting bias)	Low risk	Outcomes listed in the protocol for this trial (NCT01116076) have been published in the manuscript.
Other bias	Low risk	Characteristics of patients in family practice teaching units before and after the intervention is presented in table 1 (pg. E729), however statistical comparison has not been done. In general, key characteristics of the patients (Table 1) and family practice teaching units and physicians (Table 2) in the DECISION+2 groups were similar to those in the control group.

		First, 3 of the initial 12 clusters were lost to follow-up. DECISION+2 were integrated into the official residency training program, and all teaching units in the invention group received it simultaneously. However, because the program calendar was finalized in May, we had to perform randomisation before meeting with the invitees in July and receiving their formal acceptance to participate. We believe that the impact of this limitation was minimal because loss was balanced between experimental and control groups and the characteristics of the participating units were similar. Second, we did not report an objective measure of antibiotic use by patients, such as antibiotics dispensed, because it was impossible in this clinical context. However, the decision to use antibiotics reported independently by physicians and patients showed a high degree of agreement. In addition, a high level of adherence to the decision was reported by the patients. Third, because this was a pragmatic trial, we did not control for other potential variables external to the residency program (e.g., whether participating physicians had taken other training programs on antibiotic prescribing or read material about acute respiratory infections beyond their residency requirements). Fourth, we collected data from patients who had consulted with a participating physician but not from all patients who consulted a physician at the walk-in clinics of the participating family practice teaching units, so we do not know if the impact of DECISION+2 would have been similar on physicians who did not enroll in this trial but who were still exposed to the training

		program. Fifth, although the biostatistician was unaware of group allocation, the researchers and research assistants who recruited patients and collected data were not.

Little 2013

Methods	• Design: Cluster Randomised controlled trial (Factorial design). • Recruitment method: All general practices in the localities of study centers were approached and all clinicians (and nurse pre scribers in the UK) in eligible practices who prescribed antibiotics for respiratory-tract infections were invited to participate. • Randomization: Yes, randomisation was carried out by computer generated random numbers. • Speciality: Primary care. • Setting: University. • Country: United Kingdom (Multinational study).
Participants	• Type of participants: Patients seeking care in primary-care practices in six European countries. • Inclusion criteria: Eligible practices were those that had not previously used any interventions to reduce rates of antibiotic prescribing and could include more than ten patients in the baseline audit. • Exclusion criteria: Not stated. • No of clusters / participants randomised: 246 practices / 4264 patients.
Interventions	• Intervention 1: CRP training. • Intervention 2: Communication training. • Intervention 3: CRP and communication training. • Control: Usual care.
Outcomes	• The primary outcome was antibiotic use, as documented on the case-report forms, several secondary outcomes were assessed, new or worsening symptoms, new signs, or hospital admission, assessed by review of medical notes (practice staff , the local study team, or both used a standard form to report

	these data. Symptom severity and duration was defined as the severity of symptoms in the 2–4 days after seeing the physician." • The antibiotic prescribing rate was lower with CRP training than without (33 % vs 48 %, adjusted risk ratio 0·54, 95% CI 0·42 – 0·69) and with enhanced-communication training than without (36 % vs 45 %, 0·69, 0·54–0·87). • The combined intervention was associated with the greatest reduction in prescribing rate (CRP risk ratio 0·53, 95% CI 0·36 – 0·74, P < 0·0001; enhanced communication 0·68, 0·50–0·89, P = 0·003; combined 0·38, 0·25–0·55, P < 0·0001).
Notes	• Study aim: The study assessed whether internet-based training methods could alter prescribing practices in multiple health-care systems. • Pedagogical approach used: Individual eLearning, Internet training was provided. • Was a learning management system (LMS) used? No. • Journal: The Lancet. • Year of publication: 2013. • Income status of country: High income. • Source of funding: This study was supported by the European Commission Framework 6 Programme (grant 518226). The work in UK was also supported by the National Institute for Health Research and the Research Foundation Flanders (grant G.0274.08N). • Conflict of interest: None stated.

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Randomisation of practices was done by KH and MK, was achieved by computer generation of random numbers, and was stratified by network (pg. 1176, randomisation and masking).

Allocation concealment (selection bias)	Low risk	Physicians and patients were unaware of initial group allocation (pg. 1176, randomisation and masking, ln 15).
Blinding of outcome assessment (detection bias)	Low risk	Masking of physicians or patients to the intervention itself was not possible (pg. 1176, ln 16).
Incomplete outcome data (attrition bias)	Low risk	Analyses were done by intention to treat and used multilevel logistic regression modelling for a factorial study to assess the main outcome (antibiotic use) (pg. 1178, statistical analysis, ln 43).
Selective reporting (reporting bias)	Low risk	Outcomes listed in the protocol for this trial (ISRCTN99871214) have been published in the manuscript.
Other bias	Low risk	All groups were well balanced (table 1).Table 1 shows the clinical characteristics of factorial groups at baseline and follow-up, the characteristics looks fairly similar, but statistical testing has not been done.

Macrae 2004

Methods	• Design: Randomised controlled trial. • Recruitment method: All 838 active members of the Canadian Association of General Surgeons were contacted by letter and invited to participate in the trial. • Randomization: Yes, randomisation was carried out by computer generated random numbers. • Speciality: Surgery. • Setting: University. • Country: Canada.
Participants	• Type of participants: Surgeons. • Inclusion criteria: The requirements for participation outlined in the letter were that the surgeon must have access to the Internet and to E-mail, must agree to being randomised, and must agree to complete a written examination. • Exclusion criteria: Surgeons with postgraduate training in clinical epidemiology were excluded from the study.

	• No of participants randomised: 55 surgeons.
Interventions	• Intervention: The intervention was a curriculum in critical appraisal skills that included a clinical and methodologic article, a listserve discussion, and clinical and methodologic critiques. • Control: The control group received only the clinical articles.
Outcomes	• The primary outcome measure for this study was a locally developed test of critical appraisal skills. • Subjects in the intervention group performed better on the test of critical appraisal skills than those in the control group (mean score: intervention group, 58 % ± 8 vs control group, 50 % ± 8), with a large effect size of 1.06 standard deviation units (t + 3.92, P < .0001). • Training conditions accounted for 22 % of the variance in total scores.
Notes	• Study aim: The objective of this study was to evaluate whether an Internet-based intervention would lead to enhanced critical appraisal skills in practicing surgeons. • Pedagogical approach used: Facilitated eLearning, hard copy reading materials, listserve discussion moderated by a general surgeon. • Was a learning management system (LMS) used? No. • Journal: Surgery. • Year of publication: 2004. • Income status of country: High income. • Source of funding: Supported by the physicians of Ontario through the Physician's Services Incorporated. The program, Evidence-based Reviews in Surgery, is supported by an unrestricted educational grant from Ethicon and Ethicon Endo-surgery. • Conflict of interest: None stated.

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Surgeons who agreed to complete all aspects of the study were randomised into either the intervention or control group (pg. 642, study design and intervention). Computer generation random numbers were used for randomisation.
Allocation concealment (selection bias)	Unclear risk	No details given to enable judgement.
Blinding of outcome assessment (detection bias)	Unclear risk	No details given to enable judgement.
Incomplete outcome data (attrition bias)	Low risk	The sample size was computed anticipating a dropout rate of 50%. All subjects who completed the final examination were analysed in their assigned groups, even if they did not complete all of the packages (pg. 643, statistical analysis). 150 surgeons initially expressed interest in participating in the Evidence-based Reviews in Surgery (EBRS) program; after all of the requirements of the study were outlined, only 86 agreed to participate. Three were excluded prior to randomisation, and another 2 were excluded after randomisation (1 in each group) because they had previous clinical epidemiology training, leaving 81 participants. Fifty-five of the 81 eligible surgeons completed the final examination (68 %): 26 (58 %) in the intervention group (9 academic practice, 17 community practice) and 29 (76 %) in the control group (pg. 643, outcome measures, ln 9).
Selective reporting (reporting bias)	Low risk	All pertinent outcomes listed in the methods section were reported.
Other bias	Low risk	Baseline similarity: There was no significant difference between the 2 groups (v2 = 1.38, P = 0.24) (pg. 643,

		results). A limitation of this study is that only improvement in critical appraisal skills was evaluated. The major potential bias that may have affected our result was that subjects were recruited on a volunteer basis, and are thus more motivated, and perhaps more likely to benefit from the intervention than the general population of surgeons. However, choice of participation in continuing professional development is almost always on a volunteer basis, and only those interested in participating in a journal club are likely to sign up. Furthermore, the control groups were also motivated to enhance their critical appraisal skills and were free to consult any sources they chose; yet we showed a significant benefit of the intervention.

Marsh-Tootle 2011

Methods	• Design: Cluster randomised controlled trial. • Recruitment method: Not stated. • Randomization: Yes, randomisation was carried out by computer. • Speciality: Primary care. • Setting: University. • Country: United States.
Participants	• Type of participants: Primary care physicians. • Inclusion criteria: Providers who filed claims for at least eight WCVs for children aged 3 or 4 years during 1 year were eligible for further consideration. Other eligibility criteria were (1) adequate contact information including fax numbers, (2) filing claims under the individual provider's name, and (3) having Internet access. To make sure that provider enrolment and behavior were not influenced by the goals of the study, we recruited providers to enroll in a study to "improve care for children. • Exclusion criteria: Not stated. • No of clusters / participants randomised: 132

	providers.
Interventions	• All participants were offered four sequential web-based modules consisting of physician-targeted, interactive case vignettes, along with tool kits designed to enhance the assessment of preschool "vision" in IPs or blood pressure in CPs. • Intervention: Intervention practices (IPs). • Control: Control practices (CPs). • IPs responded to questions at three time periods: baseline (before the presentation of guidelines or evidence-based practices regarding vision assessment), after completing module 1 (short-term delay), and after completing module 4 (long-term delay). • CPs responded to the same "vision" questions only once, after finishing all control modules. Questions were in identical format for the CPs' only vision evaluation and for IPs at short- and long-term delays. The short-term delay was within 1 hour after initial log-on for more than half (n = 38) the IPs.
Outcomes	• A set of questions was used to assess knowledge, attitudes, and practice environment. • Most IPs (57 / 65) responded at baseline and after the short delay (within 1 hour after baseline for 38 IPs). A sub-group (27 IPs and 42 CPs) completed all vision questions after a long delay averaging 1.8 years. Scores from IPs improved after the short delay (median score, 3 vs. 6; P = 0.0065). • Compared to CPs, scores from IPs were similar at baseline (P = 0.6473) and higher after the short-term (P < 0.0001) and long-term (P < 0.05) delay.
Notes	• Study aim: To evaluate the efficacy of a physician-targeted website to improve knowledge and self-reported behavior relevant to strabismus and amblyopia ("vision") in primary care settings. • Pedagogical approach used: Individual eLearning, interactive website with videos and animations. • Was a learning management system (LMS) used? No. • Journal: Investigative Ophthalmology and Visual Science.

	• Year of publication: 2011. • Income status of country: High income. • Source of funding: Supported by Award Number R01EY015893 from the National Eye Institute. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Eye Institute or the National Institutes of Health. • Conflict of interest: None stated.

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Providers were sent to the intervention or control websites according to a cluster-randomised schedule that was executed on log-in (pg. 7161, eligible pool of providers and enrolment). Randomisation was done by computer generated sequence.
Allocation concealment (selection bias)	Unclear risk	No details given to enable judgement.
Blinding of outcome assessment (detection bias)	Unclear risk	No details given to enable judgement.
Incomplete outcome data (attrition bias)	Low risk	Sixty-five providers were enrolled into the intervention arm and 71 into the control arm. For IPs, responses were available from 61 (93.8 %) providers at baseline, 57 (87.7 %) after the short delay, and 27 (41.5 %) after the long delay. For CPs, responses to vision questions were available from 42 providers (59.2 %) after completing all control modules (pg. 7162, results).
Selective reporting (reporting bias)	Low risk	All pertinent outcomes were reported.
Other bias	Unclear risk	Baseline characteristics, Table 2 presents demographic and practice characteristics for those who did and those who did not participate in the

		study (NP), despite being eligible. The latter group includes eight IPs and eight CPs who logged on but did not complete module 1. Participating providers were more likely to be female, to reside in the state in which the project originated (Alabama), to have graduated slightly earlier, and to have filed more claims for WCVs; they were less likely to be family physicians. Other characteristics were not different between participating and nonparticipating providers (age, U.S.-trained, residency-trained in Alabama, employment setting, and baseline PVS rate for children aged 3 to 5 years) (pg. 7162, results). Although the programming allowed us to track usage at the level of the computer, we cannot be certain that only the enrolled person participated and furnished responses. Post intervention outcome measures were higher in all but two IPs; one of these differed by 5 points (five correct initially versus zero correct after the intervention), and it is possible that later responses were obtained from a different individual.

Matzie 2009

Methods	• Design: Randomised controlled trial. • Recruitment method: All general surgery residents in postgraduate years 1 to 5 at Brigham and Women's Hospital (BWH) during the academic year 2005–2006 were recruited via e-mail to participate in the study. • Randomization: Yes, participants were block randomised into two groups, but method not described. • Speciality: Surgery. • Setting: Hospital. • Country: United States.
Participants	• Type of participants: General surgery residents. • Inclusion criteria: All general surgery residents in

	postgraduate years 1 to 5 at Brigham and Women's Hospital (BWH) during the academic year 2005-2006. • Exclusion criteria: None. • No of participants randomised: Surgical residents: 55; Fourth year-medical students: 324
Interventions	• Intervention: Weekly spaced education e-mail during a 9-month period containing teaching bullets on how to provide effective feedback. The spaced education program was structured to provide each of the 15 feedback-bullets weekly for 15 weeks and thereafter to repeat this cycle for the remainder of the study. • Control: Residents assigned to group 2 (controls) were sent no spaced education e-mails. (Self-directed learning)
Outcomes	• Rating of frequency and quality of feedback was assessed among students. • Students reported 45 % (67 of 149) of the spaced education residents gave frequent feedback, compared with 31 % (55 of 175) of control residents (relative risk [RR], 1.43; P = 0.016). • Students agreed or strongly agreed that resident feedback was “useful and helpful” in their learning in 92% (132 of 143) of their evaluations of residents who received the spaced education e-mails, compared with 82% (132 of 161) of their evaluations of residents who did not receive the e-mails (RR, 1.13; 95% CI, 1.03–1.23; P=.010 [Fisher exact test]). • Frequency of feedback RR=1.43; 95% CI, 1.08 – 1.90; P =.016.
Notes	• Study aim: The study investigated whether feedback given by surgery residents to students could be improved through an online spaced education program. • Pedagogical approach used: Individual eLearning, spaced education e-mails. • Was a learning management system (LMS) used? No. • Journal: The American Journal of Surgery. • Year of publication: 2009. • Income status of country: High income. • Source of funding: This study was supported in part

	by the Research Career Development Award Program of the Veterans Affairs Health Services Research & Development Service, the American Urological Association Foundation (Linthicum, MD), and Astellas Pharma US, Inc. • Conflict of interest: None stated.

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Participating general surgery residents were stratified by year of training and whether they attended a 1-hour pretrial didactic seminar on delivering effective feedback (given on August 3, 2005, by E.M.B. and J.P.H.), and then were block randomised into 2 groups (pg. 253, study participants). Randomisation method not described.
Allocation concealment (selection bias)	Unclear risk	No details given to enable judgement.
Blinding of outcome assessment (detection bias)	Unclear risk	No details given to enable judgement.
Incomplete outcome data (attrition bias)	Low risk	Ninety-five percent (38 of 40) of the medical students' submitted feedback surveys, completing a total of 324 feedback evaluation of the residents over 9 months. Strengths of this study include its randomised controlled design and intention-to-treat analysis (Discussion).
Selective reporting (reporting bias)	Low risk	All pertinent outcomes were reported.
Other bias	Low risk	Baseline characteristics of the randomised residents were similar between the 2 cohorts (Table 1) (pg. 254, results). This study had several limitations, including that the study was performed at a single residency

		program and within a single specialty. In this pilot study it was unable to monitor the actual feedback residents gave students to see if residents truly learned from the spaced e-mails.

McLeod 2010

Methods	• Design: Cluster randomised controlled trial. • Recruitment method: Programs were initially invited to participate by an email invitation. Subsequently, all program directors were called to ensure they understood the commitments of the trial and that they had an administrative assistant who could coordinate with the research coordinator of the trial. • Randomization: Yes, cluster randomisation was used to allocate the programs to the internet or moderated journal club format groups. • Speciality: Surgery. • Setting: Hospital. • Country: Canada.
Participants	• Type of participants: Surgical Residents. • Inclusion criteria: General surgery training programs in the United States were recruited to participate in the trial provided they were not currently using EBRS packages in their journal club and there were at least 10 residents in their program who were agreeable to participating in the trial. • Exclusion criteria: Not stated. • No of clusters / participants randomised: 12 general surgery programs, 441 residents.
Interventions	• Intervention: Internet journal club group. • Control: Moderated journal club group.
Outcomes	• All participating residents completed a critical appraisal test within 1 month of completion of the EBRS packages. • Secondary outcome was the mean number of packages that each resident completed or journal clubs he or she attended. In addition, satisfaction with the clinical and methodological topics, reviews, and

	listserv discussion (internet group only) were assessed on a Likert scale. • In the Internet group, only 18 % of residents completed at least 1 EBRS package compared with 96 % in the moderated group. One hundred and thirty (57.8 %) residents in the Internet group completed the test compared with 157 (72.7 %) in the moderated group. The residents in the moderated group scored considerably better on the critical appraisal test, with a mean score of 42.1 compared with 37.4 in the Internet group (P = 0.05), with a moderate effect size of 0.6 SD.
Notes	• Study aim: The objective of this randomized controlled trial was to determine whether teaching critical appraisal skills to surgical residents through the Internet is as effective as a moderated in-person journal club. • Pedagogical approach used: Facilitated eLearning, internet based learning, Listserv discussion group. • Was a learning management system (LMS) used? No. • Journal: Journal of the American College of Surgeons. • Year of publication: 2010. • Income status of country: High income. • Source of funding: This trial was funded by Physician Services Incorporated. • Conflict of interest: None stated.

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Cluster randomisation was used to allocate the programs to the Internet or moderated journal club format groups (pg. 770, allocation of subjects). Randomisation method was not described.
Allocation concealment (selection bias)	Unclear risk	No details given to enable judgement.

Blinding of outcome assessment (detection bias)	Unclear risk	No details given to enable judgement.
Incomplete outcome data (attrition bias)	Low risk	Thirteen general surgery programs agreed to participate in the trial and were randomised to the 2 groups. However, before starting the trial, there was a change in program director at 1 program, so this site dropped out, leaving 12 programs that were randomised equally to the 2 groups. There were 225 residents in the Internet journal club and 216 residents in the moderated group (pg. 772, results).
Selective reporting (reporting bias)	Low risk	All pertinent outcomes were reported.
Other bias	Unclear risk	Baseline characteristics of the programs as shown in Table 2 (pg. 772), demographic characteristics of the residents were not presented. Limitations: Individuals in the same cluster (program in this case) tend to share similar characteristics and the effective sample size is decreased. To compensate for this, the proposed sample size in this study was adjusted by a factor of 1.45 as discussed in the Methods section. A mixed modelling approach was used to analyse the data to account for correlation within programs, and incorporate random error at the level of the program. Lastly, because study subjects are randomised in groups, it is possible that the groups are not similar and inferences about the effectiveness of the treatment can be biased. To minimize this risk, we included only general surgery programs in the United States in the study. Baseline characteristics of the programs as shown in Table 2 were similar (pg. 774).

Meeker 2016

Methods	• Design: Cluster Randomised controlled trial • Recruitment method: 49 primary care practices from 3 health systems using 3 different electronic health records (EHRs) in 2 geo-graphically distinct regions: Massachusetts (Partners Health-Care: 22 practices affiliated with Brigham and Women's Hospital or Massachusetts General Hospital) and Southern California (AL tamed Medical Group, 22 practices; The Children's Clinic, 5 practices were recruited. • Randomization: Yes, R statistical program was used for randomization • Speciality: Primary care • Setting: University. • Country: United States
Participants	• Type of participants: Primary care practices from 3 health systems using 3 different electronic health records (EHRs) • Inclusion criteria: A visit for an antibiotic-inappropriate acute respiratory tract infection was eligible for outcome inclusion if (1) the patient was 18 years or older, (2) the clinician and practice were enrolled in the study, (3) the visit occurred during the 18-monthbaseline or 18-month intervention period, and (4) the patient had no visit for acute respiratory tract infection within the prior 30 days. • Exclusion criteria: Visits were excluded when patients had medical comorbidities that were acute respiratory tract infection guideline exclusions (e.g., chronic lung disease; or patients had concomitant visit diagnoses indicating presence of other, potentially antibiotic appropriate, infections (e.g., cellulitis, acute sinusitis). • No of participants randomised: 49 primary care practices
Interventions	• Intervention: Intervention group (Peer comparison) received email together with feedback and suggestions • Control: Control group received no email intervention
Outcomes	• Change in practice / behavior: Antibiotic prescribing

	rates from 18 months preintervention to 18 months afterward
Notes	• Study aim: To assess effects of behavioral interventions and rates of inappropriate (not guideline-concordant) antibiotic prescribing during ambulatory visits for acute respiratory tract infection. • Pedagogical approach used: Facilitated learning • Was a learning management system (LMS) used? No • Journal: Journal of American Medical Association • Year of publication: 2016 • Income status of country: High income • Source of funding: This study was supported by the American Recovery & Reinvestment Act of 2009 (RC4AG039115) from the National Institutes of Health/National Institute on Aging and Agency for Healthcare Research and Quality (Dr Doctor, University of Southern California). The project also benefited from technology funded by the Agency for Healthcare Research and Quality through the American Recovery & Reinvestment Act of 2009 (R01 HS19913-01) (Dr Ohno-Machado, University of California, San Diego).Data for the project were collected by the University of Southern California's Medical Information Network for Experimental Research (Med-INFER) which participates in the Patient Scalable National Network for Effectiveness Research (pSCANNER) supported by the Patient-Centered Outcomes Research Institute (PCORI), Contract CDRN-1306-04819 (Dr Ohno-Machado). • Conflict of interest: None.

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Yes, the study used R statistical program for randomization
Allocation concealment	Unclear risk	No details given to enable judgement.

(selection bias)		
Blinding of outcome assessment (detection bias)	Unclear risk	Insufficient information to make judgement.
Incomplete outcome data (attrition bias)	Low risk	3 clinicians from control group and 1 clinician from Peer comparison group were excluded due to loss of follow-up. (pg. 565, figure 1)
Selective reporting (reporting bias)	Low risk	All pertinent outcomes were reported.
Other bias	High risk	First, baseline comparison of characteristics not presented, the number of clinicians within each cluster was small. Although a high proportion of invited clinicians chose to participate, some did not, which may limit generalizability. Similarly, trial findings might not generalize to primary care practices dissimilar to those enrolled. (pg. 569, limitations)

Midmer 2006

Methods	• Design: Randomised controlled trial. • Recruitment method: Not stated. • Randomization: Yes, method not described. • Speciality: Family and community medicine. • Setting: University. • Country: Canada.
Participants	• Type of participants: Community physicians. • Inclusion criteria: Not stated. • Exclusion criteria: Not stated. • No of participants randomised: 110 physicians.
Interventions	• Intervention: Workshop plus e-mail case discussion group. The intervention group participated in 10 weeks of e-mail case discussions, with designated participants responding to questions on cases. An addictions physician facilitated the discussion. Several months after the e-mail discussion, participants took part in a mock telephone consultation; a blinded researcher posing as a medical

	colleague asked for advice about 2 cases involving opioid and benzodiazepine prescribing. • Control: Workshop only.
Outcomes	• Beliefs, knowledge and practices. • On post-testing, both groups expressed greater optimism about treatment outcomes and were more likely to report using a treatment contract and providing advice about sleep hygiene. • There were no significant differences between pre-testing and post-testing between the groups on the survey. • During the telephone consultation, the intervention group asked significantly more questions and offered more advice than the control group (odds ratio for question items, 1.27 [P = .03]; advice items, 1.33 [P = .01]).
Notes	• Study aim: Our objective was to determine the effectiveness of a series of e-mail case discussions in improving physicians' attitudes and clinical performance in the prescribing of opioids and benzodiazepines. • Pedagogical approach used: Facilitated eLearning, email case discussion. • Was a learning management system (LMS) used? No. • Journal: The Journal of Continuing Education in the Health Professions. • Year of publication: 2006. • Income status of country: High income. • Source of funding: Not stated. • Conflict of interest: None stated.

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	At the end of each of the workshops, physicians were randomly assigned to a workshop-only group (control) or to a workshop plus e-mail case discussion group (intervention) (pg. 296, design, ln 39). Randomisation method was not

		descried.
Allocation concealment (selection bias)	Unclear risk	No details given to enable judgement.
Blinding of outcome assessment (detection bias)	Unclear risk	No details given to enable judgement.
Incomplete outcome data (attrition bias)	High risk	In all, 110 physicians completed the baseline survey and were randomly assigned to the intervention and control groups. Twenty-two subjects failed to complete the study (their pretest data were not analysed), leaving a final sample of 88 physicians (50 men and 38 women) (Table 1) (pg. 297, baseline characteristics).
Selective reporting (reporting bias)	Low risk	All pertinent outcomes were reported.
Other bias	High risk	There were no significant differences between the 2 groups in age, size of city, type or size of practice, medical school attended, or assessment of addiction or pain services in the community. However, on chi square testing, the intervention group had more men and fewer women than the control group (P = .07). Also, the intervention group prescribed opioids to a larger number of patients in the past month (35.4 versus 13.1, P = .006.) (pg. 299, baseline characteristics). Small sample size, two groups were not similar at baseline despite randomisation.

Ngamruengphong 2015

Methods	• Design: Randomised controlled trial • Recruitment method: Not stated • Randomization: The PC residents at one teaching hospital were then randomly assigned in a 1:1 ratio to one of two groups: a control group (C) and an educational intervention (E) group. (pg. 511, phase 2, methods) • Speciality: Primary care • Setting: University.

	• Country: United States
Participants	• Type of participants: Primary care residents • Inclusion criteria: Not stated • Exclusion criteria: Residents (n = 5) who did not wish to participate in the study were excluded (pg. 511, methods, phase 2) • No of participants randomised: 39 residents
Interventions	• Intervention: The intervention group received the standard education and an additional 30-minute didactic lecture, a pocket card, and monthly e-mail reminders that consisted of the lecture content for 2 months. • Control: The control group received only standard education from the residency program.
Outcomes	• Knowledge and documentation skills
Notes	• Study aim: To evaluate knowledge and practice regarding HBV and to assess the effectiveness of a multifaceted educational program. • Pedagogical approach used: Individual eLearning • Was a learning management system (LMS) used? No • Journal: Southern Medical Journal • Year of publication: 2015 • Income status of country: High income • Source of funding: Not stated. • Conflict of interest: None.

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	The PC residents at one teaching hospital were then randomly assigned in a 1:1 ratio to one of two groups: a control group (C) and an educational intervention (E) group. (pg. 511, phase 2, methods)
Allocation concealment (selection bias)	Unclear risk	No details given to enable judgement.

Blinding of outcome assessment (detection bias)	Unclear risk	No details given to enable judgement.
Incomplete outcome data (attrition bias)	Low risk	100% completed no attrition or drop out.
Selective reporting (reporting bias)	High risk	Control data was not reported for posttest comparison (fig 2, pg. 513)
Other bias	Low risk	Both groups (E and C) produced similar baseline knowledge scores (mean T standard deviation, 29% to 13% vs 29% to 12%, re-respectively= 0.92; Fig. 2).

Pape-Koehler 2013

Methods	• Design: Randomised controlled trial (2 x 2 factorial designs). • Recruitment method: For recruitment of participants, hospitals and universities were contacted and given written information about the study. They were asked to send back the completed questionnaire. Based on the responses received from the questionnaire, we selected the subjects and invited them to participate in the study. • Randomization: Yes, randomisation was done by lot. (pg. 1739, randomisation). • Specialty: Surgery. • Setting: Hospital. • Country: Germany.
Participants	• Type of participants: Medical doctors (MDs) participating in surgical fellowships at hospitals in Cologne. • Inclusion criteria: Eligible participants were medical doctors (MDs) participating in surgical fellowships at hospitals in Cologne within a 30-km radius and medical students in their final year at the University of Witten/Herdecke and Cologne University. • Exclusion criteria: Not stated. • No of participants randomised: 70 participants (18

	participants randomised to the multimedia-based training group, 17 to the practical training group, 18 to the combination group, and 17 to the control group).
Interventions	• 2 x 2 factorial study with four interventions groups (multimedia-based training, practical training, and combination training using either multimedia-based + practical training or no training [control group]) and blinded assessment of training results.
Outcomes	• Pre-posttest objective structured assessment of technical skills (OSATS) scores. • The groups were homogeneous in terms of demographic parameters, surgical experience, and pretest OSATS scores. • The DOSATS results were highest in the multimedia-based training group (4.7 ± 3.3; P = 0.001). • The practical training group achieved 2.5 ± 4.3 (P = 0.028), whereas the combination training group achieved 4.6 ± 3.5 (P = 0.001), and the control group achieved 0.8 ± 2.9 (P = 0.294).
Notes	• Study aim: This study aimed to evaluate the effect of multimedia-based training on surgical performance. • Pedagogical approach used: Individual eLearning, multimedia-based training vs practical training vs combination vs no training. • Was a learning management system (LMS) used? No. • Journal: Surgical endoscopy. • Year of publication: 2013. • Income status of country: High income. • Source of funding: The study received financial support by the European Surgical Institute, Johnson & Johnson Medical GmbH, and Karl Storz GmbH & Co. KG. • Conflict of interest: None.

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Four participants were invited to each appointment. After the baseline procedure (pretest), they were randomised by lot (pg. 1739, randomisation). Method not described.
Allocation concealment (selection bias)	Low risk	Each participant drew an opaque envelope from a box containing one of four different instructions corresponding to the study groups (pg. 1739, randomisation).
Blinding of outcome assessment (detection bias)	Low risk	Enrollment in the study, camera assistance, and evaluation were blinded (pg. 1739, randomisation), (pg. 1739, randomisation).
Incomplete outcome data (attrition bias)	Low risk	No dropout's in the study.
Selective reporting (reporting bias)	Low risk	All pertinent outcomes were reported.
Other bias	Low risk	Baseline data of participants are presented in table 3. The groups look fairly similar, though the statistical comparison was not done. The groups were homogeneous in terms of age, sex, and practical experience. Surgical fellows and students were equally distributed (Table 3).

Pelayo-Alvarez 2013

Methods	• Design: Randomised controlled trial. • Recruitment method: PCPs from 17 Spanish health regions. • Randomization: Yes, randomisation method not described. • Speciality: Primary care. • Setting: Hospital. • Country: Spain.
Participants	• Type of participants: Primary care physician (PCPs). • Exclusion criteria: Not stated.

	• Inclusion criteria: Not stated. • No of participants randomised: 169 PCPs.
Interventions	• Intervention: Online model. • Control: Traditional training.
Outcomes	• Patients' symptom control, quality of life, caregiver satisfaction and PCP knowledge and attitude at 18 months. Sixty-seven physicians enrolled 117 patients. • The intervention group had reduced scores for pain, symptoms, and family anxiety. The global RSCL scale showed a difference between groups. There was no significant difference in the questionnaires used. Caregiver satisfaction was comparable between groups. • Physicians in the intervention group significantly increased their knowledge without any differences in attitude. Online training was completed by 86.6 % in the intervention group, whereas 13.4 % in the control group accessed traditional training.
Notes	• Study aim: This study tested the clinical effectiveness of online PC education of physicians through impact on symptom control, quality of life (QOL), caregiver satisfaction, and knowledge-attitude of physicians at 18 months of the intervention. • Pedagogical approach used: Individual eLearning, online training. • Was a learning management system (LMS) used? No. • Journal: Journal of Palliative Medicine. • Year of publication: 2013. • Income status of country: High income. • Source of funding: This work was supported by National Health Research Fund grant PI07051; German Clinical Trials Register DRKS00000694. • Conflict of interest: None stated.

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	169 PCPs from all the 17 Spanish Health Regions (HR), who were randomly assigned to two groups (pg. 1189, methods, ln 3). Randomisation method was not described.
Allocation concealment (selection bias)	Unclear risk	No details given to enable judgement.
Blinding of outcome assessment (detection bias)	Unclear risk	No details given to enable judgement.
Incomplete outcome data (attrition bias)	High risk	Linear mixed effects multiple regression with multiple imputation for missing data, 17 was used to analyze questionnaire scores in both occasions (pg. 1189, statistical analysis). One hundred and sixty-nine PCPs were included; 145 remained after dropouts, of which 67 enrolled 124 patients: 66 in the intervention group (n = 66) and 58 in the control group (n = 58). Of the 124 patients enrolled, 7 were excluded, leaving 117 patients for analysis (63 intervention and 54 control) (Figure 1). Of the 78 PCPs who did not enrol any patients, 40 (24.4 %) (16 intervention, 24 control) claimed that they did not have any patients meeting the inclusion criteria. Excluded physicians and dropouts did not enrol patients (pg. 1190, results).
Selective reporting (reporting bias)	Low risk	All pertinent outcomes were reported.
Other bias	Unclear risk	Baseline comparison of characteristics of physicians was not mentioned (pg. 1190, results).

Perkins 2012

Methods	• Design: Randomised controlled trial. • Recruitment method: Participants were recruited from 31 study centers located in England (n = 25), Wales (n = 1), Scotland (n = 2), Northern Ireland (n =1), and Australia (n = 2). Study centers advertised courses locally through newsletters, Web sites, and word of mouth and nationally through the Resuscitation Council (UK) course list (www.resus.org.uk/pages/courses.htm) and Australian Resuscitation Council Web site (www.resus.org.au/als_ils/default.htm) (pg. 20, settings and participants). • Randomization: Yes, central randomisation carried out by www.sealedenvelope.com. • Speciality: Primary care. • Setting: Hospital. • Country: United Kingdom.
Participants	• Type of participants: Health care professionals, either registered or in training, who held a current clinical (or training) appointment. • Exclusion criteria: Not stated. • Inclusion criteria: Exclusion criteria were refusal to provide informed consent, lack of space for a participant to attend the course at the chosen center, and enrolment less than 4 weeks before the course began. • No of participants randomised: 3732 healthcare professionals (2022 physicians).
Interventions	• Intervention: A 1-day course supplemented with e-learning on advanced life support (ALS). • Control: A conventional 2-day ALS course.
Outcomes	• The primary outcome was performance during a standardised simulated cardiac arrest, known as the cardiac arrest simulation test (CASTest), taken immediately after the face-to-face course. • Secondary outcomes were knowledge (measured by pre- and post-course multiple-choice question [MCQ] tests), technical skills assessment (patient assessment, defibrillation, CPR, and airway management),

	CASTest domain scores, overall course pass rate, the proportion of candidates identified with exceptional performance and invited for instructor training, and the costs of training. • 440 of the 1843 participants randomly assigned to the blended course and 444 of the 1889 participants randomly assigned to conventional training did not attend the courses. • Performance in the cardiac arrest simulation test after course attendance was lower in the electronic advanced life support (e-ALS) group compared with the conventional advanced life support (c-ALS) group; 1033 persons (74.5 %) in the e-ALS group and 1146 persons (80.2 %) in the c-ALS group passed (mean difference, - 5.7 % [95% CI, - 8.8 % to - 2.7 %]). • Knowledge- and skill-based assessments were similar between groups, as was the final pass rate after remedial teaching, which was 94.2 % in the e-ALS group and 96.7 % in the c-ALS group (mean difference, - 2.6 % [CI, - 4.1 % to 1.2 %]). • Faculty, catering, and facility costs were $438 per participant for electronic ALS training and $935 for conventional ALS training.
Notes	• Study aim: To determine whether a blended approach to ALS training that includes electronic learning (e-learning) produces outcomes similar to those of conventional, instructor-led ALS training. • Pedagogical approach used: Facilitated eLearning, Blended training, e-lectures with voice over, interactive workshops, face-to-face training. • Was a learning management system (LMS) used? Yes, customised system. • Journal: Annals of Internal Medicine. • Year of publication: 2012. • Income status of country: High income. • Source of funding: National Institute of Health Research and Resuscitation Council (UK). • Conflict of interest: None stated.

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Secure electronic randomisation was provided by Sealed Envelope (Sealed Envelope, London, United Kingdom; www.sealedenvelope.com). Randomization (1: 1 allocation to a conventional vs. blended learning course) was stratified by course center by using random, permuted blocks of 6 (pg. 20, randomisation and interventions).
Allocation concealment (selection bias)	Low risk	Secure electronic randomisation was provided by Sealed Envelope (Sealed Envelope, London, United Kingdom; www.sealedenvelope.com). Randomization (1:1 allocation to a conventional vs. blended learning course) was stratified by course center by using random, permuted blocks of 6 (pg. 20, randomisation and interventions).
Blinding of outcome assessment (detection bias)	Low risk	Authors used Computerised evaluation of knowledge based outcome.
Incomplete outcome data (attrition bias)	Low risk	A total of 4212 participants were assessed for eligibility; 3732 of these persons gave informed consent and were randomly assigned (Figure 1); of this group, 1843 were randomly assigned to the e-ALS group and 1889 to the c-ALS group. A total of 440 participants in the e-ALS group and 444 in the c-ALS group withdrew after randomizations but before attending the course. E-mail follow-up of non-responder indicated that most people withdrew because they were unable to secure leave for the assigned course dates. Thirteen participants randomly assigned to the e-ALS group attended the conventional course; 21 participants allocated to the c-ALS group attended the e-learning course. No participants were lost to follow-up

		(pg. 22, results). Intention-to-treat analysis and a per-protocol analysis according to the actual course attended were done. Results presented here are for the intention-to-treat analysis. The per-protocol analysis led to similar conclusions (pg. 22, results).
Selective reporting (reporting bias)	Low risk	No deviations from the outcomes listed in the study protocol (International Standardized Randomized Controlled Trial Number Register: ISCRTN86380392).
Other bias	Low risk	Baseline characteristics of participants are presented in table 1; the groups were well-matches with respect to age, profession, specialty, and grade (pg. 23). Approximately 25 % of randomly assigned participants withdrew before receiving the intervention, which could have a large effect in a non-inferiority trial. The proportions were similar in both groups (23 % in the e-ALS group and 22 % in the c-ALS group). This finding suggests that these withdrawals were non differential, which was confirmed by e-mail follow-up. The study was open-label; as a result, the assessors could not be blinded to the participant's course. The potential bias that this may have introduced was limited by using standardized and validated outcome-based performance criteria; using a broad instructor base from multiple centers and countries; using 2 assessors for all skill or simulation-based tests; and including blinded, computerized evaluation of knowledge-based outcomes.

Pernar 2012

Methods	• Design: Randomised controlled trial. • Recruitment method: Not described. • Randomization: Yes, method not described. • Speciality: Surgery. • Setting: Hospital.

	• Country: United States.
Participants	• Type of participants: General surgery faculty members. • Inclusion criteria: Not stated. • Exclusion criteria: Not stated. • No of participants randomised: 29 faculty members
Interventions	• Intervention: Weekly spaced education emails with content designed to improve teaching (group A). • Control: No emails (group B).
Outcomes	• Students' perception of faculty members' teaching effectiveness and faculty members' perception of the usefulness of the spaced education e-mails. • All 41 medical students who rotated through the Core Surgery Clerkship rated the quality of teaching for each faculty members; 172 online rating surveys were completed. • Overall, faculty members received high ratings on the teaching skills included on the surveys. Additionally, no significant differences were found between the perceived skill level of the faculty members who received the weekly e-mails and those who did not. Specifically, 53.8 % and 54 % (P = 0.47) of the faculty were felt to deliver feedback more than three times per week; 87.1 % and 89.9 % (P = 0.15) of faculty were felt to deliver useful feedback; 89.2 % and 90.8 % (P = 0.71) of faculty were perceived to encourage student autonomy; and 78.1 % and 81.9 % (P = 0.89) of faculty were felt to set clear learning expectations for students. Post program comments from faculty revealed they did not find the e-mails useful as a faculty development tool.
Notes	• Study aim: To determine the effectiveness of spaced education as a faculty development tool designed to improve teaching skills in a surgery department. • Pedagogical approach used: Individual eLearning, spaced e-mails. • Was a learning management system (LMS) used? No. • Journal: Journal of Surgical Education. • Year of publication: 2012. • Income status of country: High income.

	• Source of funding: Not stated. • Conflict of interest: None stated.

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	The faculty members were randomised into 2 groups, an intervention group (group A) and a control group (group B) (pg. 53, methods). Randomisation method was not described.
Allocation concealment (selection bias)	Unclear risk	No details given to enable judgement.
Blinding of outcome assessment (detection bias)	Unclear risk	No details given to enable judgement.
Incomplete outcome data (attrition bias)	Unclear risk	No details given to enable judgement.
Selective reporting (reporting bias)	Low risk	All pertinent outcomes mentioned in the methods section were reported.
Other bias	Low risk	Baseline similarity, the groups were not different by either experience (P = 0.7) or sex (P = 0.8) composition. Other characteristics were not compared. This study has several limitations, including that it was conducted at a single institution and involved faculty members working in a single specialty. This may hamper the generalisability of our results. An additional drawback is that our outcome measures were based on subjective student reports of faculty teaching; this in fact is an acknowledged obstacle to evaluating faculty development programs. Also, the response rate of faculty in the intervention group was very low.

Platz 2010

Methods	• Design: Randomised controlled trial. • Recruitment method: Recruitment for study participation took place by e-mail and announcement on the 2 participating hospitals' bulletin boards. The announcements stated that previous ultrasonographic knowledge or skills were not required for participation. Resident and attending physicians were uniformly welcome. Enrollment was voluntary and occurred on a first-come, first-served basis. No incentives were offered to the subjects. • Randomization: Yes, method not described. • Speciality: Emergency medicine (ED). • Setting: Hospital. • Country: United States.
Participants	• Type of participants: ED physicians. • Inclusion criteria: We included physicians aged 18 years or older and currently practicing in a German ED, regardless of their specialty training. • Exclusion criteria: Learners unable to participate in all aspects of the study, e.g., because of scheduling conflicts and, within the control group only, those not completing the pretest, were excluded. • No of participants randomised: 55 physicians.
Interventions	• Intervention: Web group watched lectures online. • Control: Classroom group with traditional lectures.
Outcomes	• 25-item MCQ evaluated factual knowledge, image recognition and interpretation, and the ability to incorporate ultrasonographic findings into patient management scenarios. Primary outcome measure was difference in mean score between groups. • Both the classroom and Web group showed significant improvement in pre- and posttest 1 scores (75.9 % versus 93.9 % and 77.8 % versus 92.5 %; P = .001 for both), with similar knowledge retention after 8 weeks (88.6 % and 88.9 %; P = .87). • No statistically significant difference in mean test scores could be found between the 2 groups at each point: – 1.9 % (95% confidence interval [CI] – 5.2 %

	to 1.4 %) for the pretest, 1.4 % (95% CI – 0.6 % to 3.4 %) for posttest 1 and – 0.3 % (95% CI – 3.9 % to 3.3 %) for posttest 2. The control group showed no learning effect without intervention (83.3 % versus 82.8 %, P = .88).
Notes	• Study aim: The study evaluates whether Web-based didactics result in similar knowledge improvement and retention of basic ultrasonographic principles and the Extended Focused Assessment with Sonography for Trauma (EFAST) compared with the traditional method. • Pedagogical approach used: Individual eLearning, online lectures. • Was a learning management system (LMS) used? No. • Journal: Annals of Emergency Medicine. • Year of publication: 2010. • Income status of country: High income. • Source of funding: This study was supported by the Esther B. Kahn Fund from the Department of Emergency Medicine, Brigham and Women's Hospital, Boston. • Conflict of interest: None.

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	High risk	After enrolment, study group participants at each site were allocated to a classroom (Class) and a Web group (Web) according to their last name in alphabetical sequence (A = Web, B = Class, C = Web, D = Class, etc.). Allocation was performed for both study sites separately (to ensure similar group sizes at each site) by the principal investigator after receipt of the name lists. Control subjects were not included in the allocation process (pg. 662, study design).

Allocation concealment (selection bias)	High risk	Allocation protocol was predictable by the personnel responsible for determination of eligibility and execution of group assignment (pg. 665, limitations, ln 9).
Blinding of outcome assessment (detection bias)	Unclear risk	No details given to enable judgement.
Incomplete outcome data (attrition bias)	High risk	Sixty-four subjects were enrolled, of whom 55 participated in the study and were included in the data analysis (85.9 %) (Figure 1): 19 subjects in the classroom group, 23 in the Web group, and 13 in the control group. Of these, 6 subjects in the classroom group and 5 subjects in the Web group did not complete all 3 tests. Reasons for incomplete participation included limited Internet access, illness, and scheduling conflicts. Basic demographic data are summarized in Table 1 (pg. 663, results).
Selective reporting (reporting bias)	Low risk	All pertinent outcomes mentioned in the methods section were reported.
Other bias	High risk	Baseline characteristics by study group are presented in table 1. Baseline differences are evident for gender, previous ultrasound training and level of training (pg. 663). Our study has several limitations. First, it was limited by a small sample size, and a larger group of study participants might have led to more precise estimates of test score improvement attributable to didactic technique. Second, subjects in the study groups (Web and Class) were allocated according to the first initial of their last name, which represents a pseudo randomization design. A bias may have been introduced because of lack of concealment, because the allocation protocol was predictable by the personnel responsible for determination of eligibility and execution of group assignment. Third, study participants of the Web-based group had access to the online presentations as frequently as desired,

		whereas the classroom group attended the presentations once. Although repeated access to Web-based presentations may present an advantage over one-time classroom lectures, in our study only a minority of Web group participants reported accessing the Web-based lectures more than once, supporting comparability of the 2 educational concepts. Fourth, we were not able to track the time elapsed between viewing of the online lectures by the Web group and their completion of posttest 1, although all had to view the lectures and complete the test within 2 weeks. This inability might have resulted in a variable interval between didactic training and posttest 1 in this group, whereas in the class group all subjects completed the posttest 1 after attending the lectures. This potentially different interval in the 2 groups may have affected the test performance. Fifth, the online pre- and posttests were open-book tests for all 3 groups. Study participants could have used additional resources to determine the correct answer or collaborated with other study participants to solve the questions. Only the Web group had access to the online lectures during the first posttest, whereas the classroom group completed this test in class after completion of the lecture. However, neither group had access to the online course during the pretest or the second posttest. Sixth, more subjects in the Web group sought additional training after completion of the practical instruction and before taking posttest 2, which might have influenced their performance in posttest 2 and biased our results. Seventh, the majority of study participants had undergone some form of ultrasonographic training in the past. Whether our findings are applicable to groups without previous ultrasonographic education warrants further investigation. Last, although all physicians

		underwent hands-on instruction, this study did not assess practical competency in the performance of an EFAST examination. Although there is literature to support an association between operator confidence and accuracy of abdominal ultrasonography (including the Focused Assessment with Sonography for Trauma), 16, 17 we are unaware of evidence that performance on multiple-choice tests is predictive of actual ultrasonographic competence and skill in practice. Our study results are therefore limited to assessment of didactic performance, and the effect on practical performance cannot be inferred (pg. 665, limitations).

Putnam 2015

Methods	• Design: Randomised allocation only. • Recruitment method: • Randomization: Yes, randomisation was performed using the proc project procedure in SAS/STAT (pg. 3, study design) • Speciality: General and Orthopedic surgery • Setting: University/Hospital. • Country: United States
Participants	• Type of participants: General and Orthopedic surgery residents • Inclusion criteria: Not stated • Exclusion criteria: Not stated • No of participants randomised: 70 residents
Interventions	• Intervention: Online course on "Mastering Difficult Family Conversations in Surgical Care" • Control: No training.
Outcomes	• OSCE performance performance change score for end of life and error disclosure conferences
Notes	• Study aim: The study tested the hypothesis that at

	post-test, the treatment group (Online course on "Mastering Difficult Family Conversations in Surgical Care") would outperform the control group on EOL and ED case encounters. • Pedagogical approach used: Individual learning • Was a learning management system (LMS) used? No • Journal: American Journal of Surgery • Year of publication: 2016 • Income status of country: High income • Source of funding: This study was supported in part from a grant from the Association of Surgical Education and the Association of Program Directors in Surgery (Collaboration Award for 2014) and from internal research funds at both institutions. • Conflict of interest: None stated.

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Randomization was done, method not described.
Allocation concealment (selection bias)	Unclear risk	No details given to enable judgement.
Blinding of outcome assessment (detection bias)	Unclear risk	No details given to enable judgement.
Incomplete outcome data (attrition bias)	High risk	High dropout rates at 6 month follow up (table), pgS128.
Selective reporting (reporting bias)	Low risk	All pertinent outcomes mentioned in the methods section were reported.
Other bias	Low risk	Baseline data is reported.

Ruf 2010

Methods	• Design: Cluster randomised controlled trial. • Recruitment method: Not stated. • Randomization: Yes, method not described. • Speciality: Primary care. • Setting: Hospital. • Country: Germany.
Participants	• Type of participants: General practitioners. • Inclusion criteria: use of broadband Internet and a practice team consisting of at least one nurse, all willing physicians in the region of South Baden–Württemberg were included in the trial. • Exclusion criteria: None. • No of participants randomised: 112 general practices.
Interventions	• Intervention 1: The first group (n = 43) received access to the online system and a training programme for the general practitioners (GPs). • Intervention 2: The second group (n = 42) additionally received education for the whole practice team. • Control: The third group (n = 27) acted as control and received only access to the online system.
Outcomes	• Usage of the system, frequency of usage, diagnostic assessment. • There were no significant differences concerning the use of the system between the groups: 41.9 % of the GPs in the first group, 42.9 % in the second group and 44.4 % in the control group used the system. • In terms of only the system users, 55.6 % of the GPs in the first group, 33.3 % in the second group and 8.3 % in the control group used the system six times or more (P = 0.019). • Diagnostic assessments made by the GPs in the groups differed substantially: 72.2 % of diagnoses in the first group were correct, while this figure lay at 69.7 % in the second group and 36.4 % in the control group (P = 0.034).
Notes	• Study aim: This project investigated different dissemination strategies of an online quality

	improvement programme for alcohol-related disorders into routine care in South Baden and South Württemberg in Germany. • Pedagogical approach used: Facilitated eLearning, online lectures and training. • Was a learning management system (LMS) used? No. • Journal: Alcohol and Alcoholism. • Year of publication: 2010. • Income status of country: High income. • Source of funding: German Ministry for Education and Research. • Conflict of interest: None stated.

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	We randomised 112 practices to the three Strategy groups by minimization, a valid alternative to ordinary randomisation in small trials (pg. 71, randomisation). The allocation sequence was generated using the software MINIM v1.5 by a researcher who was blind to the identity of the practices (pg. 71, randomisation, ln 23).
Allocation concealment (selection bias)	Low risk	The allocation sequence was generated using the software MINIM v1.5 by a researcher who was blind to the identity of the practices (pg. 71, randomisation, ln 23).
Blinding of outcome assessment (detection bias)	Unclear risk	No details given to enable judgement.
Incomplete outcome data (attrition bias)	Low risk	A primary intention-to-treat (ITT) analysis was performed including all physicians who were randomised. Additionally, a per-protocol (PP) analysis of completers and an as-treated (AT) analysis were performed

		(pg. 72, statistical methods). One hundred and twelve (4 %) practices agreed to participate and were randomised. There were no statistically significant differences between the contacted practices and the randomised ones concerning sex and specialization. In the ITT analysis, we analysed 43 practices in Strategy 1 (GP group: training only for the GPs), 42 practices in Strategy 2 (GP + nurse group: training for the GPs and the practice team) and 27 in Strategy 3 (no training). Twenty-eight of the 43 practices allocated to Strategy 1 actually took part in the training; 10 of the 42 practices allocated to Strategy 2 (GP + nurse) took part with the GP and nurses, and eight participated with the GP but without nurses. Fig. 1 shows the number of practices in each group for the ITT analysis, the PP analysis and the AT analysis and the number of baseline and follow-up documentations. The drop-out rate of practices was significantly higher in the GP + nurse group, but there were no differences concerning sex, age, population of the town/city, patients seen per quarter and Internet know-how (pg. 72, results).
Selective reporting (reporting bias)	Low risk	All pertinent outcomes mentioned in the methods section were reported.
Other bias	Low risk	Baseline characteristics of the GPs and patients are presented in table 1. There were no statistically significant differences on any variables (pg. 72). Some methodological shortcomings of the present study should be considered. Only 112 of the invited 2,647 practices ultimately took part in the study. Although representativeness of the sample for the reference population can be assumed regarding gender and qualifications, other factors (e.g. attitude towards the use of the Internet

		and of online CME) might have led to a self-selective non-responder bias, meaning that we cannot rule out a specific motivational bias. Moreover, the amount of practices which received the per-protocol intervention was only about 65 % in the GP group and as low as 24 % in the GP+nurse group. The number of documented patients by the GPs was low. The low number of documented patents limits power of the conclusions concerning clinical outcomes. The results of the study are based on a selective practice population, meaning that generalisability is limited

Sangvai 2012

Methods	• Design: Cluster randomised controlled trial. • Recruitment method: Not stated. • Randomization: Yes, method not described. • Speciality: Paediatrics. • Setting: Hospital. • Country: United States.
Participants	• Type of participants: Paediatric residents. • Inclusion criteria: Not stated. • Exclusion criteria: Not stated. • No of participants randomised: 58 residents.
Interventions	• Intervention: Interactive web-based module on injury prevention. • Control: Non-interactive web-based module of identical content.
Outcomes	• 20 MCQ questions were used to measure knowledge acquisition. Clinical practice was measured by evaluation of video-taped well child encounters before and after intervention. • Fifty-seven residents completed the modules. The control group had higher posttest scores than the intervention group (P = .036). Thirty-seven residents completed the long-term test with scores that were significantly higher than pretest scores (P = .00).

	Thirty-six residents had videotaped encounter scores (232 visits), with no difference in these scores after the intervention (P = .432). • Web-based interactive modules: mean 0.5, SD 0.7, n=29, Control: Non-interactive web-based modules, mean 0.9, SD 1.2, n=29.
Notes	• Study aim: To determine the effectiveness of an interactive Web-based module on knowledge acquisition, retention, and clinical practice by residents. • Pedagogical approach used: Individual eLearning, interactive web-based module. • Was a learning management system (LMS) used? No. • Journal: Clinical Pediatrics. • Year of publication: 2012. • Income status of country: High income. • Source of funding: This study was funded in part by the Special Projects Grant, Association of Pediatric Program Directors (APPD). • Conflict of interest: Yes, the author reported receiving compensation for her work on this study.

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Pediatric residents from 3 levels of training in 1 residency program who consented were enrolled and randomised in the study. Residents were randomised based on alternating order after enrolment was completed (pg. 166, methods). Randomisation method was not described.
Allocation concealment (selection bias)	Unclear risk	No details given to enable judgement.
Blinding of outcome assessment (detection	Unclear risk	No details given to enable judgement.

bias)		
Incomplete outcome data (attrition bias)	High risk	There were 133 pre-intervention and 173 post intervention VEs completed by 45 and 47 residents, respectively. However, there were only 36 residents who had both pre-intervention and post intervention VE scores, representing 232 (108 pre and 124 post) visits for which we based our analysis (pg. 169, videotaped encounter scores). Figure 1 shows the drop outs from the study.
Selective reporting (reporting bias)	Low risk	All pertinent outcomes listed in the methods section were reported.
Other bias	Unclear risk	Table 2 shows characteristics of residents, but differences were not tested statistically. As a method to measure clinical practice, we scored the number of injury prevention topics mentioned during the clinic visit. We did not, however, measure the quality of the discussion. While one could argue that the quality of injury prevention counselling is of greater importance than the amount of topics covered, it is undoubtedly even more difficult to measure (pg. 172, clinical practice, ln 58).

Satterwhite 2012

Methods	• Design: Random allocation only. • Recruitment method: Not stated. • Randomization: Yes, method not described. • Speciality: Surgery. • Setting: Hospital. • Country: United States.
Participants	• Type of participants: PGY-1 to PGY-6 plastic surgery residents. • Inclusion criteria: Not stated. • Exclusion criteria: Not stated. • No of participants randomised: 17 residents.

Interventions	• Intervention: The experimental group completed this online resource. • Control: No intervention.
Outcomes	• Written test scores, time to complete surgical task and self-assessment. • Residents who completed the web-based curriculum showed dramatic improvement in their knowledge and skills, with a 17-percentage point increase in their test scores (P = 0.01) compared with controls (P = 0.80). • The experimental group was more likely to perform micro anastomoses faster with an average of 4.5-minute improvement compared with 1.25-minute change among the control group. • Residents performed self-assessments, and those who rated themselves as "very confident" had higher overall test scores (85 % test score vs. 59 %, P = 0.004), as well as shorter times to complete the microsurgical task (7.5 minutes vs. 13.6 minutes, P = 0.007). • Overall, 62 % of residents rated the online webpage as extremely valuable. The majority of residents reported the webpage improved their knowledge and markedly improved their microsurgical technique, which was confirmed by faculty experts.
Notes	• Study aim: To assess the effectiveness of a web-based microsurgical curriculum. • Pedagogical approach used: Individual eLearning, web-based curriculum. • Was a learning management system (LMS) used? No. • Journal: Annals of Plastic Surgery. • Year of publication: 2012. • Income status of country: High income. • Source of funding: Not stated. • Conflict of interest: None.

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Residents were then randomly divided (Fig. 2): one group had access to the online resource over a 1-week time period, and the other group did not (pg. 411, methods). Randomisation method was not described.
Allocation concealment (selection bias)	Unclear risk	No details given to enable judgement.
Blinding of outcome assessment (detection bias)	Unclear risk	No details given to enable judgement.
Incomplete outcome data (attrition bias)	Low risk	A total of 17 residents were included in this study, representing all years of the program from PGY-1 to PGY-6. Nine residents were randomized to have access to the "Microsurgery Essentials" Web site, whereas the remaining 8 residents did not. The average number of prior intraoperative microvascular anastomoses performed by the residents was 16, with a range from 0 to 80. No drop outs in the study (pg. 412, results).
Selective reporting (reporting bias)	Low risk	All pertinent outcomes were reported.
Other bias	High risk	Baseline comparison of characteristics not reported. Sample size was small.

Saxon 2015

Methods	• Design: Random allocation only • Recruitment method: Recruitment was conducted vial e-mail; volunteer internal medicine interns were recruited. • Randomization: Randomisation method not described. • Speciality: Internal medicine, Internal medicine-pediatrics. • Setting: University • Country: United States
Participants	• Type of participants: Residents and fellows from Internal medicine, Internal medicine-pediatrics • Inclusion criteria: Not stated • Exclusion criteria: Not stated • No of participants randomised: Participants were randomised to group A or group B. E-mails were sent to 44 physicians in each group.
Interventions	• Intervention: A journal article with hyperlink Access (group A) • Control: No hyperlink access (group B)
Outcomes	Residents and fellows knowledge of selected bio statistical terms was measured by pretest and posttest consisting of 5 unique items
Notes	• Study aim: A randomised trial of a novel computer-based intervention, a hyperlink-embedded journal article (HEJA), geared toward improving the understanding of bio-statistical terms by physicians-in-training. • Pedagogical approach used: Individual learning • Was a learning management system (LMS) used? No • Journal: Journal of Graduate Medical Education • Year of publication: 2015 • Income status of country: High income • Source of funding: No external funding. • Conflict of interest: None.

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	The study was randomised, but method not described. However, the study used Qualtrix software for the survey administration; the software has option to randomise participants. (pg. 655, procedure)
Allocation concealment (selection bias)	Unclear risk	No details given to enable judgement.
Blinding of outcome assessment (detection bias)	Low risk	Open-responses were blinded and graded by a statistician. (pg. 655, procedure)
Incomplete outcome data (attrition bias)	High risk	Participants were randomised to group A or B, email were sent to 44 physicians-in-training in group A and 44 in group B. However only 22 each completed the survey in group A and B. (Table, pg. 656)
Selective reporting (reporting bias)	Low risk	All pertinent outcomes listed were reported.
Other bias	High risk	Baseline scores were reported, however the study had many limitations, small sample size of physicians-in-training at 1 academic institution, lack of validity testing of the questions and questions were focused on small number of bio statistical terms.

Schmitz 2016

Methods	• Design: Random allocation only • Recruitment method: PG year 1 and year 3 residents were enrolled in the study. (pg. 2, methods) • Randomization: Randomisation was done using block group design with stratified random assignment for 3 strata: pretest performance, specialty, and training site using the proc project procedure in SAS/STAT. • Speciality: Surgery • Setting: University • Country: United States
Participants	• Type of participants: Residents from general and orthopedic surgery programs • Inclusion criteria: Not stated • Exclusion criteria: Not stated • No of participants randomised: 72 residents
Interventions	• Intervention: Online course, "Mastering Difficult Family Conversations in Surgical Care" • Control: No training
Outcomes	• Objective structured clinical exam (OSCE) performance • Total group performance: Residents in the treatment group improved their OSCE scores from 58.8 to 72.5, change score = 13.7); residents in the control group improved from 60.9 to 68.0 (change score =7.0), P>0.05.
Notes	• Study aim: The randomised study tested the hypothesis that at post-test, the treatment group would outperform the control group on EOL and ED case encounters. • Pedagogical approach used: Individual learning • Was a learning management system (LMS) used? No • Journal: American Journal of Surgery • Year of publication: 2016 • Income status of country: High income • Source of funding: This study was supported in part

	from a grant from the Association of Surgical Education and the Association of Program Directors in Surgery and from internal research funds at both institutions. • Conflict of interest: None.

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Randomisation was done using block group design with stratified random assignment for 3 strata: pretest performance, specialty, and training site using the proc project procedure in SAS/STAT.
Allocation concealment (selection bias)	Unclear risk	No details given to enable judgement.
Blinding of outcome assessment (detection bias)	Unclear risk	No details given to enable judgement.
Incomplete outcome data (attrition bias)	High risk	The unexpected attrition at 1 site lowered our power to detect smaller, but potentially meaningful differences between treatment and control group subjects at post-test. (pg. 8, discussion) Attrition in the sample was due to residents leaving the program (n=2), excused absences from the post-test (n =5), and missing data (n=9). Most of the attrition occurred at 1 site (Mayo), and within 1 specialty (orthopedics), largely due to technical difficulties with B-Line unfortunately occurring on the day many of the orthopedic residents were scheduled. Response rates to the OSCE feedback survey items were n=30 (83%) for the treatment group, n=23 (72%) for the control group. Intervention group survey

		response rates by site were 100% for UMN, 74% for Mayo.
Selective reporting (reporting bias)	Low risk	All pertinent outcomes listed were reported.
Other bias	High risk	Baseline difference not reported. OSCE clinical raters knew the subjects they were rating, and some knew which were in the intervention group. Standardised family members were blinded, but the potential for surgeon and nurse rater bias existed. EOL and ED rating tools validity were not tested. (pg. 8, discussion)

Schroter 2011

Methods	• Design: Randomised controlled trial. • Recruitment method: Volunteers were recruited (between 20/02/09 and 01/04/09) through targeted emails to registered users of univadis® (provider of online health care resources) and health professionals on the BMJ's contact database. Advertisements inviting English and German speaking practicing doctors and nurses to take part in an educational research project were placed in the BMJ, two German magazines (Der Hausarzt and Der Allgemeinarzt), and a newsletter (Aerztezeitung). • Randomization: Yes, method not described. • Speciality: Primary care. • Setting: Hospital. • Country: United Kingdom.
Participants	• Type of participants: Doctors. • Inclusion criteria: Not stated. • Exclusion criteria: Not stated. • No of participants randomised: 650 doctors.
Interventions	• Intervention: Diabetes Needs Assessment Tool (DNAT), Learning Management System.

	• Control: Diabetes learning modules alone.
Outcomes	• Knowledge, acceptability and changes to clinical practice. • For the 650 doctors completing both tests, mean (SD) knowledge scores increased from 47.4 % (12.6) to 66.8 % (11.5) [intervention group (n = 321, 64 %)] and 47.3 % (12.9) to 67.8 % (10.8) [control group (n = 329, 66 %)], (ANCOVA P = 0.186). • Both groups were satisfied with the usability and usefulness of the learning materials. • Seventy seven percent (218 / 284) of the intervention group reported combining the DNAT with the recommended reading materials was “very useful"/"useful”. • The majority in both groups (184 / 287, 64.1 % intervention group and 206 / 299, 68.9 % control group) [95% CI for the difference (- 2.8 to 12.4)] reported integrating the learning into their clinical practice.
Notes	• Study aim: To evaluate the effectiveness of an interactive online Diabetes Needs Assessment Tool (DNAT) (which constructs an e-learning curriculum based on individually identified knowledge gaps), compared with self-directed e-learning of diabetes guidelines. • Pedagogical approach used: Individual eLearning, online interactive resource. • Was a learning management system (LMS) used? Yes. • Journal: BMC Medical Education. • Year of publication: 2011. • Income status of country: High income. • Source of funding: BMJ Group received a grant of £110,000 from MSD to help fund this study. All other expenses for the study, except translation costs, were paid by BMJ Group. • Conflict of interest: None.

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Eligible registered participants on completion of Test 1 (described below) were randomised to either the control or intervention group (pg. 2, randomisation). Randomisation method was not described.
Allocation concealment (selection bias)	Unclear risk	Optimal allocation with a ratio of 1:1 was used. Randomisation was balanced for language, ability (based on Test 1 score), doctor or nurse, years since qualification, and whether they were registered users of the web service univadis® and/or BMJ Learning, using a minimisation technique. The total sample of health professionals recruited was divided into blocks of 24 and within each block a process of optimal allocation was undertaken. This involved obtaining all possible allocations and calculating a balance statistic. One thousand allocations with the greatest degree of balance were identified and passed to an independent statistician within the South East Wales Trials Unit (SEWTU) at Cardiff University, who randomly selected a single allocation for each block. This was then returned to the trial statistician (RP) and the study database manager informed of the allocations (pg2, randomisation).
Blinding of outcome assessment (detection bias)	Unclear risk	No details given to enable judgement.
Incomplete outcome data (attrition bias)	Low risk	All analyses followed the intention to treat (ITT) principle and groups were analysed as randomised. Missing Test 2 scores were assumed to have remained unchanged for the ITT analysis. A complete case analysis (CCA) was also carried out

		excluding those missing follow-up test scores. Attrition rates were similar in both groups (pg. 6, discussion). Authors have also included additional unplanned analysis (pg. 4).
Selective reporting (reporting bias)	Low risk	No deviations from the study protocol (ISRCTN: ISRCTN67215088).
Other bias	Low risk	Table 1 shows baseline characteristics of the sample. The characteristics were fairly similar, (pg. 4, primary outcome). Limitations of the study include the self-selected and highly motivated sample. At the start of the study, the majority of the participants were already registered users of online learning resources (BMJ or univadis®) and may prefer online learning. Also, practice change was assessed in the short term and based on self-reporting rather than observation. The study was conducted with two language groups, we do not know if the results are generalisable to other language groups.

Shariff 2015

Methods	• Design: Randomised controlled trial. • Recruitment method: General surgical speciality trainees (ST) and research fellows at ST level 3–8 or equivalent (irrespective of subspeciality interest) from the London deanery were invited to participate by e-mail (lead investigator); this included a study flyer attachment and hyperlink (http://www.colorectaltraining.co.uk) with access to an online information sheet and a consent form. • Randomization: Yes, randomisation was carried out using computer-generated random permuted blocks. • Speciality: Surgery. • Setting: University. • Country: United Kingdom.

Participants	• Type of participants: General surgical speciality trainees (ST) and research fellows at ST level 3–8 or equivalent. • Inclusion criteria: Not stated. • Exclusion criteria: Not stated. • No of participants randomised: 59 trainees.
Interventions	• Intervention: Multimedia group. Participants in the multimedia group were provided access to the online tool for 30 days. • Control: Study day, the study day was held at the end of this period for the control group (7 December). The study day was delivered as a series of interactive lectures by two colorectal surgeons (SD and PNH) using MICROSOFT POWERPOINT and covered all steps of open and laparoscopic anterior resection surgery. The content delivered was identical to that in the multimedia tool and equal time was devoted to open and laparoscopic procedures.
Outcomes	• Fifty-nine trainees were randomised but 27 % dropped out, leaving 43 trainees randomised to the multimedia group (n = 25) and study day group (n = 18) who were available for analysis. • Posttest scores improved significantly in both groups ($P < 0.01$). • The change in scores (mean ± SD) in the multimedia group was not significantly different from the study day group (6.02 ± 5.12 and 5.31 ± 3.42, respectively; $P = 0.61$). • Twenty-five trainees completed the evaluation survey and experienced an improvement in their decision making (67 %) and in factual and anatomical knowledge (88 %); 96 % agreed that the multimedia tool was a useful additional educational resource.
Notes	• Study aim: This study aimed to determine the effectiveness of a multimedia educational tool developed for an index colorectal surgical procedure (anterior resection) in teaching and assessment of cognitive skills and to evaluate its

	acceptability amongst general surgical trainees. • Pedagogical approach used: Individual eLearning, online multimedia interactive resource. • Was a learning management system (LMS) used? No. • Journal: Colorectal Disease. • Year of publication: 2012. • Income status of country: High income. • Source of funding: Educational study agreement was provided by Ethicon Endo-Surgery for the production of the multimedia educational tools. • Conflict of interest: None stated.

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Enrolled participants were randomly allocated into the intervention (multimedia) or control (study day) group. Block randomisation was performed using computer-generated random permuted blocks of four within strata defined by age (< 34, ≥ 34), training experience (junior, < ST5 level; senior, ST5 level or higher) and length of experience working in colorectal firms at ST3 level or above (< 12 months, 12 months or more), generated by a University of Sheffield statistician (pg. 442, methods).
Allocation concealment (selection bias)	Unclear risk	The investigator recruiting the trainees was unaware of the random sequence, ensuring allocation concealment (pg. 442, methods).
Blinding of outcome assessment (detection bias)	Unclear risk	No details given to enable judgement.
Incomplete outcome data (attrition bias)	Unclear risk	All data were analysed according to ‘intention to treat' (pg. 444, statistical methods). A total of 358 potential participants were contacted, and of these 61 (17 %) trainees were

		initially recruited. Fifty-nine trainees provided complete demographic data and were randomised to the multimedia group (n = 30) or study day group (n = 29). The flow of participants in the study is detailed in Fig. 3. The overall drop-out rate following randomisation was 27 %, leaving 43 participants (25 in the multimedia group and 18 in the study day group) for the final analysis. All 25 multimedia participants completed the post intervention test and evaluation forms; all 18 study day participants completed the post intervention test (pg. 444, results).
Selective reporting (reporting bias)	Unclear risk	No deviations from the study protocol (ClinicalTrials.gov ID: NCT01866436).
Other bias	Unclear risk	The demographics of participants are summarized in Table 1. The two groups were comparable with no significant differences in age (P = 0.96), seniority of training (P = 0.71), subspecialty interest (P = 0.68) or experience in colorectal surgery (P = 0.71). This study had a number of limitations. The response rate was low (17 %) and the drop-off rate was 27 %; contributory factors may include busy clinical schedules, lack of participant 'enthusiasm' and the length of the study period. The study focused on the lower levels of clinical competence and the impact of the educational intervention on patient-centered outcomes was therefore not assessed. The primary outcome measure used can best be considered as a short-term surrogate of operative competency; especially in relation to cognitive skills. The improvement in scores in the multimedia group was much less than what was expected during a priori sample size calculations. This means that the study could be criticized for not having adequate

		power to show a difference between the groups. Lastly, the use of identical pre–post tests may have contributed to improvement in scores simply by repetition, regardless of the intervention (pg. 448, discussion).

Sharma 2013

Methods	• Design: Randomised allocation only. • Recruitment method: Not stated. • Randomization: Yes, randomisation was carried out using computer-generated random number. • Speciality: Anaesthesia. • Setting: Hospital. • Country: United Kingdom.
Participants	• Type of participants: 28 anaesthetic trainees (specialty training (ST) year 4 to year 6). • Inclusion criteria: Not stated. • Exclusion criteria: Trainees with any previous experience of either transoesophageal or transthoracic. echocardiography was not studied, thus creating an 'echo-naıve' cohort of subjects. • No of participants randomised: 28 trainees.
Interventions	• Intervention: Internet based echocardiography. • Control: Learning via traditional methods such as review of guidelines and other literature (non-internet group).
Outcomes	• Knowledge. • Mean (SD) scores of subjects in the non-inter-net group were 28 (10) %, 44 (10) % and 63 (5) % in the pre-test, post-intervention test and post-simulation test, respectively, whereas those in the internet group scored 29 (8) %, 59 (10) %, (P = 0.001) and 72 (8) %, P = 0.005, respectively.
Notes	• Study aim: The primary objective of this study was to identify whether internet-based interactive TOE learning assists anaesthetic trainees with no previous experience of echocardiography to

	identify the 20 standard TOE views better than traditional methods such as journal articles, textbooks and lecture-based teaching. The secondary objective of the study was to determine if simulation based TOE training acts as an effective supplement to either method and augments basic TOE view recognition. • Pedagogical approach used: Individual eLearning, online learning resource. • Was a learning management system (LMS) used? No. • Journal: Anaesthesia. • Year of publication: 2013. • Income status of country: High income. • Source of funding: None stated. • Conflict of interest: None.

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Study subjects were randomly assigned using computer-based software to one of the two groups: traditional learning methods (non-Internet group); and online learning (Internet group) (pg. 622, methods).
Allocation concealment (selection bias)	Unclear risk	No details given to enable judgement.
Blinding of outcome assessment (detection bias)	Low risk	Certified in perioperative TOE who were blinded to all aspects of this study (pg. 622).
Incomplete outcome data (attrition bias)	High risk	A total of 28 anaesthetic trainees (23 ST4 / 5 and five ST6 trainees) undertook the pre-test. Five subjects did not attempt the post-intervention test and were therefore excluded (Fig. 1) (pg. 624, results).
Selective reporting (reporting bias)	Low risk	All pertinent outcomes were reported.

Other bias	Unclear risk	There was no difference in baseline knowledge as ascertained by the pre-test between the non-Internet and Internet groups. There was also no difference in the mean (SD) baseline knowledge between ST4 and ST6 trainees, 30 (9) % vs 31 (10) %, respectively, P = 0.44 (pg. 623, results). Demographics have not been compared. There are some limitations in the study. Although the study was larger than previous TOE training studies, the sample size is still relatively small; this may limit the generalisation of these results to a larger population. Due to the voluntary nature of participation and the need to adhere to a time schedule for the administration of the tests, five subjects were not studied as, despite reminders, they failed to attempt the second test. The subjects were asked to attempt this test with minimal notice, to eliminate the possibility of revision on their part. It is possible that the subjects in the non-Internet group could have gained access to the Internet-based learning resource; however, all subjects were specifically questioned on this point at the time of the post-simulation test and all study subjects denied accessing any TOE Internet resource. This study was only set up to evaluate the effect of this multi-modular learning on short-term retention of knowledge, and further investigation would be required to ascertain the effects of these methods on longer term acquisition of competence. This implies that, although a multi-modular learning process significantly enhances the ability of anaesthesia trainees to understand basic echocardiographic anatomy and image recognition, repeated reinforcement of this learning process and further training in the intraoperative milieu is required to achieve an advanced level of competency.

Shaw 2012

Methods	• Design: Randomised controlled trial. • Recruitment method: Incoming interns were randomised into two groups. • Randomization: Yes, randomisation was using the Randomiser software. • Speciality: Surgical and Medical Specialities. • Setting: University. • Country: Australia.
Participants	• Type of participants: Interns. • Inclusion criteria: Residents in surgery and medicine. • Exclusion criteria: Not stated. • No of participants randomised: 371 interns.
Interventions	• Intervention 1: Online spaced education. • Intervention 1: Program with online slide show.
Outcomes	• The outcome measures included national patient safety goals (NPSG)-knowledge improvement, NPSG-compliant behaviours in a simulation scenario, self-reported confidence in safety and quality, programme acceptability and programme relevance. • Both online learning programmes improved knowledge retention. On four out of seven survey items measuring satisfaction and self-reported confidence, the proportion of SE interns responding positively was significantly higher ($P < 0.05$) than the fraction of SQ interns. • SE interns demonstrated a mean 4.79 (36.6 %) NPSG-compliant behaviours (out of 13 total), while SQ interns completed a mean 4.17 (32.0 %) ($P = 0.09$). Among those in surgical fields, SE interns demonstrated a mean 5.67 (43.6 %) NPSG-compliant behaviours, while SQ interns completed a mean 2.33 (17.9 %) ($P = 0.015$). • Focus group data indicates that SE was more contextually relevant than SQ, and significantly more engaging.

Notes	• Study aim: To compare the effectiveness of two types of online learning methodologies for improving the patient-safety behaviours mandated in the Joint Commission National Patient Safety Goals (NPSG). • Pedagogical approach used: Individual eLearning, online spaced education, MCQs with case-scenarios. • Was a learning management system (LMS) used? No. • Journal: BMJ Quality and Safety. • Year of publication: 2012. • Income status of country: High income. • Source of funding: This project was partially supported by a grant from Partners Healthcare. A small grant was awarded to JH as an intern to fund use of software. • Conflict of interest: None.

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Incoming interns were randomised at each hospital into two groups (using the Research Randomiser Software http://www.randomizer.org) (pg. 820, study design).
Allocation concealment (selection bias)	Unclear risk	No details given to enable judgement.
Blinding of outcome assessment (detection bias)	Low risk	All researchers involved in evaluation of performance were blinded to randomisation (pg. 820, study design).
Incomplete outcome data (attrition bias)	High risk	Three hundred and seventy-one trainees participated in the study (196 at Brigham and Women's Hospital (BWH) and 175 at Massachusetts General Hospital (MGH)), only 71 % of all those who completed pre-test completed the

		posttest.
Selective reporting (reporting bias)	Low risk	All pertinent outcomes mentioned in the methods were reported.
Other bias	Unclear risk	Baseline comparison not presented.

Short 2006

Methods	• Design: Randomized controlled trial. • Recruitment method: Community physicians in specialities of internal medicine, family medicine, pediatrics, obstetrics, and gynaecology, and psychiatry in Kansas City and Phoenix were recruited to participate through local medical societies, direct mail, intimate partner violence (IPV) advocacy groups, and an independent practice association assisted with recruitment. • Randomisation: Yes, method not described. • Speciality: Primary care. • Setting: Hospital. • Country: United States.
Participants	• Type of participants: Primary care physicians. • Inclusion criteria: Physicians had to be in private (non-university, non-government) practice in the appropriate medical speciality, in a group of sever or fewer physicians, and have internet access. • Exclusion criteria: Not stated. • No of participants randomised: 81 physicians.
Interventions	• Intervention: Online intimate partner violence CME program. • Control: No CME.
Outcomes	• Intimate partner violence knowledge, attitudes, beliefs, and self-reported behaviours (KABB). • Use of the online CME program was associated with a significant improvement in eight of ten KABB outcomes, including physician self-efficacy and reported IPV management practices, over the study period. These measures did not improve in the control group. • There were significant positive changes for the two

	background PREMIS scales (perceived preparation, P = 0.000, and perceived knowledge, P = 0.000), five of the six opinion scales (preparation, P = 0.000; legal requirements, P = 0.011; workplace issues, P = 0.002; self-efficacy, P = 0.013; and victim understanding, P = 0.044); and the practice issues scale (P = 0.000). • Actual knowledge also improved, but the change was only significant at $P \leq 0.10$ (P = 0.06). The only scale that clearly showed no improvement was the opinions scale related to alcohol/drugs and IPV (P = 0.445)
Notes	• Study aim: there is a need to determine whether well-designed online Intimate Partner (Domestic) Violence (IPV) CME programs can lead to durable improvements in IPV educational outcomes, and provide the type of cost-effective, easily distributed, educational solutions needed to improve the medical management of IPV. • Pedagogical approach used: Individual eLearning, Online CME with interactive multimedia case-scenarios. • Was a learning management system (LMS) used? No. • Journal: American Journal of Preventive Medicine. • Year of publication: 2006. • Income status of country: High income. • Source of funding: Development of the online CME program and the research study were supported by a small business innovation and research grant (R44-MH62233) from the National Institute of Mental Health. • Conflict of interest: None.

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Physicians were randomly assigned to the CME (study) or to the control group, stratified by city, after completing the initial KABB survey and site visit (Figure 1). (pg. 182, participants, ln 16). Randomisation method not described.
Allocation concealment (selection bias)	Unclear risk	No details given to enable judgement.
Blinding of outcome assessment (detection bias)	Unclear risk	No details given to enable judgement.
Incomplete outcome data (attrition bias)	High risk	Figure 1, (pg. 182), shows loss to follow up in the intervention and control groups, however there is not mention of intention to treat analysis in the manuscript.
Selective reporting (reporting bias)	Low risk	All pertinent outcomes were reported.
Other bias	Unclear risk	There were no significant differences between study and control groups in any of the measured demographic variables. The two groups were of similar average age (47 years), gender (52 % vs 56 % male), average years in practice (17 vs 18 years), and previous IPV training (68 % vs 70 % had no training). The groups were also similar in specialty mix, patient load, and average practice size (pg. 183, results, ln 15). Change in physician self-reported intimate partner violence (IPV) management practices (behaviours) following the CME program was not independently verified by chart audits, referral rates, or other patient-related measures.

Stewart 2005

Methods	• Design: Random controlled trial. • Recruitment method: Study investigators used a list of physicians from southwestern Ontario (n=1,074) and placed calls to those they knew. A total of 209 physicians were approached. Those physicians who expressed interest in participating in the study were then sent an information package describing the study in greater detail. Of the 209 physicians approached, 58 (28%) agreed to participate. • Randomisation method: Yes, participants were randomised using a random number table. • Speciality: Family medicine. • Setting: University. • Country: Canada.
Participants	• Type of participants: Family physicians. • Inclusion criteria: Family physicians in southwestern Ontario with access to and willingness to check their e-mail at least twice per week. • Exclusion criteria: Not stated. • No of participants randomised: 58 physicians.
Interventions	• Intervention: Two case-based on-line learning modules on type 2 diabetes, prevention, each lasting 2 weeks modules. • Controls: Waitlisted to receive the intervention at a later stage.
Outcomes	• Physician knowledge scores, quality of practice measured by chart-audit scores and physician behavior scores. • Intervention group showed statistically significant improvements compared to the control group for knowledge and chart-audit scores for one of the two cases. Significant results presented below. • **Physician knowledge scores, prevention topic** Intervention group (n = 27),Before, n = 27, Mean ± SD, 53.8 ± 12.8, 2 months after, n = 27, 63.8 ± 17.6, P < 0.05, 6

	months after, n = 27, 65.7 ± 15.2, P < 0.05, Control group (n = 31, Before, n = 31, Mean ± SD, 51.9 ± 9.5, 2 months after, n = 31, 50.5 ± 13.8, P < 0.05, 6 months after, n = 24, 53.3 ± 10.5, P < 0.05 • **Quality of practice (chart-audit)** Intervention group (n = 27), Before, n = 27, Mean ± SD, 52.2 ± 11.1, 2 months after, n = 27, 52.2 ± 11.7, 6 months after, n = 27, 55.0 ± 10.0, P < 0.05 Control group (n = 31), Before, n = 31, Mean ± SD, 51.1 ± 14.4, 2 months after, n = 31, 47.7 ± 13.8, P < 0.05, 6 months after, n = 24, 50.0 ± 14.4, P < 0.05
Notes	• Study aim: This project evaluated the use of e-mail to deliver evidence-based moderated case discussions to family physicians. • Pedagogical approach used: Individual eLearning, online learning modules and discussions. • Was a learning management system (LMS) used? No. • Journal: Family Medicine. • Year of publication: 2005. • Income status of country: High income. • Source of funding: Financial support was received from the Medical Research Council of Canada, Health Systems Research Unit Program, Ministry of Health and Long-term Care, Ontario. • Conflict of interest: None stated.

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Family physicians were allocated to the immediate intervention group or wait-list control group in a stratified random fashion (pg. 132, methods, ln 20). Family physicians within each stratum were then allocated by the study co-coordinator using a random numbers table to the intervention or

		control group (pg. 132, methods, ln 35).
Allocation concealment (selection bias)	Unclear risk	No details given to enable judgement.
Blinding of outcome assessment (detection bias)	Unclear risk	No details given to enable judgement.
Incomplete outcome data (attrition bias)	Unclear risk	No details given to enable judgement.
Selective reporting (reporting bias)	Low risk	All pertinent outcomes were reported.
Other bias	High risk	Table 5 (pg. 135) shows the baseline comparison of knowledge scores between the intervention groups. there were substantial differences between the groups based on rural/urban practice location and solo/group practice structure. Because the latter was related to outcomes, we conducted all analyses controlling for solo/group status. Small sample size, hence not able to detect significant differences. Possibility of bias in subject enrolment as subject enrolment was done using non-random sampling, and lastly the study used an experienced moderator on on-line education and hence the results cannot necessarily be generalized to other settings (pg. 137, limitations).

Sullivan 2010

Methods	• Design: Random controlled trial. • Recruitment method: Participating medicine residencies were recruited through the Educational Innovation Project (EIP) of the Residency Review Committee for Internal Medicine (RRC-IM). • Randomisation method: Yes, method not described. • Speciality: Internal medicine. • Setting: University and Hospital. • Country: United States.

Participants	• Type of participants: Internal medicine residents. • Inclusion criteria: Not stated. • Exclusion criteria: Not stated. • No of participants randomised: 213 residents.
Interventions	• Intervention 1: Project comparing access to interactive web-based training (COPE: Collaborative Opioid Prescribing Education). • Intervention 2: Access to the Veterans Affairs/Department of Defense Clinical Practice Guideline for the Management of Opioid Therapy for Chronic Pain.
Outcomes	• Knowledge of the role of opioids in chronic non-cancer pain (CNCP), self-rated competence in both general management of CNCP and the specifics of opioid prescribing, physician satisfaction in caring for patients with CNCP. • Knowledge test (range: 0-9), Intervention (COPE course):n=109, mean:8.4, SD:0.8; Control (VA guidelines):n=104, mean:6.1, SD:1.3 • Four domains of attitude was measured, the study reported mixed results for attitude change. We have presented "Agree to prescribe opioids when patients request this" in the data analysis. Intervention (COPE course):n=109, mean:37.8, SD:27.4; Control (VA guidelines):n=104, mean:38, SD:29.9 • Residents in both groups reported more satisfaction with managing chronic pain care after training (w2 = 52.72, P < 0.0001), though the web training was superior on sub scales concerning training adequacy (w2 = 4.94, P = 0.026) and relationship quality (w2 = 5.79, P = 0.016).
Notes	• Study aim: The treatment of chronic non-cancer pain with chronic opioid therapy has increased rapidly, but medicine residents receive little training concerning this therapy. Therefore we conducted a trial to determine if an interactive web-based training focusing on shared decision-making for chronic opioid therapy improves knowledge and competence compared with exposure to practice guidelines. • Pedagogical approach used: Individual eLearning,

	interactive web-based training. • Was a learning management system (LMS) used? No. • Journal: Clinical Journal of Pain. • Year of publication: 2010. • Income status of country: High income. • Source of funding: This research was supported by an educational grant from Ortho McNeil Janssen Scientific Affairs with donated web support from Aetna Inc. These sponsors had no role in the design, conduct, or reporting of the study. • Conflict of interest: None.

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	After consenting, residents were randomised in blocks according to gender and residency year to either COPE or the VA guidelines. Both were accessed on line through links embedded in email sent to randomised residents (pg. 513, randomizations and interventions). Randomisation method not described.
Allocation concealment (selection bias)	Unclear risk	No details given to enable judgement.
Blinding of outcome assessment (detection bias)	Unclear risk	No details given to enable judgement.
Incomplete outcome data (attrition bias)	Low risk	The authors used generalised estimating equations (GEE) to conduct intent-to-treat analysis (pg. 514, statistical analysis). GEE employs all available data, allowing for the inclusion of those residents who may be missing a pre or post-measure. Of 570 eligible residents, 213 consented to be randomised for

		the training trial. As this was a randomised educational trial, participation was voluntary and optional. Almost 143 (67 %) residents completed both pre-training and post-training tests, whereas 70 residents were missing the pre, post, or both tests (pg. 514, results).
Selective reporting (reporting bias)	Low risk	All pertinent outcomes were reported.
Other bias	Low risk	Demographic characteristics of the randomised groups are presented in table 1, no difference was observed among residency year, residency program and gender (pg. 515). First, participating residents and residency programs were volunteers. As residents were randomised and tested for publication, multiple institutional review boards required informed consent and the right to refuse participation in the study. Second, the study assessed only knowledge and self-reported resident outcomes. Third, COPE did not increase rates of selected pain management behaviours by residents more than the VA guidelines. Fourth, COPE included a few updated items about new regulations and opioid risk factors that were not included in the 2003 VA guidelines.

Szmuilowicz 2012

Methods	• Design: Randomised controlled trial. • Recruitment method: Consenting PGY1 internal medicine residents were recruited. • Randomization: Yes, method not described. • Speciality: Internal medicine. • Setting: University. • Country: United States.
Participants	• Type of participants: PGY1 internal medicine residents. • Inclusion criteria: Not stated. • Exclusion criteria: Not stated.

	• No of participants randomised: 38 residents.
Interventions	• Intervention: Multimodality communication skills education, Intervention group residents completed a 2 hour teaching session with deliberate practice of communication skills, online modules, self-reflection, and a booster training session in addition to assigned clinical rotations. • Control group residents completed clinical rotations alone. CSD skills of residents in both groups were assessed 2 months after the intervention using an 18 item behavioral checklist during a standardized patient encounter. • Residents in the control group completed clinical rotations alone. They did not participate in the initial small group sessions, complete the self-study component, or attend the ‘‘booster’’ session.
Outcomes	• The primary outcome measure was the difference in performance on a CSD skills examination between intervention and control group residents. Secondary outcomes included self-confidence in facilitating a CSD, and participant satisfaction with the intervention. • Intervention group (n=19) residents displayed significantly higher overall performance with less variation than did control group residents (n=19) on the CSD checklist outcome evaluation (75.1% –8.9 versus 53.2% –16.2, p <0.001).
Notes	• Study aim: The study looked at the efficacy of a CSD communication skills training intervention for internal medicine residents. • Pedagogical approach used: Collaborative eLearning, small group sessions for multimodality communication skills intervention which included seminars taught by palliative medicine faculty, self-study materials and internet based communication skills teaching modules. • Was a learning management system (LMS) used? No. • Journal: Journal of Palliative Medicine. • Year of publication: 2012. • Income status of country: High income.

	• Source of funding: Supported by grant ULRR 025741 from the National Center for Research Resources. • Conflict of interest: None.

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Residents were randomly assigned to receive the educational intervention (n = 19) or serve as controls (n = 19) (Fig. 1) (pg. 769, participants). Randomisation method not described.
Allocation concealment (selection bias)	Unclear risk	No details given to enable judgement.
Blinding of outcome assessment (detection bias)	Unclear risk	No details given to enable judgement.
Incomplete outcome data (attrition bias)	Low risk	All 38 PGY-1 residents at Northwestern University were eligible for the study. All 38 consented to participate in the study and completed the entire protocol (pg. 769, results).
Selective reporting (reporting bias)	Low risk	All pertinent outcomes were reported.
Other bias	High risk	Comparison of participant characteristics are presented in table 1 (pg. 770). The baseline assessment of participants was limited to a few items; it is a single institution study with a small sample size. The baseline assessment of participants was limited to a few items; it is possible that unknown factors medical school education, exposure to different experiences or teachers during internship, or other unmeasured demographic variables – would have impacted resident performance.

Talib 2010

Methods	• Design: Random controlled trial. • Recruitment method: Not stated. • Randomisation method: Yes, participants were randomised using a random number generator. • Speciality: Paediatrics. • Setting: Hospital. • Country: United States.
Participants	• Type of participants: Paediatric residents. • Inclusion criteria: Residents in any year of training were considered eligible for the study; recruitment took place in January 2007. • Exclusion criteria: Not stated. • No of participants randomised: 56 residents.
Interventions	• Intervention: Web-based training (WBT) + Hands-on training (HOT), the Web-based curriculum provided information to the paediatric residents on dental caries topics such as (1) assessment of risk of caries, (2) prevention of caries, which included application of fluoride varnish, and (3) appropriate dental referral indications and documentation for billing and reimbursement by Medicaid. HOT was provided by 1 of the 2 pediatric dentists. The training included a 1-time demonstration of the technique of an oral examination, fluoride varnish application, and provision of anticipatory guidance. • Control: Web-based training alone.
Outcomes	• Change in practice was evaluated by a retrospective chart review. • Fifty-six residents were included in the analysis (WBT + HOT: 29; WBT: 27). • Resident knowledge improved after the WBT from 69 % to 81 % (95% confidence interval [CI]: 9 % – 15 %). • Overall skills improved in the WBT + HOT group participants compared with those in the WBT group (87 % vs 73 %; difference: 14 % [95% CI: 1.2 % – 26.6 %]). • Seventy-nine percent of participants in the WBT + HOT group compared with 44 % of those in the

	WBT provided follow-up instructions (relative risk: 0.56 [95% CI: 0.35 – 0.89]). • Resident opinions regarding incorporating preventive oral health into the well-child visit decreased by 33 % in the WBT + HOT group compared with 11 % in the WBT group (95% CI: 2 % – 43 %). • There were no significant differences in confidence regarding preventive oral health and practice between the groups.
Notes	• Study aim: To assess the effect of Web-based training (WBT) on resident knowledge of preventive oral health and compare the addition of hands-on training (HOT) to WBT on resident skills, confidence opinions, and practice. • Pedagogical approach used: Individual eLearning (blended learning), online self-study materials (video instructions). • Was a learning management system (LMS) used? No. • Journal: Pediatrics. • Year of publication: 2010. • Income status of country: High income. • Source of funding: This project received support from Reach Healthcare Foundation of Greater Kansas City grant 07A-037-PRa-SN-MU. • Conflict of interest: None stated.

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	After completion of the WBT, each resident was assigned a study number and randomly assigned to an intervention (WBT + HOT) or control (WBT) (pg. 548, study procedures, ln 41). Randomisation was done using a random number generator.
Allocation concealment (selection bias)	Unclear risk	This allocation was kept separately with the study coordinator and used at the time of data analysis (pg. 548,

		study procedures, ln 47).
Blinding of outcome assessment (detection bias)	Unclear risk	No details given to enable judgement.
Incomplete outcome data (attrition bias)	Unclear risk	No details given to enable judgement.
Selective reporting (reporting bias)	Low risk	No deviation from the registered trial protocol, (identifier NCT00846066) (pg. 547).
Other bias	Unclear risk	Baseline comparison of characteristics are presented in table 1 (pg. 550), however statistical testing has not been done. The demographics of the residents are shown in Table 1. There were 11 (38 %) first-year residents and 18 (62 %) second- and third-year residents in the WBT + HOT group. In the WBT group there were 12 (44 %) first-year residents and 15 (56 %) second- and third-year residents. Both the groups were similar regarding gender and level of training. There was no difference in the pretest knowledge scores between the groups or in the change of scores between the pretest and posttest. Although the subjects were randomly assigned, they were all recruited from 1 residency program, which resulted in limitation of generalisability of the findings. Using chart audit as an outcome measure is another limitation of the study.

Thompson 2012

Methods	• Design: Randomised controlled study. • Recruitment method: Trainees were identified from the American Society of Gastrointestinal Endoscopy (ASGE) membership database and were emailed an invitation to participate. • Randomisation method: Yes, method not described. • Speciality: Gastroenterology. • Setting: Hospital. • Country: United States.

Participants	• Type of participants: Gastroenterology trainees. • Inclusion criteria: Not stated. • Exclusion criteria: Not stated. • No of participants randomised: 1220 trainees.
Interventions	• Intervention: Web-based tutorial on quality related measures in colonoscopy with links to appropriate references. • Control: No tutorial.
Outcomes	• Baseline knowledge of endoscopy-related quality indicators and impact of the tutorial. • Baseline scores were similar for the tutorial (n = 106) and no tutorial (n = 102) groups (56.4 % vs 56.9 %, respectively). Scores improved after intervention for the tutorial group (65 %, P = 0.003) but remained unchanged in the no tutorial group. • On multivariate analysis, each additional year in training (odds ratio [OR] 2.3; 95% confidence interval [CI], 1.5 – 3.4), training at an academic institution (OR 2.6; 95% CI, 1.1 – 6.3), and receiving the tutorial (OR 3.2; 95% CI, 1.7 – 5.9) were associated with scores in the upper tertile.
Notes	• Study aim: To assess knowledge of endoscopy-related quality indicators among U.S. trainees and determine whether it improves with a Web-based intervention. • Pedagogical approach used: Individual eLearning, web-based tutorial • Was a learning management system (LMS) used? No. • Journal: Gastrointestinal endoscopy. • Year of publication: 2012. • Income status of country: High income. • Source of funding: Not stated. • Conflict of interest: None stated.

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Respondents were randomised to receive access to a web-based tutorial with links to appropriate references ("tutorial" arm) or not ("no tutorial" arm). Randomisation method not described.
Allocation concealment (selection bias)	Unclear risk	No details given to enable judgement.
Blinding of outcome assessment (detection bias)	Unclear risk	No details given to enable judgement.
Incomplete outcome data (attrition bias)	High risk	Twenty-eight percent (347 / 1220) completed the online survey and were subsequently randomized into the tutorial versus no tutorial arms. Of the 347 randomized participants, 208 (59 %) completed the second survey. A schematic on participation is presented in Figure 1.
Selective reporting (reporting bias)	Low risk	All pertinent outcomes were reported.
Other bias	Low risk	There was no significant difference in the baseline scores (overall and by individual question) between those trainees randomised into the tutorial and no tutorial arms (56.4 % vs 56.9 %, respectively; P = 0.40), (Table 2) (pg. 5). There were no differences in demographic characteristics among those trainees randomized to either the tutorial or no tutorial arms.

Viguier 2015

Methods	• Design: Randomised controlled trial • Recruitment method: Online survey of Rheumatologists was conducted, the survey respondents was randomised • Randomisation method: Yes, randomisation was done through a website (pg. 3, Materials and Methods)

	• Speciality: Rheumatologists • Setting: University • Country: France
Participants	• Type of participants: Rheumatologists • Inclusion criteria: Not stated. • Exclusion criteria: Not stated. • No of participants randomised: 141
Interventions	• Intervention: Online training on skin tumours • Control: No training
Outcomes	• The primary end-point was Score 1 (diagnosis of the benign vs premalignant /malignant nature of the lesions) at Test 2. The secondary end-points were Scores 2 (Level of confidence), score 3 (precise diagnosis) and score 4 (MCQ).
Notes	• Study aim: The study was aimed to demonstrate that an online training dedicated to skin tumours increase the abilities of rheumatologists to discriminate skin cancers from benign skin tumours • Pedagogical approach used: Individual eLearning, web-based tutorial • Was a learning management system (LMS) used? No • Journal: PLOS one • Year of publication: 2015 • Income status of country: High income • Source of funding: The study was supported by an unrestricted grant from AbbVie Ltd. • Conflict of interest: Yes, the authors received funding from a commercial source, AbbVie Ltd.

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Randomisation was done through a website (pg. 2, Materials and Methods)
Allocation concealment (selection bias)	Low risk	After Test 1, rheumatologists were randomised into 2 arms through the web site randomisation module to ensure allocation concealment. (pg. 2, Materials and Methods)
Blinding of outcome assessment (detection bias)	Unclear risk	No details given to enable judgement.
Incomplete outcome data (attrition bias)	High risk	Figure 1, shows that there were 14 rheumatologists who were lost to follow up in the online training group and 3 were lost to follow-up in the control group (pg. 4)
Selective reporting (reporting bias)	Low risk	All results mentioned in methods are reported.
Other bias	High risk	The limits of our study include a 34% response rate for the initial survey that could have selected rheumatologists basically more interested in the field of skin tumours, and the absence of long term evaluation.

Vollmar 2010

Methods	• Design: Cluster Randomised trial. • Recruitment method: Members of the study team visited the quality circles (QCs) at their regular meeting places (e.g., surgery, restaurant, or other). After a short introduction to the study, the GPs were recruited and signed written consent was obtained. • Randomisation method: Yes, method not stated. • Speciality: General practice. • Setting: Hospital.

	• Country: Germany.
Participants	• Type of participants: General practitioners. • Inclusion criteria: Clusters (QCs) were recruited for participation either by letter or through personal telephone call to the responsible QC moderator. All available GP QCs within a radius of 50 kilometers around Witten/Herdecke University was contacted regardless of their speciality. Participants should be able to participate in an additional quality circle meeting and they have access to the Internet. • Exclusion criteria: Not stated. • No of clusters / participants randomised: 26 QCs / 389 GPs.
Interventions	• Intervention: Study arm A, blended learning with online modules, which included two interactive case stories on dementia related to the guideline content. During the QC meeting, participants of the "study arm A" immediately started with the structured case discussion (about 45 minutes, content identical to study arm B). At the end of the meeting, participants were asked to complete the knowledge test. • Study arm B: classical learning, GP's received a dementia-related training based on a slide presentation that lasted about 30 minutes, after the lecture, a structured case discussion was held identical to study arm A (about 45 minutes). At the end of the meeting, participants filled out the knowledge test. • Control: Non-randomised control. Participants in this group received only a printed pocket version (two pages) of the dementia guideline.
Outcomes	• Primary outcome was knowledge gain (KG) and secondary outcome was comparison of KG of the two groups at t2 (calculated as the difference t2-t0). • 166 GPs were available for analysis and filled out a knowledge test at least two times. A significant increase of knowledge was found in both groups that indicated positive learning effects of both approaches. However, there was no significant difference between the groups. A subgroup analysis of the GPs who self-reported that they had actually used the online

	modules showed that they had a significant increase in their knowledge scores. • Difference in knowledge gain (t1-t0): Study group A (n = 84) and B (n = 82) did not show any statistically significant difference in knowledge gain within all 20 questions at t1 (3.67 versus 3.60 questions, mean difference: 0.07; CI: - 0.84 to 0.98; P = 0.881; T = 0.15). • Difference in knowledge gain (t2-t0): Study group A (n = 46) and B (n = 51) did not show any statistical significant difference in knowledge gain at t2 (2.39 versus 2.00 questions, mean difference: 0.39; CI: - 0.83 to 1.61; p = 0.526; T = 0.636). The ANCOVA with QCs as a random effect and the pre-test (t0) as covariate achieved a result that can be compared (adjusted mean difference: 0.498; CI: - 0.589 to 1.584; P = 0.365).
Notes	• Study aim: The aim of this study was to compare knowledge acquisition about dementia management between a blended learning approach using online modules in addition to quality circles (QCs) and QCs alone. • Pedagogical approach used: Individual eLearning, online modules with interactive case stories, case discussion. • Was a learning management system (LMS) used? No. • Journal: Implementation Science. • Year of publication: 2010. • Income status of country: High income. • Source of funding: The work was supported by a grant from the Federal Ministry of Education and Research (BMBF) under project number 01GK0512. • Conflict of interest: None.

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Cluster randomisation took place at QC level (two arms). Stratified randomisation was performed by a statistician separately for small and large QCs (definition for large QCs: 12 or more participating GPs as reported by the QC moderators) (pg. 4, arrangements for data oversight: Cluster randomisation). Randomisation method not described.
Allocation concealment (selection bias)	Low risk	Group allocation was then placed in sealed opaque envelopes with consecutive numbering of each stratum. Members of the study team did not know whether a QC was randomised into group A or group B until they had opened the envelope in front of the participating GPs at t0 (pg. 4, arrangement for data oversight: Cluster randomisation, ln).
Blinding of outcome assessment (detection bias)	Unclear risk	No details given to enable judgement.
Incomplete outcome data (attrition bias)	High risk	Figure 1 shows the loss to follow up in the study arm A and B, the study had substantial loss to follow up, and also intention to treat analysis has not been done.
Selective reporting (reporting bias)	Low risk	No deviations from the study protocol which has been published.
Other bias	Low risk	Table 1 shows the characteristics of participants in study arm A and B, no difference in the compared characteristics (pg. 5). There were no significant differences between participants in groups A or B with regard to sponsorship of the QCs; in study arm B, the percentage of single doctor practices was slightly higher than in study arm A (Table 1).

Wang 2013

Methods	• Design: Randomised controlled trial. • Recruitment method: Voluntary participants which included radiology residents (post graduate year (PGY) 2-5), fellows and faculty (PGY≥6). • Randomisation method: Method not described. • Speciality: Radiology. • Setting: Hospital. • Country: United States.
Participants	• Type of participants: Radiology residents, fellows and faculty. • Inclusion criteria: Not stated. • Exclusion criteria: Not stated. • No of participants randomised: 44 Radiology residents, fellows and faculty.
Interventions	• Intervention: Computer based training. • Control: Hands-on high fidelity simulation-based training.
Outcomes	• Changes in test scores before training, immediately after training and four months after training. • There was no statistically significant difference between the computer and hands-on groups' written pretest, immediate post-test or delayed post-test scores ($P > 0.6$ for all). • Both groups' scores improved immediately following the intervention ($P < 0.001$). The delayed test scores 4 months later were still significantly higher than the pre-test scores ($P \leq 0.02$). • The computer and hands-on groups attained similar scores in the final scenario (mean: 85.4 % vs. 87.8 %, difference: − 2.4 % [95% CI: − 8.5, 3.6 %], $P = 0.7$). There were also no significant differences between the computer and hands-on groups in performance on the individual core competencies of contrast reaction management during the contrast reaction scenario.
Notes	• Study aim: The study compared the effectiveness to high-fidelity hands-on simulation training. • Pedagogical approach used: Facilitated eLearning, computer based interactive online simulation with

	training scenarios and videos, proctored by a facilitator. • Was a learning management system (LMS) used? No. • Journal: European Journal of Radiology. • Year of publication: 2013. • Income status of country: High income. • Source of funding: A Society of Uroradiology Research Award as well as the RSNA/AUR/APDR/SCARD Radiology Education Research Development Grant supported this research. • Conflict of interest: None stated.

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	22 were randomised into the computer group and 22 were randomised into the hands-on group. Method not described (pg. 2250, results).
Allocation concealment (selection bias)	Unclear risk	No details given to enable judgement.
Blinding of outcome assessment (detection bias)	Unclear risk	No details given to enable judgement.
Incomplete outcome data (attrition bias)	Low risk	All results presented correspond to an intention-to-treat (ITT) analysis, where all possible participants were included at every step and participants were excluded from an analysis only when missing the outcome of interest (pg. 2249, data analysis).
Selective reporting (reporting bias)	Low risk	All pertinent outcomes were reported.
Other bias	Low risk	Comparison of participant characteristics by treatment groups is presented in table 2 (pg. 2250). Table 2 summarizes the prior experience of the participants in each group. No significant differences in experience were seen between the participants in

		the two groups (P > 0.4 for all factors considered). (pg. 2251, discussion).

Westmoreland 2010

Methods	• Design: Randomised Controlled trial. • Recruitment method: Postgraduate year (PGY) 1 residents from the Medicine and Medicine–Pediatrics residency training programs from 2 academic years, 2001/02 (n = 47) and 2002/03 (n = 49), were enrolled in the study. Residents were enrolled during their 1-month ambulatory rotation. • Randomisation method: Block randomisation was used (pg. 1164, methods). • Speciality: Medicine / Pediatrics. • Setting: University. • Country: United States.
Participants	• Type of participants: Residents from the Medicine and Medicine-Pediatrics residency training programs. • Inclusion criteria: Not stated. • Exclusion criteria: Not stated. • No of participants randomised: 96 residents.
Interventions	• Intervention: Web-based instruction, four Web-based modules were designed containing evidence-based best practice geriatrics content reviewed by three board-certified academic geriatricians and posted on ANGEL. Modules were textual, with pictorial content. Video streaming was included that demonstrated how to administer the Folstein Mini-Mental State Examination (dementia module), Geriatric Depression Scale (depression module) and Get Up and Go Test (falls module). Residents randomised to the Web-based instruction arm of the study had 2 half-day sessions assigned as a group to the computer laboratory on the campus of Indiana University School of Medicine for medical education (IUSM). • Control: Paper-based instruction, residents randomised to paper-based instruction had 2 half-day sessions dedicated to reading assigned articles (two articles per module) covering the same content as the Web

	modules. They took their pretest before receiving the articles. Because residents in the paper-based instruction group elected not to read the articles together in the room provided, their posttest session occurred at the end of the month, once all the articles were read. They were given incentive to read the articles by being told at the beginning of the rotation that the research assistant would attend their end-of-the-month posttest session. The questions on the pre- and posttests for Web- and paper-based instruction were the same.
Outcomes	• Outcome measures were mean change scores for before and after testing and scores from SP and ASP clinical encounter forms (checklist, chart abstraction, and electronic order entry). • Residents who completed the Web-based instruction showed significantly greater improvement on the knowledge tests than those who received paper-based instruction. • There were no significant differences in the scores from the SP and ASP clinical encounters except that the chart abstraction score was better for Web-based group than the paper-based group for dementia.
Notes	• Study aim: To compare knowledge of postgraduate year (PGY) 1 residents after Web-based with that after paper-based instruction and to compare residents' clinical application of their instruction using unannounced standardized patients (SPs) and unannounced activated standardized patients (ASPs). • Pedagogical approach used: Collaborative eLearning, web-based modules (text, video), group work, research assistant for technical support. • Was a learning management system (LMS) used? No. • Journal: Journal of the American Geriatrics Society. • Year of publication: 2010. • Income status of country: High income. • Source of funding: The study is supported by the Robert Wood Johnson Foundation and the Generalist Physician Faculty Scholars Program. • Conflict of interest: None.

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	PGY 1 residents were assigned to a month-long ambulatory rotation during which they were randomised as a block to Web-or paper-based instruction covering the same four geriatric syndromes (dementia, depression, falls, and urinary incontinence) (pg. 1164, methods, ln 9). Randomisation method not described.
Allocation concealment (selection bias)	Unclear risk	No details given to enable judgement.
Blinding of outcome assessment (detection bias)	Low risk	The third measure was chart abstraction scores. Using a chart abstraction form that the principal investigator created, a research assistant, blinded to the study question and subjects, scored the resident paper medical record charts.
Incomplete outcome data (attrition bias)	High risk	No drop outs. there were substantial missing data for the clinical performance measures, mandatary resident participation may have been a limitation. ITT not used for analysis.
Selective reporting (reporting bias)	Low risk	All pertinent outcomes were reported.
Other bias	High risk	There were no significant differences in baseline characteristics between the intervention (n = 48) and control residents (n = 48) (pg. 1166, results). Lack of data on the reliability and validity of the outcome measures, the posttest for Web-based instruction occurred immediately after interaction with the educational material, whereas it occurred at the end of the ambulatory month for the paper-based instruction group. The immediacy of post testing in the Web-based instruction group may be a confounding factor and explain the higher scores than with the paper-based instruction group, there were substantial missing data for the clinical performance measures, and mandatary

		resident participation may have been a limitation (pg. 1168, discussion).

Weston 2008

Methods	• Design: Randomised Controlled trial. • Recruitment method: Primary care physicians were identified through a national medical association membership list. • Randomisation method: Yes, method not described. • Speciality: Primary care. • Setting: University. • Country: United States.
Participants	• Type of participants: Primary care physicians. • Inclusion criteria: Physicians with specialties in family practice, general practice, and internal medicine from Pennsylvania, New Jersey, Delaware, and Maryland. • Exclusion criteria: Not stated. • No of participants randomised: 113 physicians.
Interventions	• Intervention: Online type 2 diabetes seminar. • Control: Online seminar about systolic heart failure. • To evaluate the impact of the diabetes seminar on clinical practices, physicians who viewed the diabetes seminar were identified as the treatment group, and physicians assigned to the SHF seminar served as the control group. Conversely, in evaluating the impact of the SHF seminar on clinical practices, physicians who viewed the SHF seminar constituted the treatment group, and those assigned to the diabetes seminar were the controls.
Outcomes	• Quality of care measures for clinical vignettes. • Physicians who viewed the seminars were significantly more likely to recommend guideline-consistent care to patients in the vignettes. For example, physicians who viewed the diabetes seminar were significantly more likely to order an eye exam for diabetes patients (63 %) compared with physicians in the control group (27 %). For some guidelines there

	were no group differences.
Notes	• Study aim: To evaluate the potential for online continuing medical education (CME) seminars to improve quality of care. • Pedagogical approach used: Individual eLearning, online CME seminars. • Was a learning management system (LMS) used? No. • Journal: American Journal of Medical Quality. • Year of publication: 2008. • Income status of country: High income. • Source of funding: Not stated. • Conflict of interest: None.

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	The study was designed as a randomised controlled trial. Study participants were randomly assigned (by a computer) to view a seminar on either type 2 diabetes or SHF. Participants only viewed 1 seminar (diabetes or SHF) but answered questions and responded to clinical vignettes about both conditions (pg. 476, study design and hypotheses). Randomisation method not described.
Allocation concealment (selection bias)	Unclear risk	No details given to enable judgement.
Blinding of outcome assessment (detection bias)	Low risk	Responses to the clinical vignettes were read and scored by 2 independent raters who were blinded to which seminar the respondent had completed.
Incomplete outcome data (attrition bias)	Low risk	No drop outs.
Selective reporting (reporting bias)	Low risk	All pertinent outcomes were reported.

Other bias	High risk	Baseline comparison of knowledge between physicians in the groups was not done. Only a small percentage of the doctors who were approached were actually recruited, hence the generalisability is questionable. Since medical conditions with overlapping comorbid conditions were chosen (e.g., high blood pressure, high cholesterol) this may have clouded the results. Another potential limitation of the study was the use of a posttest only design, in which baseline data on physicians were not obtained prior to receiving the intervention.

Wilkinson 2016

Methods	• Design: Randomised Controlled trial. • Recruitment method: Not stated • Randomisation method: Yes, method not described. • Speciality: Internal medicine • Setting: University. • Country: Canada
Participants	• Type of participants: Internal medicine residents • Inclusion criteria: Not stated. • Exclusion criteria: Not stated. • No of participants randomised: 24 residents
Interventions	• Intervention: Technology-driven simulation-based cardiac ultrasonography teaching • Control: Conventional teaching
Outcomes	• Interpretation ability, Scanning ability (Skills)
Notes	• Study aim: To compare 2 models of teaching: a conventional peer-to-peer ward-based model and a fully simulated technology-based teaching program. • Pedagogical approach used: Facilitated eLearning • Was a learning management system (LMS) used? No • Journal: Canadian Journal of Cardiology • Year of publication: 2016 • Income status of country: Canada

	• Source of funding: The study was supported by a personnel award from the Heart and Stroke Foundation, Ontario Provincial Office. • Conflict of interest: None stated.

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Randomisation method not described.
Allocation concealment (selection bias)	Unclear risk	No details given to enable judgement.
Blinding of outcome assessment (detection bias)	Unclear risk	No details given to enable judgement.
Incomplete outcome data (attrition bias)	Low risk	One resident was excluded before recruitment because of previous training in HHCU.(pg. 2, results)
Selective reporting (reporting bias)	Unclear risk	All pertinent outcomes were reported.
Other bias	Unclear risk	Baseline comparison of characteristics was done. A limitation of our study was that the peer-to-peer teaching was taught primarily by senior residents rather than attending staff, which may have resulted in reduced learning outcomes. In addition, we could not guarantee the absence of crossover between groups.

Xiao 2007

Methods	• Design: Randomised Controlled trial. • Recruitment method: All residents who rotated for 1 month through the trauma service were recruited into the study. • Randomisation method: Yes, method not described. • Speciality: Surgery / Emergency medicine. • Setting: Hospital. • Country: United States.
Participants	• Type of participants: Surgical and emergency medicine residents. • Inclusion criteria: Surgical and emergency medicine residents rotating through the trauma services. • Exclusion criteria: Not stated. • No of participants randomised: 50 residents (performed 73 elective central venous catheter insertions on 68 patients).
Interventions	• Intervention 1: Video, the video group was trained with the online video-based training course. • Intervention 2: Paper, the paper group received the same training content of the online video-based course but on a paper handout printed in color, with the exception of video. Video clips were replaced by representative still images extracted from the video. • Control: The residents who inserted CVCs but received neither the paper nor video training served as a control group.
Outcomes	• Sterile-practice compliance was judged through video review by two surgeons blinded to the training status of the residents. • Fifty residents inserted 73 elective central venous catheters (19, 31, and 23 by the video, paper, and control group operators, respectively) into 68 patients. Overall compliance with proper operator preparation, skin preparation, and draping was 49 % (36 of 73 procedures). The training had no effect on selection of site and skin preparation agent. • The video group was significantly more likely than the

	other two groups to fully comply with sterile practices (74 % vs. 33 %; odds ratio, 6.1; 95% confidence interval, 2.0 – 22.0).
Notes	• Study aim: To evaluate the effect of an online training course containing video clips of central venous catheter insertions on compliance with sterile practice. • Pedagogical approach used: Individual eLearning, online training course, video clips. • Was a learning management system (LMS) used? No. • Journal: Critical Care Medicine. • Year of publication: 2007. • Income status of country: High income. • Source of funding: Grant P20 HS 11562 from the Agency for Healthcare Research and Quality, Rockville, MD. • Conflict of interest: None.

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	High risk	New residents were randomised into the video or paper group based on the month of their rotation starting times, which were assigned independent of the study (pg. 1303, procedure). Randomisation method was not described.
Allocation concealment (selection bias)	Unclear risk	No details given to enable judgement.
Blinding of outcome assessment (detection bias)	Low risk	Video records of the CVC insertions were reviewed independently by two surgeons who were blinded to study group assignment.
Incomplete outcome data (attrition bias)	Low risk	No drop outs.
Selective reporting	Low risk	All pertinent outcomes were reported.

(reporting bias)		
Other bias	High risk	Table 2, shows the comparison of characteristics and the study group, however baseline knowledge has not been tested (pg. 1304). There was no random assignment to the control group. Completion of the paper-based training was not tracked and cannot assert that all residents in the group read the paper version of the training material. The effects of online training and those of the video content were not differentiated. Furthermore, it was not clear from the study why the video-based online course did not improve compliance with recommended choices of CVC site and skin preparation agent. Fourth, the study design did not allow the authors to correlate compliance with long-term patient outcomes such as bloodstream infection rates, because of the relatively small numbers of patients in each group. There were no longitudinal follow-up measures to assess the persistence of learning in the study.

Yardley 2013

Methods	• Design: Cluster Randomised Controlled trial • Recruitment method: Not stated • Randomisation method: Yes, method not described • Speciality: Surgery and Emergency medicine • Setting: University • Country: United Kingdom
Participants	• Type of participants: Surgical and emergency medicine residents. • Inclusion criteria: Surgical and emergency medicine residents rotating through the trauma services. • Exclusion criteria: Not stated • No of participants randomised: 50 residents (performed 73 elective central venous catheter

	insertions on 68 patients).
Interventions	• Intervention 1: Web-based intervention to reduce antibiotic prescribing in lower respiratory tract infection. C-reactive protein point of care (CRP) tests (CRP). • Intervention 2: Web-based intervention to reduce antibiotic prescribing in lower respiratory tract infection - module providing training in communication skills. • Intervention 3: Combined (intervention 1 & 2). • Control: usual care.
Outcomes	• Patient enablement, satisfaction with the consultation, and beliefs about the risks and need for antibiotics. • GPs in all countries and intervention groups had very positive perceptions of the intervention and the web-based training, and felt that taking part had helped them to reduce prescribing. All GPs perceived reducing prescribing as more important and less risky following the intervention, and GPs in the communication groups reported increased confidence to reduce prescribing. Patients in the communication groups who received the booklet reported the highest levels of enablement and satisfaction and had greater awareness that antibiotics could be unnecessary and harmful. In the post-intervention survey there were clear group differences in overall perceptions of the extent to which taking part in the study had helped GPs reduce their antibiotic prescribing [F (3,287) = 11.06, P < 0.001]; those in the communication and combined groups had the highest scores, and those in the control group the lowest (see Figure 1, pg. 5), with those in the CRP group intermediate. • Examination of changes in attitudes from baseline to post-intervention in the intervention groups (Table 2, pg. 6) confirmed that GPs saw reducing antibiotic prescribing as more important [F (1,226) = 15.23, p < 0.001] and less risky [F (1,226) = 13.32, p < 0.001] at follow-up (with no significant group differences). Of those in the communication and combined groups, 1,514 / 1,804 (83.9 %) reported having been given a

	GRACE/ INTRO booklet, most of whom also reported having used it (1,335 / 1,718; 77.7 %). A third of those in the control and CRP groups (503 / 1,520; 33.1 %) also reported having been given a booklet of some kind (presumably as a normal part of routine care), and a similar proportion (445 / 1,334; 33.4 %) reported using it. Comparison of patient attitudes across intervention arms (controlling for country effects) also revealed small but significant differences [F (12, 6942) = 2.93, P < 0.001]; mean scores are shown in Table 4. Beliefs that antibiotics were harmful did not differ between groups but beliefs that antibiotics were necessary were lowest in the CRP and combined groups [F (3, 2315) = 5.43, P = 0.001]. Specific effects of the interventions on patient attitudes were clarified by factorial analyses of group allocations and by examining the effects of actual receipt of the CRP test and booklet (again controlling for between country differences). Table 5 shows that allocation to one of the groups employing CRP testing resulted in lower antibiotics necessity beliefs, but actually receiving the CRP test did not. However, being allocated to one of the groups employing CRP testing resulted in slightly lower patient enablement scores, whereas actually receiving the CRP test resulted in lower enablement and lower satisfaction with the consultation. Conversely, being allocated to one of the booklet groups resulted in higher patient enablement and consultation satisfaction. Actually receiving the booklet resulted in lower antibiotics necessity beliefs and higher beliefs in the potential harm of antibiotics, as well as greater enablement and satisfaction with the consultation.
Notes	• Study aim: This study is a process analysis of the GRACE / INTRO trial of a multifactorial intervention that reduced antibiotic prescribing for acute LRTI in six European countries. The aim was to understand how the interventions were implemented and to examine effects of the interventions on general practitioners' (GPs') and patients' attitudes. • Pedagogical approach used: Individual eLearning, web-based training • Was a learning management system (LMS) used? No

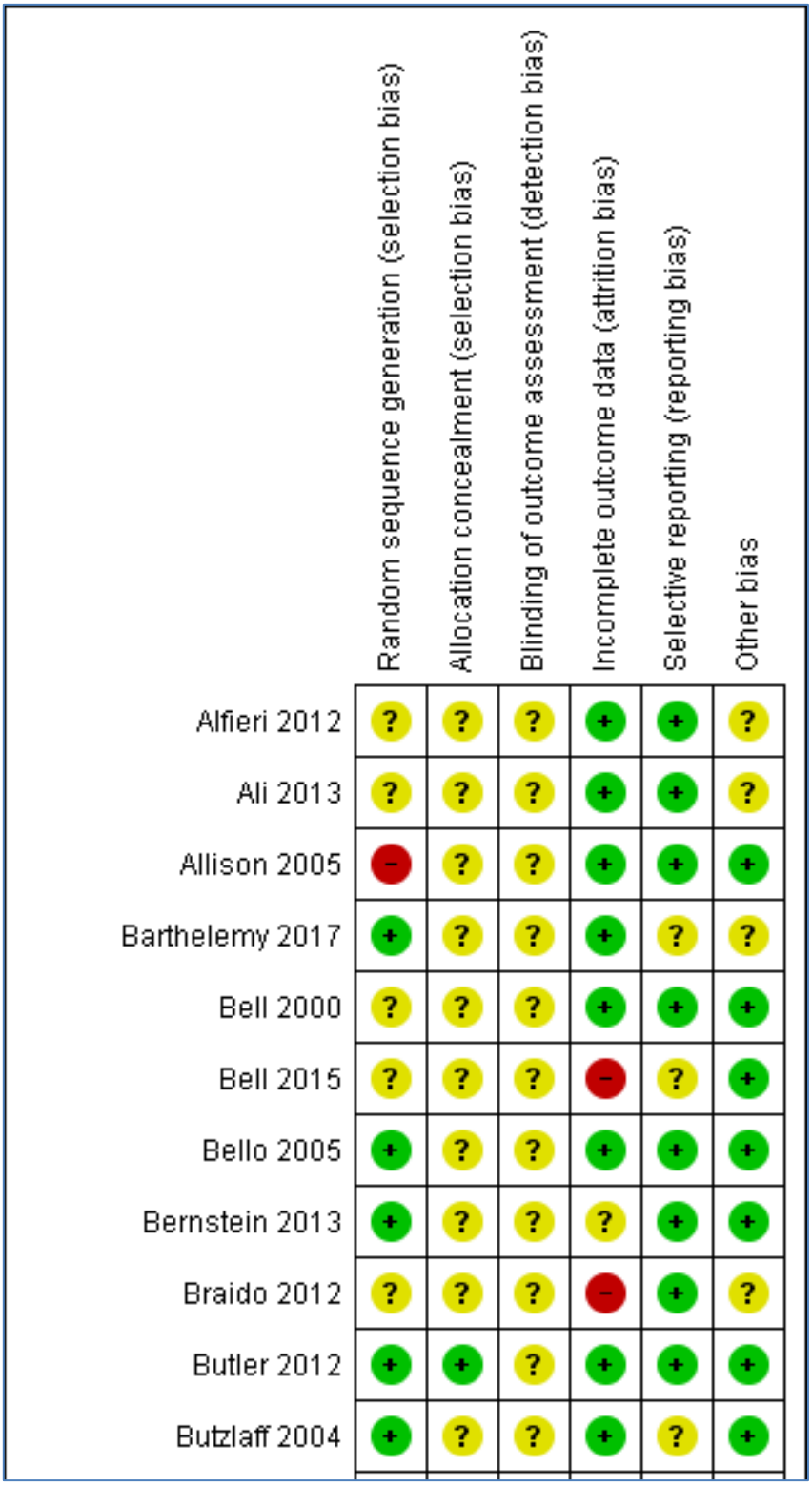
	• Journal: Implementation Science • Year of publication: 2013 • Income status of country: High income • Source of funding: The research performed by the GRACE (Genomics to combat Resistance against Antibiotics in Community-acquired LRTI in Europe) consortium leading to these results was funded by the European Community's Sixth Framework Programme under grant agreement no. 518226. ED, SA, ST-C, G'OR were funded by this grant, LY, BS, EA-C, AWV, TJMV, HG, CCB, NAF, PL were funded by their institutions, and AWAG was funded by a UK National Institute for Health Research post-doctoral fellowship. • Conflict of interest: None

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	GP practices were cluster randomised to intervention group. Method not described.
Allocation concealment (selection bias)	Unclear risk	No details given to enable judgement.
Blinding of outcome assessment (detection bias)	Unclear risk	No details given to enable judgement.
Incomplete outcome data (attrition bias)	Low risk	This sample represented 93.0% of the 372 GPs who supplied at least one case in the trial (pg. 4, results). Since many self-report items were assessed by a single item, we did not replace missing data, but instead give the specific sample size for each analysis. All the scales employed had good internal reliability (Website Satisfaction Questionnaire, alpha = 0.93, n = 230;

		Patient Enablement instrument, alpha = 0.92, n = 2,847; Consultation Satisfaction Questionnaire, alpha = 0.93, n = 2,888) (pg. 4, analysis).
Selective reporting (reporting bias)	Low risk	All pertinent outcomes were reported.
Other bias	High risk	Baseline comparison not done. Control group did not access the website at baseline, and so their attitudes were not assessed pre-intervention. Although many of the findings were statistically significant, the effect sizes we observed were small.

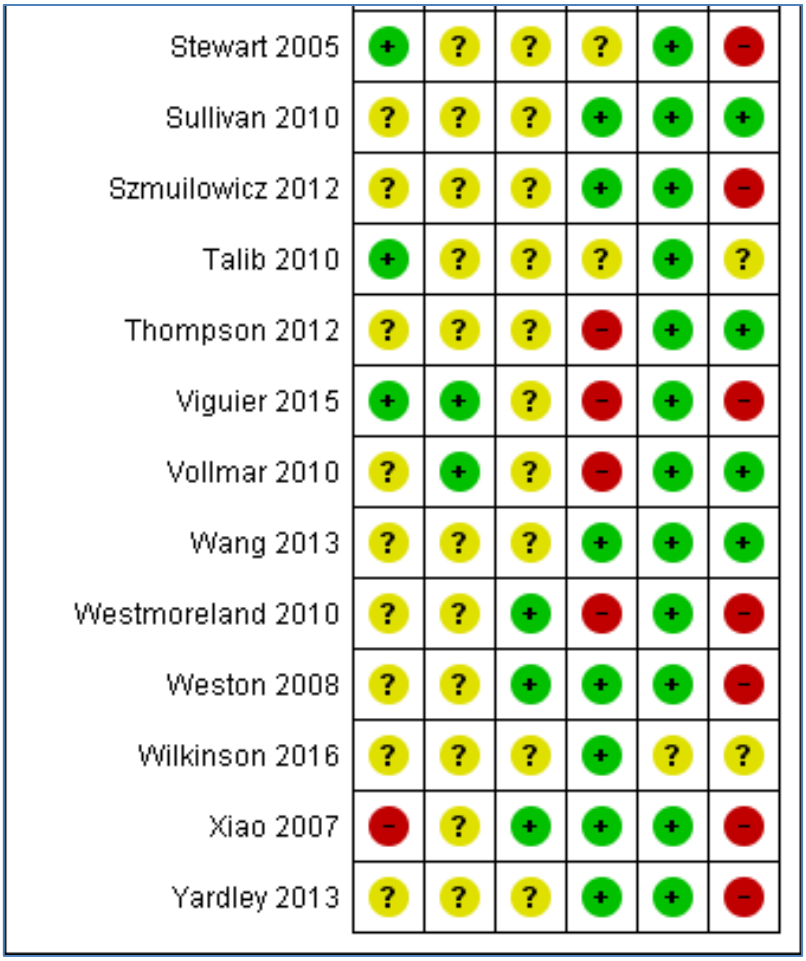
APPENDIX I D: RISK OF BIAS SUMMARY FOR EACH INCLUDED STUDY



Cabrera-Muffly 2015	?	?	?	?	+	?
Chan 1999	?	?	?	−	?	+
Chang 2014	+	?	?	−	?	−
Chenkin 2008	+	?	+	+	?	+
Chung 2004	+	+	?	+	?	+
Claxton 2011	?	?	?	−	?	+
Connolly 2014	+	?	+	−	+	+
Conroy 2015	+	?	+	+	+	−
Cullinan 2017	+	+	?	+	+	+
Curtis 2007	+	?	?	+	+	+
Daetwyler 2010	+	?	?	−	−	?
Dayton 2000	+	?	?	?	?	?
Dolan 2015	+	?	?	+	+	+
Edrich 2016	+	?	+	+	+	?
Enders 2006	?	?	?	−	+	+
Epstein 2011	+	?	−	+	+	?
Estrada 2011	?	+	+	+	−	?
Farah 2012	+	+	?	+	+	?
Feng 2013	?	?	?	+	+	?
Ferguson 2015	?	?	?	+	+	−
Fordis 2005	−	?	+	+	+	+
Franchi 2016	?	+	+	+	+	−
Gerbert 2002	?	?	?	−	?	−

Girgis 2009	+	?	?	+	+	−
Gold 2004	?	?	?	?	+	−
Grover 2010	+	?	?	?	+	+
Gyorki 2013	+	?	?	−	+	?
Hadley 2010	+	+	?	+	+	?
Harris 2002	?	?	?	−	+	+
Hearty 2013	+	?	?	+	+	−
Hemmati 2013	?	?	?	+	+	+
Houwink 2014	+	?	?	−	+	+
Houwink 2015	?	?	?	−	+	+
Hugenholtz 2008	?	?	?	+	+	?
Hymowitz 2007	+	?	?	?	+	?
Kerfoot 2007	?	?	?	−	+	+
Kerfoot 2014	?	?	?	+	+	+
Koppe 2016	?	?	?	+	+	−
Kronick 2003	?	?	?	−	+	+
Kulier 2009	+	?	?	+	+	+
Kulier 2012	+	+	?	−	+	−
Kutob 2009	−	?	?	?	+	+
Le 2010	−	?	?	−	+	−
Lee 2015	?	?	+	+	+	−
Legare 2012	+	?	+	+	+	+
Little 2013	+	+	+	+	+	+

Macrae 2004	+	?	?	+	+	+
Marsh-Tootle 2011	+	?	?	+	+	?
Matzie 2009	?	?	?	+	+	+
McLeod 2010	?	?	?	+	+	?
Meeker 2016	+	?	?	+	+	−
Midmer 2006	?	?	?	−	+	−
Ngamruengphong 2015	?	?	?	+	−	+
Pape-Koehler 2013	?	+	+	+	+	+
Pelayo-Alvarez 2013	?	?	?	−	+	?
Perkins 2012	+	+	+	+	+	+
Pernar 2012	?	?	?	?	+	+
Platz 2010	−	−	?	−	+	−
Putnam 2015	?	?	?	−	+	+
Ruf 2010	+	+	?	+	+	+
Sangvai 2012	?	?	?	−	+	?
Satterwhite 2012	?	?	?	+	+	−
Saxon 2015	?	?	+	−	+	−
Schmitz 2016	+	?	?	−	+	−
Schroter 2011	?	?	?	+	+	+
Shariff 2015	+	?	?	?	?	?
Sharma 2013	+	?	+	−	+	?
Shaw 2012	+	?	+	−	+	?
Short 2006	?	?	?	−	+	?


Stewart 2005
Sullivan 2010
Szmuilowicz 2012
Talib 2010
Thompson 2012
Viguier 2015
Vollmar 2010
Wang 2013
Westmoreland 2010
Weston 2008
Wilkinson 2016
Xiao 2007
Yardley 2013

APPENDIX II A: CHARACTERISTICS OF INCLUDED STUDIES ASSESSING KNOWLEDGE

Study ID	No. of participants / Specialty	Assessment method	eLearning type	Control	Post-intervention knowledge scores
eLearning vs self-directed learning					
Alfieri et al. 2012	36 / Radiation oncology	Test	eLearning radiation oncology module	Self-directed (text-based learning)	**Intervention** (n=19): Pre-test = 35% Post-test = 52% Mean improvement = 17% (P<0.05) **Control** (n=17): Pre-test = 37% Post-test = 42% Mean improvement = 5% (P=not significant)
Bell et al. 2000	162 / Primary care practitioners	MCQs	SAGE (Self-study Acceleration with Graphic Evidence) or printed materials on acute myocardial infarction	Self-directed learning (printed self-study materials)	**Immediate post-test scores** were similar in SAGE (n=82) and control groups (n=76) (median score = 15.0 vs 14.5, P>0.2, not significant. Mean and SD was calculated using median and range. **Follow-up after 4-6 moths**: SAGE group: median = 12, 95% CI: 11 to 13. Control group: median

					= 11, 95% CI: 10 to 12. Control group: mean = 11.8, (SD = 2.5) and SD were estimated from the values. SAGE group: mean = 12 (SD = 2.5).
Braido et al. 2012	60 / Primary care practitioners	Questionnaire	Respiratory allergic diseases: monitoring study of GINA and ARIA guidelines (blended CME)	Self-directed learning (text-based learning)	Knowledge improved significantly after training (P< 0.001, correct answers to key questions + 13%). Training resulted in pharmaceutical cost containment (trained general practitioners + 0.5% vs controls + 18.8 %) and greater attention to diagnosis and monitoring (increase in spirometry + 63.4%, P< 0.01).
Butzlaff et al. 2004	72 / Primary care practitioners	MCQs	Clinical guidelines via the Internet or CD-ROM	Self-directed learning (text-based learning)	There was no significant knowledge increase in the intervention group (n=38) (April 2001-13, June 2011-15) (P = 0.69) compared to the control (n=34) (April 2001-13, June 2011-13).

Cabrera-Muffly et al. 2015	37 / Otolaryngology	Exam/test	Informative otolaryngology videos module	Self-directed learning (text-based learning)	Significant improvements in the experimental arm vs the control arm in three of the subspecialty sections (facial plastic surgery, otology, and paediatric otolaryngology); overall mixed results. Otolaryngology training examination (OTE), otology intervention: OTE scores among residents (n=18) with access to modules: mean difference = 7 (SD = 20.9). Control: OTE scores among residents (n=19) with access to modules: mean difference = 4 (SD = 28.7). mean difference and SD estimated from OTE scores from 2012 and 2013.
Chang et al. 2014	458 / Multispeciality	MCQs	Asynchronous eLearning curriculum (Group A, Group B modules)	Self-directed learning	Asynchronous eLearning led to improvement in post-test scores from a mean score of 18.45 (95%

					CI: 17.92 to 18.98) to 21.30 (95% CI: 20.69 to 21.91); a large effect (partial g2 = 0.19).
Chung et al. 2004	63 / Emergency medicine	MCQs (34 items)	Online bio-terrorism educational resource	Self-directed learning	No difference between pre- and post-test scores among groups at 1-month and 6-months. 1 month: web intervention (n=24): 48% +/- 10% ; control: (n=29) 45% +/- 10%; mean difference: 3.3%; 95% CI: -8.5% to 2.0%). 6-months: web intervention (n=22): 51% +/- 8% vs control (n=26): 47% +/- 9%; mean difference: 3.9, 95% CI: -8.8% to 1.2%
Claxton et al. 2011	82/ General medicine or internal medicine	MCQs	Fast Facts and Concept e-mails	Self-directed learning	Knowledge post-test scores. Intervention (n=41): mean: 15.7 (SD = 2.0). Control(n=41): mean:14.2 (SD = 2.8). SD was estimated from the median and range.
Connolly et al. 2014	56 / Paediatrics	Questionnaire	'Beyond Milestones' online interactive teaching resource	Self-directed learning	Teaching group scored higher on markers pre- to post-A (mean difference z-score =

					0.405, P = 0.033), and compared to the control group, at post-A (mean difference z-score = 1.078, *P*< 0.0001) and post-B (Mean difference z-score = 0.730, P= 0.005). Teaching group scored higher on observational expertise pre- to post-A (mean difference z-score = 0.521, P=0.002) and pre- to post-B (mean difference z-score = 0.452, P =0.022), and compared to the control group, at post-A (mean difference z-score = 1.243, P<0.0001) and post-B (Mean difference z-score = 1.075, P<0.0001).
Cullinan et al. 2017	146 / Multispeciality	MCQs and case studies	Standard Computerised Revalidation Instrument for Prescribing and Therapeutics (SCRIPT)	Self-directed learning	4-week MCQ intervention group: 15.36, (SD = 2.91); control group: 10.71 (SD = 3.01), 95% CI of the difference: 3.44 to 5.84, P<0.0001.
Dolan et al. 2015	41 / General medicine or	Questionnaire	Adaptive, longitudinal,	Self-directed learning	Residents correctly answered questions on

	internal medicine		online formative self-assessment curriculum delivered via MCQs		bone mineral testing. Intervention (n=21): 15/21, 73%. Control (n=20): 13/20, 66%. P=0.04; effect size =0.65.
Enders et al. 2006	265 / Public health	Exam/test	Internet-based introductory bio-statistics course	Cooperative learning	Change in cumulative examination scores between the Cooperative group vs Internet group was estimated by linear model: 4.7 (-5.3, 14.7)
Farah et al. 2012	45 / General medicine or internal medicine	MCQs	Information aids, decision aids and the Internet (prostate cancer screening)	Self-directed learning	Intervention (n=22) Control (n=20) Those who read information aids were more knowledgeable (mean score out of 9: 7.45 vs 5.75, P<0.0001.
Ferguson et al. 2015	41/ Surgery	MCQs	Online short course on frailty	Self-directed learning	Frailty questions answered correctly. Intervention (n=20): 93.7% Control (n=21): 75.2%, P<0.001
Gold et al. 2004	69 / Surgery	MCQs	Internet CD-ROM thoracic surgery eLearning system, a hybrid surgery curriculum	Self-directed learning (test-based)	No difference between those residents randomised to receive a CD-ROM set and those randomised to receive the curriculum outline.

Gyorki et al. 2013	97 / Multispeciality	Questionnaire, Likert-type scale	Online spaced education program on the impact of a didactic seminar	Self-directed learning	The residents randomised to the spaced education group (n=28) had a significantly higher post-test score than the control group (n=31): 72% vs 67%, P=0.03
Harris et al. 2002	99/ Multispeciality	MCQs	Interactive case-based domestic violence education program	Self-directed learning	Domestic violence knowledge at baseline: Intervention = 2.40, control = 2.50 Post-test mean: Intervention = 3.94, control = 3.53. Mean score change: Intervention = 0.18, control = -0.04, P<0.001
Hearty et al. 2013	28 / Orthopaedic	Questionnaire	eLearning surgical training module on the computer enhanced visual learning platform	Self-directed learning (text-based learning)	Preparedness and surgical decision-making: the correct mean test score (and SD) was 90.9% (SD = 6.8%) for the test group (n=14) and 73.5% (SD = 6.4%) for the control group (n=14).
Houwink et al. 2014	80 / Primary care practitioners	Questionnaire	Genetics eLearning CPD module about oncogenetics	Self-directed learning	Between-group difference was indifferent or in favour of the intervention group, starting from

					0.034 (Student's *t*-test, P=0.34, non-significant) at T0, and increasing to 0.072 (P=0.05) at T1and 0.084 (P=0.05) at T2.
Kutob et al. 2009	122 / Primary care practitioners	Exam/test	Internet-based approach to teaching cultural competence of type 2 diabetes	Self-directed learning	Intervention (n=58): pretest =183.55 (mean); post-test = 192.09, P=0.004 Control (n=64): pre-test = 177.58; post-test = 177.84, P=0.907.
Le et al. 2010	24 / Paediatrics	Questionnaire	Web-based multimedia learning modules for physicians' knowledge, attitudes and treatment on paediatric asthma	Self-directed learning	Intervention group (n=11): 4.75 (SD = 3.28); control group (n=9): 2.88 (SD = 2.03), P=0.19.
Satterwhite et al. 2012	17 / Surgery	MCQs	A webpage on microsurgery, entitled 'Microsurgery Essentials' (website)	Self-directed learning	For residents who used the webpage (n=9), there was a 17%-point improvement between their pre- and post-test scores, from 62% to 82% (P= 0.01). For residents who did not have webpage access (n=8), there was essentially no difference between

					their pre- and post-test scores (76% and 75%, respectively, P= 0.80).
Short et al. 2006	81 / Multispeciality	Questionnaire, Likert-type scale	Online intimate partner violence CME program	Self-directed learning	There were significant positive changes on perceived knowledge, P=0.000). No numerical data was reported.
Stewart et al. 2005	58 / Primary care practitioners	Questionnaire	Case-based online learning (CBOLL) group	Self-directed learning	Knowledge score: Intervention (n=27) Before (n=27): Prevention topic: 53.8 (12.8) Diabetes topic: 66.8 (14.1) 2-months after (n=27): Prevention topic: 63.8 (17.6) Diabetes topic: 72.7 (14.1) 6-months after (n=17): Prevention topic: 65.7 (15.2) Diabetes topic: 73.2 (7.7) Control (n=31) Before (n=31): Prevention topic: 51.9 (9.5) Diabetes topic: 68.6 (10.4) 2-months after (n=31): Prevention topic: 50.5 (13.8),

					Diabetes topic: 67.7 (16.8) 6-months after (n=24): Prevention topic: 53.3 (10.5) Diabetes topic: 68.6 (11.4)
Sullivan et al. 2010	213 / General medicine or internal medicine	Questionnaire	Web-based module, opioid therapy for chronic non-cancer pain. COPE: Collaborative Opioid Prescribing Education.	Self-directed learning (Veteran Affairs Opioid Guidelines)	Knowledge test (range: 0-9). Intervention (COPE course; n=109): mean = 8.4 (SD = 0.8). Control (VA guidelines; n =104): mean = 6.1 (SD =1.3).
Thompson et al. 2012	347 / Gastroenterology	Questionnaire, Likert-type scale	Web-based tutorial (gastrointestinal endoscopy)	Self-directed learning	Total score, mean (SD). No tutorial: Survey 1 = 56.9 (SD = 15) Survey 2 (n=102) = 56.9 (SD= 14 Tutorial: Survey 1 = 56.4 (SD = 15) Survey 2 = 64.5 (SD = 18).
Viguier et al. 2015	141 / Rheumatologists	Exams	Online training on skin tumours	Self-directed learning	Primary evaluation criterion (Score 1: diagnosis of the benign

					vs premalignant/malignant nature of the lesions). The means difference in the number of adequate responses at Test 2 between groups was 2.2 points, favouring the online training group (95% CI: 1.3 to 3.1), P<0.0001.
Wang et al. 2013	44 / Radiology	Questionnaire, Likert-type scale	Computer-based training procedures	Self-directed learning (hands-on simulation training procedures)	Computer group (n=22): mean (range) = 2.5 (0.0, 5.0), P<0.00. Hands-on group (n=22): mean (range) = 2.5 (0.0, 6.0), P<0.001. None of the mean scores were significantly different between groups (P>0.05 for all).
Westmoreland et al. 2010	96 / Multispeciality	Questionnaire	Web-based module (geriatrics content)	Self-directed learning (text-based learning)	Mean change score = 27.6 (SD = 18.1) for residents who completed web-based instruction and 9.0 (SD = 20.0) for residents who completed the paper-based instruction. n=48 per group.

eLearning vs face-to-face learning					
Bello et al. 2005	56 / Anaesthesiology	MCQs	Online teaching	Face-to-face learning	Knowledge gains in Group 2 were slightly, but not significantly, greater compared to Group 1 (n=2): Median from 12.0 to 29.0; Group 2 (n=28), Median from 13.5 to 30.5 in written test, (P=0.228).
Chan et al. 1999	23 / Primary care practitioners	MCQs	Problem-based small group learning on depression among elderly (face-to-face learning)	Face-to-face learning (small group discussion)	Mean pre-test MCQ score was 66.2 (SD = 7.3); follow-up test score was 67.2 (SD = 10.5). No difference in test scores (pre- and post-test combined) based on group allocation.
Chenkin et al. 2008	21/ Emergency medicine	Questionnaire	Web-based ultrasound-guided vascular access training	Face-to-face learning (didactic discussion)	No difference in mean written test scores (absolute difference = -1.4%; 95% CI: -7.8% to 5.0%), between the web group and the didactic group, P=0.65.
Fordis et al. 2005	103 / Primary care practitioners	MCQ and case vignettes with fixed-choice responses	Intervention 1: Online CME on cholesterol management	Live interactive CME	Online CME group (n=44) scored slightly higher than the live CME group (n=49) when averaged across all three testing

					occasions (4.8% additional items correct, 95% CI: 0.6% to 9.0%; partial ω2= 0.01, P= .03). 85% of the randomised participants in the online CME group and 96% in the live CME group completed the knowledge tests.
Hadley et al. 2010	7 hospitals, 237 trainees/ Not specified	MCQs	A clinically integrated eLearning course for teaching EBM	Face-to-face learning	There was no difference in the improvement of knowledge between the intervention (n=88) (baseline = mean:22.9, SD:7.0; post-test mean=27.0, SD:7.5; and the control (n=72) (baseline= mean:24.7, SD:3.9; post-test mean=28.2, SD:6.0, groups. P=0.89
Hemmati et al. 2013	80 / Primary care practitioners	Exam/test	CPR curriculum guidelines training through Internet-based learning (Group 2)	Face-to-face learning	No difference in knowledge scores between the intervention (n= 40) (pre-test: 67.87 [SD =5.41]; post-test: 85.5 [SD = 5.16]), and the control group (n=40) (pre-test: 68.5 [SD =

					5.68]; post-test 83.12 [SD = 5.84]).
Hugenholtz et al. 2008	72 / Occupational physicians	Questionnaire	Website including an eLearning module on mental health issues	Face-to-face learning	Mean score for the eLearning approach (n=37) was 52.1 (SD = 8.4) at baseline and 65.1 (SD = 9.6) at post-test (P= 0.05). For the lecture-based approach (n=35), the mean score was 52.3 (SD = 9.0) at baseline and 64.3 (SD = 9.0) at post-test, P= 0.05.
McLeod et al. 2010	12 general surgery programs, 441 residents / Surgery	MCQs	Critical appraisal skills (Internet and emails)	Face-to-face learning (didactic discussion)	Completed the appraisal test: Internet group (n=227): 57.8% Moderated group (n=216): 72.7 % Mean score: Moderated group = 43.8% (CI 40.2 to 47.5); Internet group = 39.0 % (CI 35.8 to 42.2); P=0.05, moderate effect size of 0.6 SD.
Pelayo-Alvarez et al. 2013	169 / Primary care practitioners	MCQs	Palliative care education (online program)	Face-to-face learning	Knowledge test at 4-months showed a positive difference of 5.2 (95% CI: 3.4 to 6.9) in the intervention group.

eLearning vs eLearning					
Bernstein et al. 2013	29 clusters, 208 paediatric residents/ Paediatrics	MCQs	Bright Futures Oral Health online curriculum	1-hour online curriculum (not related to intended eLearning content)	Intervention group demonstrated significant improvement in general Bright Futures knowledge (Mean-pre =71.4; mean-post=80.4, *F*=5.296) compared to the control group at 3-months (mean-pre=73.9; mean-post=74.3, P=.023).
Grover et al. 2010	210 / General medicine or internal medicine	Questionnaire, Likert-type scale	Arterial and central line placement with a web-based curriculum. Intervention 1: Both central venous line and arterial line procedures. Intervention 2: Central venous line but not arterial line. Intervention 3: Arterial line but not central venous line.	Self-directed learning (text-based learning)	Central venous line: Curriculum available (n=28): Pre-test = 64.3%; Test 1 = 65%; Test 2 = 70%; score difference = 5%, effect size/P=0.25/0.11 Central venous line: No additional curriculum available (n=37): Pre-test = 58.6%; Test 1 = 62.1%; Test 2 = 62.9%; score difference %, 0.8. Arterial line: Curriculum available (n=36): pre-test, 55.5%; Test 1 = 58.4%; Test 2 = 70.3%; score difference = 11.9%, effect size/P=0.52,

					<0.001. Arterial line: No additional curriculum available (n=49): Pre-test = 58.7%; Test 1 = 63.2%; Test 2 = 63.4%; score difference = 0.2 %; effect size/P value, 0.52/<0.001.
Kerfoot et al. 2007	537 / Urology	MCQs	Online educational program on spacing effect principle on the acquisition and retention of medical knowledge (cohort 2)	Bolus cohort	Cohort 1 (n=254), mean (SD): Overall percentile ranking = 53.2 (29.5) Percentile ranking in 4 topic areas = 54.5(28.2); Cohort 2 (n=261), mean (SD): Overall percentile ranking = 56.8 (27.6) Percentile ranking in 4 topic areas = 57.7(28.2) Follow-up at 2 years: Residents in the spaced education cohort had significantly greater test scores than residents in the bolus cohort: mean = 70.2% (SD = 9.0%) vs 66.8% (SD = 10.6 %), effect size 0.35, P= 0.03.
Marsh-Tootle et al.	136 providers /	MCQs	Strabismus and	Blood	Mean score:

2011	Primary care practitioners		amblyopia (vision) (website)	Pressure screening and Chlamydia screening	Before = 3.1 After (short term; n=57) = 5.5, P<0.0001 Before = 3.3 After (Long term, n=27) = 3.7, P=0.14; Control (n=42) = 3.0 P=0.49*; P<0.0001**; P=0.03*** * Control vs intervention at baseline **Control vs intervention after short term delay ** Control vs intervention after long term delay
Sangvai et al. 2012	57 / Paediatrics	MCQs	Motor vehicle safety, bicycle safety, poison prevention, fire/burn prevention, and firearm safety (PowerPoint presentations)	Web-based non-interactive modules	Control group (n = 28) had significantly higher post-test scores (mean = 90.36 [SD = 7.32]) than the intervention group (n = 29) (mean = 87.93 [SD = 6.88]), after adjusting for pre-test scores (control group: mean = 60.0 [SD = 11.06]; intervention group: mean = 64.31 [SD = 8.84]) and year of training (P=0.036).
Saxon et al. 2015	44 / General	Questionnaire,	Manuscript with	Manuscript	Knowledge of selected

	medicine or internal medicine	Likert-type scale	embedded hyperlinks	without hyperlinks	bio-statistical terms was measured using five questions. Pre- and post-test % of correct responses for Group A and B are reported in the manuscript.
Schroter et al. 2011	1054 / Multidisciplinary	Questionnaire	Diabetes Needs Assessment Tool (DNAT)	Diabetes learning modules	The mean knowledge test scores increased similarly in both groups, from 47.4% (SD = 12.6) to 59.0% (SD = 15.8) (n = 499) and 47.3% (SD = 12.9) to 60.1% (SD = 15.9) (n= 498) in the intervention and control groups, respectively. (P= 0.172).
Shaw et al. 2012	371 / Multispeciality	MCQs	Intervention 1: Online spaced education program to improve knowledge and compliance with the National Patient Safety Goal (NPSG). Intervention 2: Slide show based	Self-directed learning (text-based learning)	Spaced education: mean pre-test score = 12.3; mean post-test score = 13.5; pre-test versus post-test score: P<0.0001.

			online program to improve knowledge and compliance with the NPSG.		
Blended learning vs eLearning					
Talib et al. 2010	56 / Paediatrics	MCQs	Hands on training + web-based training on oral health counselling	Web-based training on oral health counselling	Compared to the baseline, resident knowledge improved after the web-based training for the whole group from 69% to 81% (Difference = 12% [95% CI: 9% to 15%], P=0.001).
Kulier et al. 2012	60 training units, 204 post-graduate trainees in obstetrics and gynaecology / Obstetrics and gynaecology	MCQs	A clinically integrated eLearning course incorporating the WHO reproductive health library for teaching basic EBM among postgraduates	Self-directed EBM course	Knowledge (overall MCQ scores): Control intervention: baseline = 38.5 (37.3 to 39.7); post-course = 38.1 (36.7 to 39.4) Experimental intervention: baseline = 38.4 (37.3 to 39.4); post-course = 43.1 (42.0 to 44.1). Adjusted mean difference: 4.9 (2.9 to 6.8), P<0.001.
Sharma et al. 2013	28 / Anaesthesiology	MCQs	Echocardiography learning (website)	Self-directed learning (guidelines)	Post-intervention test scores were higher than pre-test scores in both study groups (Non-

					Internet group [n=11]: 44 [10]; Internet group [n=12]: 59 [10]), but the increase was greater in the Internet group. The increase in the post-simulation test compared to the post-intervention test was significantly greater in the non-Internet group (Non-Internet group [n=11]: 63 [5]; Internet group: [n=12] 72 [8]).
Ali et al. 2013	30 / Primary care practitioners (family practice residents)	MCQs	ATLS delivered through telemedicine	ATLS face-to-face learning	Telemedicine (n=14): mean = 85.89 (95% CI: 82.03 to 89.76), P=0.091 Control (n=16): mean = 89.69 (95% CI: 86.94 to 92.43).
Kulier et al. 2009	6 training units 61 post-graduate trainees in obstetrics and gynaecology / Obstetrics and gynaecology	MCQs	A clinically integrated eLearning course for teaching basic EBM among postgraduates	Face-to-face learning	Intervention group outperformed the control group by 3.5 scoring points (95% CI -2.7 to 9.8) but this difference was not statistically significant (P=0.27).
Perkins et al. 2012	3732 / Multispeciality	Exam/test	Advanced life support (ALS) training (LMS)	Face-to-face learning (conventional	eALS (n=1403): 74.5%; cALS (n=1445): 80.2% 95%

				ALS course)	CI: -8.8 to -2.7
Platz et al. 2010	55 / Emergency medicine	MCQs	Web-based basic ultra-sonographic principles and the Extended Focused Assessment with Sonography for Trauma (EFAST) (PowerPoint slides)	Face-to-face training	Post-test: Both the classroom (n=19) and Web group (n=23) showed significant improvement in scores between the pre- and post-test 1 (75.9% [SD = 10.7] vs 93.9% [SD = 4.7], with a difference of 18.0% (95% CI 12.5% to 23.5%).
Vollmar et al. 2010	389 / Primary care practitioners	Questionnaire	1. Study Arm A (blended learning, online modules and structured discussion) 2. Study Arm B (lecture, structured discussion) 3. Study Arm A and B	Face-to-face learning (lecture, face-to -face discussion)	Difference in knowledge gain (t1-t0): Study group A (n=84) and B (n=82) did not show any statistically significant difference in knowledge gain on all 20 questions at T1 (3.67 versus 3.60 questions, mean difference = 0.07, CI: -0.84 to 0.98, P = 0.881; T=0.15). Difference in knowledge gain (t2-t0): Study group A (n=46) and B (n=51) did not show any statistically significant difference in knowledge gain on all 20 questions at T2

					(2.39 versus 2.00 questions, Mean difference = 0.39, CI: -0.83 to 1.61, P = 0.526; T=0.636). Outcome of control group: The non-randomised control group (n=21) also showed an improvement in knowledge, although the knowledge gain at T2 was lower (1.48, P = 0.019) compared to the intervention groups at both times.

ARIA: Allergic Rhinitis and its Impact on Asthma; ATLS Advanced Trauma Life Support; CME: continuing medical education; CPD: continuing professional development; CPR: cardiopulmonary resuscitation; EMB: evidence-based medicine; GINA: Global Initiatives for Asthma guidelines; MCQ: multiple choice question.

APPENDIX II B: CHARACTERISTICS OF INCLUDED STUDIES ASSESSING SKILLS

Study ID	No. of participants / Specialty	Assessment method	eLearning type	Control	Post-intervention skills
eLearning vs self-directed learning					
Claxton et al. 2011	82 General medicine or internal medicine	Likert scale	Fast Facts and Concept (FFAC) emails	Self-directed learning	Preparedness in symptom management skills improved more in the intervention group (n=41) than in the control group (n=41) (P=0.04, 0.01, and 0.02, respectively). Post-test: overall preparedness was 39.5 in the control group (median), and 36 in the intervention group, P=0.06.
Conroy et al. 2015	57 / Paediatric trainees	Liverpool Causality Assessment Tool	Liverpool ADR Causality Assessment eLearning Package (LACAeP)	Self-directed learning	Intervention: n=29 Control: n=28 The average score by correct classification was 9.22 (95% CI: 7.96 to 10.48) in the intervention arm and 7.88 in the control arm (95% CI: 6.76 to 9.00).
Dolan et al. 2015	41 / General medicine or	Survey	Online curriculum in bone health	Self-directed	Treatment rates for high risk fragility

	internal medicine			learning (text-based training)	fractures: Intervention: 57/75, 76% Control: 47/80, 59% P=0.03
Edrich et al. 2016	138 / Anaesthesiology	Objective structured clinical examination (OSCE)	1.Web-based training of lung ultrasound for the exclusion of pneumothorax	1. Self-directed learning (text-based learning) 2. Classroom-based training (face-to-face learning)	Mean combined test scores: Intervention (Web group; n=59): mean = 42.9 (SD = 18.1) Classroom group (n=59): mean = 39.2 (SD = 19.2). Intervention (Web group; n=59): mean = 42.9 (SD: 18.1) Control (n=20): mean = 1.2 (SD = 13.9).
Hymowitz et al. 2007	14 paediatric residency training sites, 88 residents / Paediatrics	Questionnaire	Seminar on' solutions for smoking' website served as the main teaching tool	Self-directed learning	Intervention: n=44 Control: n=44 There were no significant differences between the intervention and control groups on the post-test survey results on any of the domains tested.
Koppe et al. 2016	14 GPs, 12 GP registrars / Primary care practitioners	Objective structured assessment of technical skills	Balint groups were delivered over 8-9 fortnightly online sessions via WebEx	Self-directed learning	Task-specific checklist: Pre-test: Multimedia-based

		(OSATS)			training (n=18): 6.6 (SD = 2.8) Practical training (n = 17): 5.5 (SD = 3.7) Combined training (n = 18): 5.8 (SD = 3.3) Control group (n = 17): 5.5 (SD = 2.8).
Lee et al. 2015	125 / Primary care practitioners	Diagnostic assessment	Online cultural competency and problem-affect-concern-treatment (PACT) training	Self-directed learning (text-based training)	GP group (n=43): Correct diagnosis % = 72.2% GP and Nursing group (n=42): Correct diagnosis % = 69.7% Control group (n=27): Correct diagnosis % = 36.4%
Macrae et al. 2004	81 / Surgery	Videotape of encounters	General surgery (Internet, emails)	Self-directed learning (clinical articles)	No difference between pre- and post-intervention. Videotaped encounter scores (P=.432). Both the interactive and non-interactive groups had lower post-intervention than pre-intervention scores. No difference in post-intervention Videotaped encounter scores by group (P=.822).
eLearning vs face-to-face learning					

Bello et al. 2005	56 / Anaesthesiology	Practical skills test (on manikin)	Online teaching	Face-to-face learning	Skills gains on practical skills tests were slightly, but not significantly, greater in Group 2 (n=28) (31.5% to 46.0) compared to Group 1 (n=28; 32.5% to 47.0%, P=0.376.
Barthelemy et al. 2017	39 / Emergency medicine	Questionnaire	Online Modular Object-Oriented Dynamic Learning Environment (Moodle) for electrocardiography interpretation	Face-to-Face (lectures)	Skills: eLearning group (n=19): precourse = 42.1% (34.8-49.4), (SD = 15.15). Lecture-based group (n=20): precourse = 37.5% (30.7-44.2), P=0.42. ELearning group (n=19): postcourse: 59.5% (51.8-67.1), (SD = 15.87); Lecture-based group (n=20): postcourse = 51%, (42.4-59.6), (SD =18.38) P=0.14
Chenkin et al. 2008	21 / Emergency medicine	OSCE	Web-based ultrasound-guided vascular access training	Face-to-face learning (didactic group)	No difference in mean OSCE scores (absolute difference = -2.8%, 95% CI: = -9.3% to 3.8%) between the web group (n=11) and the didactic group

					(n=10), P=0.39.
Houwink et al. 2015	92 / Primary care practitioners	Exam/ test	1. Genetics eLearning CPD module about oncogenetics 2. GP and genetics website	Face-to-face (live genetic CPD module) learning	26 (58 %) in the intervention group (n=45) and 29 (76 %) in the control group (n=38); P=0.10. Intervention group mean score = 58% (SD= 8); control group = 50% (SD = 8); *t*=3.92, P <.0001.
Shariff et al. 2015	5959 / Surgery	Questionnaire	Multimedia educational tool for cognitive surgical skill acquisition in open and laparoscopic colorectal surgery	Face-to-face (study day group) lectures	Residents in the intervention group were significantly more likely to treat patients at high risk for fragility fracture with bisphosphonates, treating 57 of 75 compared to control group residents who treated 47 of 80 patients (76% versus 59%, P=0.03).
Schmitz et al. 2016	72/ Surgery	OSCE	Mastering Difficult Family Conversations in Surgical Care online course	Face-to-face learning	Residents in the treatment group improved their OSCE scores from 58.8 to 72.5 (change score = 13.7); residents in the control group improved their OSCE scores from 60.9 to

					68.0 (change score =7.0), P>0.05.
Wilkinson et al. 2016	24 / General medicine or internal medicine	Exam/ test	Technology-driven simulation-based cardiac ultrasonography teaching	Conventional teaching	Post-test scores improved significantly in both groups (P<0.01). The change in scores (mean, [SD]) in the multimedia group (n=30) was not significantly different from the study day group (n=29) (6.02 [SD = 5.12] and 5.31 [SD=3.42], respectively; P = 0.61).
eLearning vs eLearning					
Bernstein et al. 2013	27 continuity research network sites, 143 paediatric residents / Paediatrics	Structured clinical observations	Bright Futures Oral Health online curriculum	1-hour online curriculum	Intervention: n=52 Control: n=60 At 3-months, the intervention group demonstrated significant improvement in oral health performance (mean-pre=0.9, mean-post=1.2, *F*=15.220, P<.001), compared to the control group (mean-pre=0.9, mean-post=0.9, P=.001)
Sangvai et al. 2012	57 / Paediatrics	MCQs	Motor vehicle safety, bicycle	Web-based	Web-based interactive modules (n=29): Mean

			safety, poison prevention, fire/burn prevention, and firearm safety (PowerPoint presentations)	non-interactive modules	= 0.5 (SD= 0.7), Control (non-interactive web-based modules; n=29): Mean = 0.9 (SD = 1.2).
Wilkinson et al. 2016	24 / General medicine or internal medicine	Objective structured clinical examination	Motor vehicle safety, bicycle safety, poison prevention, fire/burn prevention, and firearm safety (PowerPoint presentations)	Web-based non-interactive modules	Interpretation ability: Before teaching, both groups could correctly identify a case as grossly normal or abnormal 29% and 27% of the time, respectively. After teaching, this increased to 55% and 65%, respectively (P=0.194). Before teaching, both groups were rarely able to make a correct singular diagnosis: 12% in the conventional group and 15% in the technology group. After teaching, the ability to make a singular correct diagnosis increased to 32% and 39% (P=0.439) in the

					conventional and technology groups, respectively. Scanning ability: In the conventional group, 7 of 13 (53.8%) had diagnostic quality images (P=0.006), compared to 2 of 11 (13.6%) in the technology group.
Blended learning vs eLearning					
Talib et al. 2010	56 / Paediatrics	MCQs	Hands-on-training (HOT) and web-based training (WBT) on oral health counselling	WBT on oral health counselli ng	ELearning: n=27 Blended learning: n=29 WBT+HOT group scored higher than those in the WBT group (87% vs 73%; difference = 13.9%, 95% CI: 1.2% to 26.6%, P=0.03)
Blended learning vs face-to-face learning					
Szmuilowicz et al. 2012	38 / General medicine or internal medicine	Behavioural checklist	Internet-based multimodality communication skills intervention	Face-to-face learning (clinical rotation) / self-directed learning	Intervention group (n=19) residents displayed significantly higher overall performance with less variation than control group residents (n=19) on the CSD checklist outcome evaluation (75.1% –8.9 versus

					53.2% –16.2, P <0.001).
Midmer et al. 2006	88 / Primary care practitioners	Checklist	Opioid- and Benzodiazepine-Prescribing Skills (emails) and discussions	Face-to-face learning (3-hour interactive presentation)	Code status discussions skills total score: Intervention (n=19): (mean = 75.1% [SD = 8.9%]) Controls (n=19): (mean = 53.2% [SD = 16.2%] P<0.001
Ngamruengphong et al. 2015	39 / Primary care practitioners	Checklist	Didactic lecture and periodic email remainders with immediate feedback on HBV vaccination	Face-to-face learning (standard education from the residency program)	Skills improvement: Intervention (WBT+HOT group) = 87% vs control (WBT group) = 73%; difference = 13.9%, 95% CI: 1.2% to 26.6%, P=.03)
Perkins et al. 2012	3732 / Multispeciality	Psychological Medicine Inventory, Professional Isolation Scale, Warr's Work-Related Affect Scale	Advanced life support (ALS) training (LMS)	Face-to-face (ALS course)	Balint participants' scores (n=8) were significantly higher post-intervention on the Psychological Medicine Inventory (mean = 6.49 [SD =0.20]) versus the control (n=5) (mean = 5.43 [SD = 0.26], P< 0.01) and similarly on Warr's Work-Related Affect scale scores:

					intervention (n=8): mean = 4.09 (SD = 0.09) versus the control (n=5): mean = 3.60 (SD = 0.12), P < 0.01). Effect size on these scales ranged from 0.46 to 0.50.
Ali et al. 2013	30 / Surgery	Instructor	ATLS delivered through telemedicine	Standard ATLS course	Control n=16: 3.125 (SD=0.5) Intervention n=14: 3.00 (SD=0.39), P=0.45
Pape-Koehler et al. 2013	70 / Surgery	Documentation skills, chart audit	Surgical performance in completing a laparoscopic cholecystectomy in a Pelvi-Trainer (web-site) 1: Multimedia training 2: Practical training 3: Combination	Text-based training	Documentation of HBV vaccine status: Intervention (E-group): 29 patients were seen by 15 residents. Control: 17 patients were seen by 10 residents. Residents in the E-group were not more likely to have documented the HBV vaccine status of their patients (10% vs 12%, respectively, P=1.00).
Ruf et al. 2010	112 general practices, 91 patients / Primary care practitioners	Problems, Affecting, Concerns, Treatment (PACT) score,	Online quality improvement program for alcohol-related disorders (online	Access to the online quality improve ment	Cross-cultural communication: Students (n=119) who participated in the online module (n=60)

		OSCE	system, web-site) 1. Online+GP training (blended 1) 2. Online+GP training +team training (blended 2)	program for alcohol related disorders	demonstrated increased use of cross-cultural communication PACT questions compared to the control group (n=59).
Kulier et al. 2012	60 training units, 204 post-graduate trainees in obstetrics and gynaecology / Obstetrics and gynaecology	Questionnaire	A clinically integrated eLearning course incorporating the WHO reproductive health library for teaching basic EBM among postgraduates	Self-directed EBM course	Skills (OSCE scores) Intervention (n=123): mean = 9.1, 95% CI: 8.7 to 9.4; Control (n=81): mean = 8.3, 95% CI: 7.9 to 8.7; Adjusted difference in mean = 0.7, 95% CI: 0.1 to 1.3; P=0.02

ATLS Advanced Trauma Life Support; CPD: continuing professional development; EMB: evidence-based medicine; MCQ: multiple choice question; OSCE: objective structured clinical examination, HBV: Hepatitis B virus, CSD: Code Status Discussions, ADR: Adverse Drug Reaction

APPENDIX II C: CHARACTERISTICS OF INCLUDED STUDIES ASSESSING ATTITUDE

Study ID	No. of participants / Specialty	Assessment method	eLearning type	Control	Post-intervention attitude
eLearning vs self-directed learning					
Connolly et al. 2014	56 / Paediatrics	Likert scale	'Beyond Milestones' online interactive teaching resource	Self-directed learning (text-based training)	Intervention (teaching group): n=30 Control: n=26 The teaching group reported higher confidence in their developmental assessment skills as compared to controls (MeD = 0.56; $t(44) = -2.170$; P = 0.035).
Harris et al. 2002	99 / Multispecialty	Questionnaire	Interactive case-based domestic violence education program	Self-directed learning (text-based training)	Eight elements of attitude were reported. Asking about domestic violence is presented here. Intervention (n=50): mean change = 0.91; control (n=49): mean change = 0.01, P=0.08
Le et al. 2010	24 / Paediatrics	Likert scale	Web-based multimedia learning modules for physicians' knowledge, attitudes and treatment for paediatric asthma	Self-directed learning	Fifteen domains of attitude were measured, however no difference was found for 14 of these. We report on 'Patients with daily asthma symptoms should be prescribed an ICS'. Intervention (n=15): MD = 0.3 (SD = 0.5); control

					(n=9): MD= -0.2 (SD = 1.6).
Sullivan et al. 2010	213 / General medicine or internal medicine	Questionnaire	Web-based module on opioid therapy for chronic non-cancer pain	Self-directed learning (opioid guidelines)	Four domains of attitude were measured. The study reported mixed results for attitude. We report the results only for 'Agree to prescribe opioids when patients request this' in the data analysis. Intervention (COPE course; n=109): mean = 37.8 (SD=27.4); Control (VA guidelines; n=104): mean = 38 (SD=29.9).
eLearning vs face-to-face learning					
Pelayo-Alvarez et al. 2013	169 / Primary care practitioners	Questionnaire	Palliative care education (online program)	Face-to-face (traditional palliative care training course)	Intervention: n=85 Control: n=84 Confidence in patient symptom management and confidence in communication of diagnosis and disease prognosis showed no differences between groups at 18-months.
Putnam et al. 2015	51 / Surgery	Questionnaire	Online curriculum on patient safety	Face-to-face learning (resident safety workshop)	Safety culture at 6-months Intervention: n=26, 68% Control: n=25, 73%
eLearning vs eLearning					
Yardley	346 / General	Questionnaire	1. CRP group	Text-based	Importance of reducing

et al. 2013	practitioners		2. Communication group 3. Combined group	training	prescribing. CRP group (n=73): mean = 6.2 (SD = 1) Communication group (n=83): mean = 6.3 (SD = 0.9)
Blended learning vs self-directed / face-to-face learning					
Kulier et al. 2009	6 training units, 61 (pg. trainees in obstetrics and gynaecology/ Obstetrics and Gynaecology	Likert scale	eLearning course for teaching basic EBM among postgraduates	Face-to-face learning (lecture)	Seven domains of attitude were reported; we have presented results for question G. Intervention (n=15): attitude gain = 14%; attitude unchanged = 57%; and attitude loss = 29%. Control (n=25): attitude gain = 41%; attitude unchanged = 45%; and attitude loss = 14%.

COPE: Collaborative Opioid Prescribing Education; EMB: evidence-based medicine, CRP: C-Reactive Protein test

APPENDIX II D: CHARACTERISTICS OF INCLUDED STUDIES ASSESSING SATISFACTION

Study ID	No. of participants / Specialty	Assessment method	eLearning type	Control	Post-intervention satisfaction
eLearning vs self-directed learning					
Bell et al. 2000	162 / Primary care practitioners	Questionnaire	Self-study Acceleration with Graphic Evidence (SAGE) or printed materials on acute myocardial infarction	Self-directed learning (printed self-study materials)	SAGE users (n=83) were more satisfied with learning compared to those in the printed material group (n=79): median rating = 17.0 vs 15.0; P<0.001.
Claxton et al. 2011	82 / General medicine or internal medicine	Likert scale	Fast Facts and Concept (FFAC) emails	Self-directed learning (no emails)	Intervention: n=41 Control: n=41 No difference between pre- and post-satisfaction in both the control (P=0.69) and intervention groups (P=0.08).
Gold et al. 2004	69 / Surgery	Questionnaire	Internet CD-ROM thoracic surgery eLearning system - a hybrid Prerequisite Curriculum (PRC)	Self-directed learning (curriculum outline)	Comfort, satisfaction, confidence, interest communication, study habits, organization etc. Post-matriculation resident assessment and resident performance results: +PRC (n=46): mean score=3.43; -PRC (n=32): mean score = 2.87, P<0.05. Post-matriculation faculty

					assessment survey and resident performance results: +PRC (n=76): Mean score = 3.84; -PRC (n=83): Mean score = 3.76; P>0.05.
Matzie et al. 2009	Surgical residents: 55; Fourth year-medical students: 324 / Surgery	Likert scale	Spaced education on how to provide effective feedback (emails)	Self-directed learning (text-based learning)	Students: intervention (n=149), controls (n=175). Students reported resident feedback was 'helpful' in their learning in 92% (132 of 143) of their evaluations of spaced education residents, compared to 82% (132 of 161) of their evaluations of control residents (RR= 1.13, P=0.01). Frequency of feedback RR=1.43, (95% CI: 1.08 to 1.90, P =.016.
Pernar et al. 2012	29 / Surgery	Likert scale	Improve teaching skills in a surgery department using spaced education	Self-directed learning	Group A (intervention, n=15) and Group B (control, n=14) 87.1% (Group A) and 89.9% (Group B) (P=0.15) of faculty were felt to deliver useful feedback; 89.2% and 90.8% (P=0.71) of faculty were perceived to encourage student autonomy; and 78.1% and

					81.9% (P= 0.89) of faculty were felt to set clear learning expectations for students.
Sullivan et al. 2010	213 / General medicine or internal medicine	Questionnaire	Web-based module, opioid therapy for chronic non-cancer pain	Self-directed learning (opioid guidelines)	General satisfaction: Intervention: pre-test mean (n=109) = 56.9 (SD = 7.1); post-test mean (n=88) = 61.9 (SD = 8.6). Control: pre-test mean (n=104) = 57.4 (SD = 8.2), post-test mean (n=85) = 60.4 (SD = 7.7).
eLearning vs face-to-face learning					
Bello et al. 2005	56 / Anaesthesiology	Questionnaire	Online teaching	Face-to-face learning course	Overall satisfaction scores. Online course (n=28): median = 10 Traditional course (n=28): median = 9; P= 0.014.
Chenkin et al. 2008	21 / Emergency medicine	Likert scale	Web-based ultrasound-guided vascular access training	Face-to-face learning (didactic group)	Found overall course to be useful: Intervention (n=11): Satisfied: 100% Control (n=8): Satisfied: 80% P=0.21
Fordis et al. 2005	103 /Primary care practitioners	Questionnaire	1. Online CME on cholesterol management 2. Live interactive CME	Face-to-face learning (lecture)	Online CME (n= 52): Satisfaction: 94% Live CME (n=51): Satisfaction: 100%
Hemmati et al.	80 / Primary care practitioners	Questionnaire	Cardiopulmonary resuscitation (CPR)	Face-to-face learning	Participants in the intervention group (n=40),

2013			curriculum guidelines training through Internet-based learning	(CPR lecture)	had significantly higher satisfaction scores (mean = 62.5; SD = 2.32) than those in the control group (n=40) (mean = 54.6; SD= 2.18).
eLearning vs eLearning					
Schroter et al. 2011	1054 / Multidisciplinary	Questionnaire	Diabetes Needs Assessment Tool (DNAT)	Diabetes learning modules	15 measures of satisfaction were reported, we have only reported on the results for 'Learning materials have improved my overall understanding of diabetes.' Intervention group (n = 285): yes=237. Control group (n=295): yes=251.
Shaw et al. 2012	371 / Multispeciality	Likert scale	Online spaced education program to improve knowledge and compliance with the National Patient Safety Goal (NPSG)	Online slide show based online program	Several domains of satisfaction were measured, we have only reported on the results for 'intervention improved'. Intervention: (n=118): yes=65% Control (n=41): yes=42% P=0.0026
Yardley et al. 2013	346 clusters (GPs); 2886 patients / Primary care practitioners	Questionnaire	1. CRP group 2. Communication Group 3. Combined group	Usual care	Patients in the CRP group reported slightly lower levels of satisfaction with the consultation, $F(3, 2315) = 4.39$, P = 0.004. Satisfaction questionnaire scores were generally high, with a mean of 8.26 (SD =

					1.52) out of a maximum score of 10, with no significant differences between groups or countries.
Blended learning vs self-directed / face-to-face learning					
Ali et al. 2013	30 / Family practice residents	Questionnaire	ATLS delivered through telemedicine	Standard ATLS course	Overall rating of the course: Intervention (n=14): mean: 3.91 (SD=0.3) Control (n=16): mean: 3.67 (SD=0.5) P=0.20
Kronick et al. 2003	81 / Not specified	Questionnaire	3-hours training on using the World Wide Web to research patient related questions	Self-directed learning (text-based learning)	8 domains of satisfaction were measured, we have only reported on the results for 'comfort in using email'. Intervention (n=30): mean score = 3.6 (SD = 1.3) Control (n=40): mean score = 3.4 (SD = 1.3)
Platz et al. 2010	55 / Emergency medicine	Likert scale	Web-based basic ultra-sonographic principles and the Extended Focused Assessment with Sonography for Trauma (EFAST) training	Face-to-face learning	Satisfaction was measured only for the Classroom and Web group. We have only reported on the results for scale '1=very much' in response to 'enjoyed didactic training'. Web (n=21): rating = 1 (42.9%) Class (n=19): rating = 1 (79.0%) P<0.0001

ATLS Advanced Trauma Life Support; CME: continuing medical education, CRP: C - reactive protein test

APPENDIX II E: CHARACTERISTICS OF INCLUDED STUDIES ASSESSING PRACTICE OR BEHAVIOUR CHANGE

Study ID	No. of participants / Specialty	Assessment method	eLearning type	Control	Post-intervention practice/ behaviour change
eLearning vs self-directed learning					
Bell et al. 2015	155 / Primary care practitioners	Clinicians' behaviour was assessed with transcripts and standardized patients	Interactive web-based genetics curriculum	Self-directed learning (genetic review articles)	Intervention: n=77 Control: n=78 Several domains of behavioural change were measured, we report on 'Benefits of genetic counselling'. Numbers of physicians who raised the topic: Intervention: n=47; Control: n=37
Braido et al. 2012	44/ Primary care practitioners	Data from a database	Respiratory allergic diseases: monitoring study of GINA and ARIA guidelines (blended CME)	Self-directed learning	Mean percentage difference between the training and control groups found a significant increase in spirometry in the training group (+63.4%, P<0.01) and a non-significant increase in RASTs (+33.6%), prick tests (+31.7%), spirometry with bronchodilation (+46.2%), and methacholine tests

					(+66.5%).
Butler et al. 2012	68 clusters (general practice), 263 clinicians / Primary care practitioners	Hospital chart audit	Stemming the Tide of Antibiotic Resistance (STAR) educational program	Self-directed learning (text-based training)	Antibiotic dispensing rate /1000 registered patients. Intervention (n=139): baseline mean = 678; follow-up mean: 664. Control (n=124) clinicians, baseline mean: 669, follow-up mean: 681 % reduction in intervention relative to control: 4.2, 95% CI: 0.6 to 7.7, P=0.02
Curtis et al. 2007	153 / Primary care practitioners	Hospital chart audit	Web-based glucocorticoid-induced osteoporosis (GIOP) course (three case-based scenarios)	Self-directed learning (text-based training)	BMD testing rates: Intervention (n=78): 19% Control (n=75): 21% Rate difference: −2%, 95% CI: −8% to 4%, P=0.48 Any osteoporosis medication prescribing: Intervention (n=78): 32% Control (n=75): 29% Rate difference: 3%, 95% CI: −3% to 9%, P=0.34
Dayton et al. 2000	29 / General medicine or Internal medicine	Scenario based decision support system	Computerised decision-support system for applying the ATS/CDC guidelines (Group A)	Self-directed learning (guideline card)	Concordance with ATS recommendations: Intervention (n=12): 96% Control (n=17): 57% P<0.001
Farah et	45 / General	MCQs	Information aids,	Self-directed	Doctors in the

al. 2012	medicine / Internal medicine		decision aids and the Internet (prostate cancer screening)	learning (information aid, delayed intervention)	intervention group were more likely to appreciate PSA screening: 91% versus 60%, P=0.02. Doctors in the intervention group were also more knowledgeable in recognising that PSA/DRE testing is associated with potential harm: 65% versus 91%, P=0.04. Doctors in the intervention group were better able to correctly identify current literature findings regarding prostate cancer screening: 35% versus 75%, P=0.03.
Feng et al. 2013	118/ Primary care practitioners	Questionnaire	Interactive web-based curriculum for prostate cancer screening 1.Intervention A: standardised patient 2. Intervention B: similar patient focus, web-based tool. (blended learning)	Self-directed learning (brochures)	Intervention: n=61 Control: n=57 Intervention physicians showed somewhat more shared decision-making behaviours (intervention 4 items vs control 11 items, P <.05), were more likely to mention no screening as an option, intervention 63% vs control (n=57) 26%, P <.05), to

					encourage patients to consider different screening options (intervention 62% vs control 39%, P <.05) and seeking input from others (intervention 25% vs control 7%, P <.05).
Gerbert et al. 2002	71/ General medicine or Internal medicine	Not stated	Skin cancer triage tutorial	Self-directed learning (delayed intervention)	Intervention group scored significantly higher than the control group in nine of the 14 outcome measures; this improvement was maintained for five of the nine outcomes.
Le et al. 2010	24 / Paediatrics	Likert scale	Web-based multimedia learning modules for physicians' knowledge, attitudes and treatment of paediatric asthma	Self-directed learning	This study presents two behavioural outcomes, we report only on 'considering the total number of your patients with persistent asthma, for what percentage of these patients did you prescribe an ICS'. Intervention (n=15): mean = 6.9 (SD = 15.3). Control (n=9): mean = 10.5 (SD = 15.7).
Little et al. 2013	246 clusters (primary care practices), 4264 patients / Primary	Case report form	1. C-reactive protein (CRP) training 2. Enhanced	Self-directed learning	Antibiotic prescription rates (crude %): No CRP training: 48% (984/2040)

	care practitioners		communication training 3. Combined training (CRP training + enhanced communication training)		CRP training: 33% (734/2224) No communication training: 45% (876/1932) Communication training: 36% (842/2332).
Meeker et al. 2016	47 Primary care practices (248 clinicians enrolled)/ Primary care practitioners	Questionnaire	Intervention group (peer comparison) received email together with feedback and suggestions	Self-directed learning (text-based training)	Antibiotic prescribing rates for antibiotic-inappropriate acute respiratory infections: Peer comparison (n= 20): mean = 19.2, 95% CI: 17.3 to 21.1 Control (n=27): mean = 24.0, 95% CI: 22.1 to 25.8 Suggested alternative (n=42): mean: 30.2, 95% CI: 28.4 to 32.1 Accountable justification (n=35): mean = 16.4, 95% CI: 14.7 to 18.0.
Short et al. 2006	81 / Multispeciality	Questionnaire	Online intimate partner violence (IPV) CME program	Self-directed learning	Online CME: n=44 Control: n=37 Online CME program was associated with a significant improvement in eight of 10 KABB outcomes, including physician self-

					efficacy and reported IPV management practices, over the study period.
Stewart et al. 2005	58 / Primary care practitioners	Clinical vignettes	Case-based on-line learning group	Wait-listed control group	The study reported knowledge on prevention and diabetes topics; we report only the mean change in quality of practice on the prevention topic at 2-months. Intervention (n=27): mean = 52.2 (SD = 11.7) Control (n=31): mean = 47.7 (SD = 13.8)
Xiao et al. 2007	50 / Surgery, emergency medicine	Video review	Online training course on central venous catheter insertions (video group)	1. Paper group 2. Self-directed learning	Compliance for sterile practice is reported. Video group: cases n=19 Paper group: cases n=31 Control group: cases n=23 The full compliance rate in the video group (14 of 19, 74%) was significantly higher (P=0.003) than that in the paper and control groups (18 of 54, 33%), with an OR of 6.1 (95% CI: 1.96 to 22.03).
eLearning vs face-to-face learning					
Fordis et al. 2005	103 / Primary care practitioners	Hospital chart audit	Intervention 1: Online CME on cholesterol	Lecture	Appropriate screening for dyslipidaemia: Online CME (n=20):

			management Intervention 2: Live interactive CME		mean difference = -0.1, 95% CI: -2.9 to 2.6 Live CME (n = 20): mean difference = -3.3, 95% CI: -5.9 to -0.7 Lecture group (n=20: mean difference = -0.8, 95% CI: -3.5 to 1.8 Patients appropriately treated: Online CME group (n=17): mean difference = 5.0, 95% CI: 1.0 to 9.1 Live CME group (n=19): mean difference= -1.1, 95% CI: -4.9 to 2.7 Control group (n=18): mean difference = 1.2, 95% CI: -2.8 to 5.1
eLearning vs eLearning					
Allison et al. 2005	209 / Primary care practitioners	Data from a database	Intervention: Multicomponent Internet CME	Internet-based CME	Pre-intervention screening rates were 18.9% for the intervention (n=103) and 16.2% for the comparison offices (n=106) (P=0.135). Post-intervention screening rates were 15.5% for the intervention and 12.4% for the comparison offices

					(P=0.044).
Schroter et al. 2011	1054 / Multidisciplinary	Questionnaire	Diabetes Needs Assessment Tool (DNAT)	Diabetes learning modules	Three practice changes were measured; we report on 'Awareness of change in level of competence'. Intervention (n=291): yes = 217 (74.6%) Control (n=306): yes = 229 (74.8%) Difference: -11.3, 95% CI: -17.8 to -4.8
Shaw et al. 2012	371 / Multispeciality	Questionnaire	Online spaced education program to improve knowledge and compliance with the National Patient Safety Goal (NPSG)	Slide show based online program (SQ) to improve knowledge and compliance with the National Patient Safety Goal (NPSG)	Spaced education (SE) interns demonstrated a mean of 4.79 (36.6%) NPSG-compliant behaviours (out of 13 total), while SQ interns demonstrated a mean of 4.17 (32.0%) (P=0.09).
Weston et al. 2008	113 / Primary care practitioners	Compliance assessed by reviewing video records of CVC insertion and marking score sheets.	Type 2 diabetes seminar	Systolic heart failure seminar	The study reported intentions to change patient management on a 3-point scale (yes, no and not sure). We report on responses for option 'yes'. Diabetes group (n=64): yes=19 (31.2%) Systolic heart failure group (n=49): yes=13 (28.9%)
Blended learning vs self-directed learning/face-to-face learning					

Daetwyler et al. 2010	54 / General or Internal medicine	Checklist	Drexel University College of Medicine's (DUCOM) group's "doc.com" and web objective structured clinical exam "WebOSCE" Intervention 1: DUCOM+MCQ Intervention 2: DUCOM +MCQ+ second web encounter exercise	Self-directed learning	Number of correct behaviours scored by standardised patients: "Doc.com + WebOSCE" (n=16): baseline mean = 44%, (SD = 21%), final mean = 71% (SD = 12%), mean change = 27% (SD = 21%) Control group (n=19): baseline mean = 56% (SD = 20%), final mean = 63% (SD = 14%), mean change = 8% (SD = 27%)
Epstein et al. 2011	8 clusters (practices), 49 paediatricians / Paediatrics	Hospital chart audit	Internet portal to improve community-based paediatric ADHD Care	Delayed intervention (6-months)	Several behavioural change outcomes were reported; we report only on the 'use of parent rating of ADHD during assessment at 6-months'. Intervention (n=27): mean = 42 (SD = 25.9) Control (n=22): mean: 18.1 (SD = 33.1).
Ruf et al. 2010	112 clusters (general practices), 91patients / Primary care practitioners	Questionnaire	Online improvement program for alcohol-related disorders (online system, web-site) 1. Online+GP training 2. Online+GP	Control: Access to the online system without any training	Patient documentation at follow-up, ITT analysis. GP group (n=43): yes = 7 GP+Nurse group (n=42): yes = 8 Control (n=27): yes = 4 Test for difference between groups, exact test=0.26, P=0.90.

			training +team training		
Midmer et al. 2006	88 / Primary care practitioners	Hospital chart audit	Opioid- and benzodiazepine-prescribing skills (emails) + Discussions	Face-to-face learning (3-hr interactive presentation)	No significant before-after changes on self-reported behaviours or on clinical confidence comfort levels, motivation, or rating of importance.

ARIA: Allergic Rhinitis and its Impact on Asthma; ATS: American Thoracic Society; CDC: Centers for Disease Control; CME: continuing medical education; GINA: Global Initiatives for Asthma guidelines; MCQ: multiple choice question, KABB: Knowledge, Attitudes, Beliefs, and Self-reported behaviors, CVC: Central Venous Catheter, SE: Spaced Education, SQ: Slide-show based online program, PSA: Prostate-Specific Antigen, DRE: Digital Rectal Examination, BMD: Bone mineral density, RASTs: Radioallergosorbent tests

APPENDIX II F: CHARACTERISTICS OF INCLUDED STUDIES ASSESSING PATIENT OUTCOMES

Study ID	No. of participants / Specialty	Assessment method	eLearning type	Control	Post-intervention patient outcomes
eLearning vs self-directed learning					
Butler et al. 2012	68 clusters (general practices), 263 clinicians / Primary care practitioners	Hospital chart audit	Stemming the Tide of Antibiotic Resistance (STAR) educational program	Self-directed learning (text-based training)	Hospital admissions: There were no significant differences in admissions between the groups. Re-consultation rates: There were no significant differences between intervention and control groups for re-consultation rates after an index consultation, expressed as re-consultations per 1000 registered patients, for respiratory tract infections the median difference was (intervention−control) −0.65 (−1.69 to 0.55) at seven days; −1.33 (−2.12 to 0.74) at 14 days; and −2.32 (−4.76 to 1.95) at 31 days.
Dolan et al. 2015	41 / General medicine or internal medicine, 458 patients	Chart audits	Online formative self-assessment curriculum in bone health	Self-directed learning (text-based learning)	Proportion of female patients appropriately screened for osteoporosis: Intervention: patient screened = 227; appropriately screened: 216 (95.2%) Control patients = 231;

					appropriately screened = 206 (89.2%), P=0.02
eLearning vs eLearning					
Estrada et al. 2011	205 practices with 95 physicians and their 1182 patients / Multispeciality	Hospital chart audit	Multi-component interactive intervention including web-based CME, performance feedback and quality improvement tools	Online web resource for diabetes without feedback or electronic communication	Intervention: n=102 practices Control: n=103 practices The proportion of patients with A1c <= 9% was similar at baseline and follow-up in both the control (AOR = 0.94; 95% CI: 0.61 to 1.47) and intervention arms (AOR = 1.16 (95% CI: 0.80 to 1.69) BP <140/90 mm Hg and LDL <130 mg/dl were also similar at both measurement points (P=0.66, P=0.46; respectively).
Franchi et al. 2016	697 / Geriatrics and internal medicine	Not stated	Web-based training including notions of CGA and geriatric pharmacology, together with training for the use of a third generation assessment instrument (InterRAI Acute Care)	eLearning refresher on the basic notions of geriatric pharmacology	Potentially inappropriate medication (PIM) among patients: Intervention (n=347): PIM = 155 Control (n=350): PIM = 137 OR = 1.29, 95% CI: 0.87 to 1.91, P=0.2 At least one potential drug-drug-interaction (DDI): Intervention (n=347): DDI = 297 Control (n=350): DDI = 320 OR = 0.67, 95% CI: 0.34 to 1.28, P=0.2
Kerfoot	111 / Primary	Questionnaire	Spaced education	Identical	The study reported on many

et al. 2014	care practitioners		for hypertension management	educational content in an online posting	patient-related outcomes; we report on the 'medication possession ratio' between the spaced education game group and the control group. Intervention (n=7224): mean = 0.94, (SD = 0.08) Control (n=7112): mean = 0.94 (SD = 0.08)
Blended learning vs self-directed learning/ face-to-face learning					
Legare et al. 2012	9 clusters (family practice teaching units), 449 patients, 250 physicians/ Primary care practitioners	Chart audit	DECISION+2: a shared decision-making training program to reduce the overuse of antibiotics for acute respiratory infections	Self-directed learning	The study reported behaviour changes among patients in five preferred roles in decision-making; we report only on: 'patient decides at physician level'. Post-intervention: Intervention (n=160): yes=16 (10%) Control (n=108): yes=9 (8.3%)
Girgis et al. 2009	375 / Radiation oncology	Not stated	Consultation skills training program	Face-to-face learning (delayed intervention)	The study reported six psychosocial outcomes in patients; we have only reported on anxiety scores at 1-week. Intervention (n=193): mean = 5.2 (SD = 4.2) Control (n=183): mean = 5.2 (SD 4.1) P=0.183

AOR: adjusted odds ratio; CME: continuing medical education; OR: odds ratio.

APPENDIX III: ELEARNING INTERVENTION TYPE BY PARTICIPANTS' SPECIALTY, COUNTRY OF PUBLICATION AND INTERVENTION DURATION

Study ID	Specialty	Country	Topic of the eLearning content or course	Duration of the intervention (average)	Time of assessment
Ali et al. 2013	Primary care practitioners	Canada	Advanced Trauma Life Support telemedicine course	2 days	Post-test
Allison et al. 2005	Primary care practitioners	USA	Multicomponent Internet CME to increase Chlamydia screening	1 year	2 years
Bell et al. 2000	Primary care practitioners	USA	SAGE (Self-study Acceleration with Graphic Evidence) or printed materials on acute myocardial infarction	Median: 27, (95% CI: 25 to 30)	Post-test: 4-6 months
Butzlaff et al. 2004	Primary care practitioners	Germany	Computerised guidelines	3 months	2.5 months; 5 months
Butler et al. 2012	Primary care practitioners	UK	Stemming the Tide of Antibiotic Resistance (STAR) educational program	N/A	12 months
Bell et al. 2015	Primary care practitioners	USA	Interactive web-based genetics curriculum	6 hours	Post-test
Braido et al. 2012	Primary care practitioners	Italy	Online CME to improve knowledge of ARIA and GINA guidelines	12 months	1 year
Chan et al. 1999	Primary care practitioners	Canada	Access to study web-based resources (URLs) on depression but without the benefit of small-group interaction	2 months	Post-test
Curtis et al. 2007	Primary care practitioners	USA	Web-based glucocorticoid-induced osteoporosis (GIOP)	N/A	1 year

			course		
Fordis et al. 2005	Primary care practitioners	USA	Interactive online CME for cholesterol management	3.8 hours (SD = 2.0)	Post-test: 12 weeks
Feng et al. 2013	Primary care practitioners	USA	Interactive web-based curriculum on physician communication regarding prostate cancer screening	30-minutes	Post-test
Hugenholtz et al. 2008	Primary care practitioners	Netherlands	Website including an eLearning module on mental health issues	Intervention: 30 minutes Control: 30 minutes	Post-test
Hemmati et al. 2013	Primary care practitioners	Iran	Cardiopulmonary resuscitation curriculum guidelines training through internet-based learning	145 minutes (range: 125-182 minutes) Face-to-face class room: 6 hours	Post-test
Houwink et al. 2014	Primary care practitioners	Netherlands	Genetics eLearning CPD module about oncogenetics	Intervention: 124 minutes Control: 2 hours	6 months
Houwink et al. 2015	Primary care practitioners	Netherlands	Genetics eLearning CPD module about oncogenetics	N/A	12 months
Kutob et al. 2009	Primary care practitioners	USA	Skills focused Internet-based course to teach cultural competence of type 2 diabetes	1-4 weeks	Post-test
Kerfoot et al. 2014	Primary care practitioners	USA	Spaced education game for hypertension management	52 weeks	52 weeks
Koppe et al. 2016	Primary care practitioners	Australia	Web 2.0 Balint group to improve psychological medicine skills and work-related affect	2 hours per fortnight	Post-test

Legare et al. 2012	Primary care practitioners	Canada	DECISION+2, a shared decision-making training program to reduce the overuse of antibiotics for acute respiratory infections	4 hours	Post-test
Little et al. 2013	Primary care practitioners	Belgium, Spain, Wales, Poland, UK, Netherlan ds	Internet-based training on antibiotic prescribing rates for acute respiratory tract infection	4 months	Post-test
Lee et al. 2015	Primary care practitioners	USA	Online cultural competence and problem-affect-concern-treatment training	1-hour (online teaching)	Post-test
Marsh-Tootle et al. 2011	Primary care practitioners	USA	Web-based intervention to improve and sustain knowledge and screening of amblyopia	N/A	Short-term: 1-hour to 17 days Long-term: 1.8 years
Meeker et al. 2016	Primary care practitioners	USA	Behavioural interventions (peer-comparison, an email-based intervention) on inappropriate antibiotic prescribing	18 months	18 months
Ngamruengp hong et al. 2015	Primary care practitioners	USA	Didactic lecture and periodic email reminders with immediate feedback on HBV vaccination	30 minutes (didactic lecture). Monthly email reminders of the lecture content for 2 months.	Post-test: 6 months
Pelayo-	Primary care	Spain	Online training in palliative	Online: 96hours	18 months

Alvarez et al. 2013	practitioners		care	Face-to-face learning: 20 hours	
Ruf et al. 2010	Primary care practitioners	Germany	An online quality improvement program for alcohol-related disorders	4 hours	3–4 months
Stewart et al. 2005	Primary care practitioners	Canada	Case-based online learning of evidence-based practice guidelines in type 2 diabetes prevention	4 weeks	2 months; 6 months
Vollmar et al. 2010	Primary care practitioners	Germany	Dementia management using a blended learning approach	Study arm A: 75 minutes Study arm B: 45 minutes	9-weeks; 4-months
Weston et al. 2008	Primary care practitioners	USA	Online CME on type 2 diabetes and systolic heart failure	N/A	Post-test
Yardley et al. 2013	Primary care practitioners	Wales, Belgium, Netherlan ds, Spain, Poland	Web-based intervention to reduce antibiotic prescribing for acute lower respiratory tract infections	N/A	Post-test
Midmer et al. 2006	Primary care practitioners	Canada	Distance learning program on opioid and benzodiazepine prescribing skills for physicians	10 weeks	4-6 months
Ali et al. 2013	Surgery	Canada	Advanced Trauma Life Support course	2 days	Post-test
Ferguson et al. 2015	Surgery	USA	Online short course on frailty	N/A	Post-test
Gold et al. 2004	Surgery	USA	Internet CD-ROM thoracic surgery eLearning system, a Novel Internet Hybrid Surgery Curriculum (Prerequisite	57.5 hours	3 months

			Curriculum)		
Macrae et al. 2004	Surgery	Canada	Teaching critical appraisal skills with an Internet-based journal club	8 months	Post-test
Matzie et al. 2009	Surgery	USA	Spaced education for improving feedback that surgical residents give to medical students	9 months	Post-test
McLeod et al. 2010	Surgery	Canada	Internet journal club for teaching critical appraisal skills	8 months	Post-test
Pernar et al. 2012	Surgery	USA	Improve teaching skills in a surgery department using spaced education	9 months (weekly emails)	Post-test
Pape-Koehler et al. 2013	Surgery	Germany	Multimedia-based training on Internet platforms to improve surgical performance in laparoscopic cholecystectomy using a Pelvic-Trainer	2 hours	Day 2
Putnam et al. 2015	Surgery	USA	Online curriculum on patient safety	NA	Post-test: 6 months; 12 months
Satterwhite et al. 2012	Surgery	USA	A webpage on microsurgery, entitled “Microsurgery Essentials” for residency training	1 week	Post-test
Shariff et al. 2015	Surgery	UK	Multimedia educational tools for cognitive surgical skill acquisition in open laparoscopic colorectal surgery	N/A	1 month
Schmitz et al. 2016	Surgery	USA	Mastering Difficult Family Conversations in Surgical Care online course	N/A	Post-test
Claxton et al. 2011	General medicine or internal	USA	Fast Facts and Concepts weekly emails for palliative care training	32 weeks	Post-test: 1 -8 weeks

	medicine				
Cullinan et al. 2017	General medicine	Ireland	Standard Computerised Revalidation Instrument for Prescribing and Therapeutics (SCRIPT)	1- 2 hours	Post-test: 4 weeks; 12 weeks
Daetwyler et al. 2010	General medicine or internal medicine	USA	Teaching bad news delivery using "doc.com" and "WebEncounter"	1 week	7-8 weeks
Dayton et al. 2000	General medicine or internal medicine	USA	Internet-based decision-support system for applying the ATS or CDC guidelines for tuberculosis preventive therapy	12 minutes	10 months
Dolan et al. 2015	General medicine or internal medicine	USA	Online curriculum in bone health	3-6 months	Post-test
Farah et al. 2012	General medicine or internal medicine	Australia	Information aids, decision aids and the Internet to improve doctors' knowledge on prostate-specific antigen or digital rectal examination screening and testing	4.04 hours	Post-test
Franchi et al. 2016	General medicine or internal medicine	Italy	Interactive online eLearning in order to improve drug prescription	1 month	12 months
Gerbert et al. 2002	General medicine or internal medicine	USA	Internet-based Skin Cancer Triage skills tutorial	N/A	Post-test: 8-weeks
Grover et al. 2010	General medicine or	USA	Arterial and central line placement with a web-based	N/A	Post-test

	internal medicine		curriculum		
Sullivan et al. 2010	General medicine or internal medicine	USA	Web-based module on opioid therapy for chronic non-cancer pain	6 months Attitude: 45-days Satisfaction: 60-days	Post-test
Szmuilowicz et al. 2012	General medicine or internal medicine	USA	Internet-based multimodality communication skills (code status discussions [CSD]) intervention	6-months (2-hours per seminar, 2-hour CSD skills booster session)	2 months
Saxon et al. 2015	General medicine or internal medicine	USA	Hyperlink-embedded journal articles	N/A	Post-test
Wilkinson et al. 2016	General medicine or internal medicine	Canada	Technology-driven simulation-based cardiac ultrasonography teaching	4 hours	Post-test: 1 month
Bernstein et al. 2013	Paediatrics	USA	Training in Bright Futures and oral health concepts	3-6 months	3 months
Connolly et al. 2014	Paediatrics	Australia	'Beyond Milestones': A innovative digital resource for observation of normal child development	5 hours (intervention)	Post-test to 1 month
Epstein et al. 2011	Paediatrics	USA	Internet portal to improve community-based paediatric ADHD care	6 hours	6 months; 15- months
Hymowitz et al. 2007	Paediatrics	USA	Solutions for smoking for paediatric residency training	4 years	2 years; 4 years

Le et al. 2010	Paediatrics	USA	Distributed Asthma Learning Initiative (DALI) program on the role of inhaled corticosteroids in asthma management	79 minutes	Short-term follow-up: 1 - 4 months Long-term follow-up: 6 - 8 months
Sangvai et al. 2012	Paediatrics	USA	Injury prevention web-based modules: motor vehicle safety, bicycle safety, poison prevention, fire or burn prevention, and firearm safety	N/A	7 months
Talib et al. 2010	Paediatrics	USA	Preventive oral health: hands on training and web-based training on oral health counselling	30 minutes (online)	Post-test
Chenkin et al. 2008	Emergency medicine	Canada	Ultrasound-guided vascular access training	1 hour	2 weeks
Chung et al. 2004	Emergency medicine	USA	Educational website for teaching physicians about bio-terrorism	70 minutes	1 month; 6 months
Platz et al. 2010	Emergency medicine	Germany	Basic ultra-sonographic principles and the Extended Focused Assessment with Sonography for Trauma (EFAST)	Classroom: 1 day Web group: 1 or 2 days	Post-test: 8 weeks
Barthelemy et al. 2017	Emergency medicine	France	Online Modular Object-Oriented Dynamic Learning Environment (Moodle) for ECG interpretation	4 months	Post-test
Kerfoot et al. 2007	Urology	USA, Canada	Online educational program on the spacing effect principle for the acquisition and retention of medical knowledge	27 weeks	6 months
Bello et al.	Anaesthesiol	Italy	Online vs live methods for	36 hours	48 hours after

2005	ogy		teaching principles and practice of difficult airway management		completion
Sharma et al. 2013	Anaesthesiology	UK	Internet and simulation- based training on transesophageal echocardiography in anaesthetic trainees	90 minutes	Post-test: 3 weeks
Edrich et al. 2016	Anaesthesiology	USA	Web-based training of lung ultrasound for the exclusion of pneumothorax	30 minutes	24-hours; 4 weeks
Girgis et al. 2009	Radiation oncology	Australia	Consultation skills training program for oncologists	2 days	1-week; 3 months
Alfieri et al. 2012	Radiation oncology	Canada	Web-based radiation oncology module	2.02 hours	Post-test
Enders et al. 2006	Public health	USA	Internet-based introductory biostatistics course	80 hours	Post-test
Hearty et al. 2013	Orthopaedics	USA	ELearning for orthopaedic resident preparedness for closed reduction and pinning of paediatric supracondylar fractures	N/A	Post-test
Viguier et al. 2015	Orthopaedics	France	Online training on skin tumours	3 weeks	3 weeks
Kulier et al. 2009	Obstetrics and gynaecology	Netherlands, UK	Clinically integrated eLearning course in evidence-based medicine	4-6 weeks	Post-test
Kulier et al. 2012	Obstetrics and gynecology	Argentina, Brazil, Democratic Republic of the Congo, India,	Clinically integrated eLearning course in evidence-based medicine for reproductive health training	8 weeks	4 weeks

		Philippines, South Africa, Thailand			
Cabrera-Muffly et al. 2015	Otolaryngology (ENT)	USA	Online otolaryngology module	1 year	N/A
Conroy et al. 2015	Pharmacology	UK	Liverpool adverse drug reaction (ADR) Causality Assessment eLearning package	1 hour	Post-test
Thompson et al. 2012	Gastroenterology	USA	Web-based intervention to improve knowledge of quality performance measures associated with endoscopy among gastroenterology trainees	N/A	6 weeks
Wang et al. 2013	Radiology	USA	Computer-based interactive simulation for teaching contrast reaction management to radiology trainees	Intervention: 5 hours	Post-test: 4-months
Chang et al. 2014	Multispeciality (emergency medicine, paediatrics and family medicine)	USA	Asynchronous eLearning curriculum for paediatric emergency medicine training	3 hours	Post-test
Estrada et al. 2011	Multispeciality (Family, general and internal medicine physicians)	USA	A web-based multi-component diabetes intervention for physicians	64.7 hours (median)	Post-test

Gyorki et al. 2013	Multispeciality (general surgery, medical oncology and radiation oncology)	Australia	Improving the impact of didactic resident training with an online spaced education program on breast cancer therapy	N/A	3 months
Harris et al. 2002	Multispeciality (emergency medicine, general medicine, surgery, cardiology, psychiatry and orthopaedics)	USA	Internet-based education to improve physician confidence in dealing with domestic violence	2 weeks	6 weeks
Perkins et al. 2012	Multispeciality (critical care or anaesthesia)	UK and Australia	Blended approach to advanced life support training (ALS) compared to conventional instructor-led ALS training	ELearning: 158 minutes + a 1day (10-hour) face-to-face learning	3-26 months
Short et al. 2006	Multispeciality (community physicians in the specialties of internal medicine, family medicine,	USA	Online intimate partner violence CME program	6-8 months	6-9 months

	paediatrics, obstetrics and gynaecology, and psychiatry)				
Westmoreland et al. 2010	Multispeciality (postgraduate year 1 residents from the medicine and medicine–paediatrics residency training programs from two academic years)	USA	Web-based training in geriatrics for medical residents	2.5 sessions	Post-test
Xiao et al. 2007	Multispeciality (surgical and emergency medicine residents rotating through the trauma services)	USA	Online training course on central venous catheter insertions on compliance with sterile practice	Video group: 19 minutes (median)	Post-test
Shaw et al. 2012	Multispeciality (included	USA	Online spaced education program to improve knowledge	4-6 weeks	4-6 weeks

	learners from surgical specialties (surgery and OB-GYN) and medical specialties (medicine, anaesthesiology, emergency medicine and psychiatry programs)		and compliance with the National Patient Safety Goal (NPSG)		
Schroter et al. 2011	Multidisciplinary (doctors, nurses)	Wales and Germany	Online interactive diabetes needs assessment tool (DNAT) vs online self-directed learning of diabetes guidelines	4 months	Post-test
Hadley et al. 2010	Not specified	UK	eLearning course in evidence-based medicine for foundation (internship) training	6 weeks	Post-test
Kronick et al. 2003	Not specified	USA	Use of World Wide Web (online medical resources) to research patient-related questions for rural physicians	6 months	Post-test

ATS: American Thoracic Society; CDC: Centers for Disease Control.

APPENDIX IV: RISK OF BIAS FOR CLUSTER RANDOMISED CONTROLLED TRIALS

Study ID	Recruitment bias	Baseline imbalance	Loss of clusters	Incorrect analysis	Comparability with individual trials
Allison et al. 2005	Low	Low	Unclear	High	Unclear
	Recruitment first occurred at the office level (Phase 1) and then at the physician level (Phase 2). In Phase 1, all potentially eligible offices were invited to participate via facsimile. In Phase 2, an active Internet link to the intervention module was delivered by email to physicians recruited in Phase 1 (pg. 286).	Mean screening rates before, during and after the intervention for the comparison offices were 18.9%, 13% and 12.4% respectively, and for the intervention offices were 16.2%, 13.3% and 15.5% respectively (Figure 2, pg. 287).	Loss of clusters not reported in the study	The analysis did not take the clustering effect into account, which would have introduced a unit of analysis error	Comparison between cRCT and RCT could not be made due to heterogeneity of the intervention content
Bernstein et al. 2013	Unclear	High	High	High	Unclear
	Recruitment of a subset of all possible residents from each continuity practice was decided by the co-investigator to	Baseline characteristics of residents in the intervention and active control groups were comparable by age,	Two sites withdrew after the randomisation phase as a result of site specific inability to accomplish all	The analysis did not take the clustering effect into account, which would have introduced a unit of analysis error.	Comparison between cRCT and RCT could not be made due to heterogeneity of the intervention content.

	minimise the research burden at each site. Insufficient information was reported to enable judgement.	gender, race, and resident year at the time of intervention (Table 2). Baseline comparisons of clusters are not presented.	study elements. (pg. 136, results).		
Butler et al. 2012	Low	High	Low	High	Unclear
	Randomisation took place once all practices were recruited and all participating clinicians had provided written consent (Randomisation and blinding, pg. 3).	The study compares the summary of demographic features of practitioners in the intervention and control groups but not across clusters (pg. 8).	Two practices, one in each group, withdrew after randomisation but were included in the intention to treat analyses (Results, pg. 4).	The analysis did not take the clustering effect into account, which would have introduced a unit of analysis error.	Comparison between cRCT and RCT could not be made due to heterogeneity of the intervention content.
Epstein et al. 2011	Low	Low	Low	High	Unclear
	To create comparable groups of practices across conditions, matched practice pairs were created according to the size of the practice (i.e., number of paediatricians) and the proportion of patients with	The study clusters are comparable (Table 1, pg. 1202).	No loss to follow-up of clusters (Figure 1, pg. e1204).	The study reported that statistical analysis did not account for potential clustering because of the small number of practices in the study (pg. e1205).	Comparison between cRCT and RCT could not be made, as there were no other studies that compared blended vs self-directed learning among the paediatricians.

	Medicaid (pg. e1203).				
Estrada et al. 2011	Low	High	High	Low	Unclear
	A detailed recruitment plan is presented in the protocol of the study and randomisation occurred online immediately after consent.	The study presented characteristics of patients between the groups but not among clusters (pg. 686).	Figure 1 presents the clusters lost to follow-up. Intention-to-treat analysis was conducted. Only 48 and 47 practices were analysed out of 102 and 103 practices from the intervention and control groups, respectively.	Generalised linear mixed models accounted for clustering of patients (Statistical approach, pg. 684).	Comparison between cRCT and RCT could not be made due to heterogeneity of the intervention content.
Franchi et al. 2016	Low	High	Low	Low	Unclear
	Patients were recruited from internal medicine and geriatric wards of the hospital. The wards participating in the pilot phase remained in the same randomisation arm in the full study.	There were no between-arm statistically significant differences pertaining to socio-demographic variables, risk factors and clinical variables, except for the number of diagnoses ($P < 0.0001$), Cumulative Illness Rating Scale	No loss to follow-up of clusters, drop out of patients is reported in Figure 1, pg. 56.	The study assessed the primary end-point (differences between intervention and control arms in the prevalence of subjects with at least one potentially inappropriate medication (PIM) at discharge) by means of a logistic regression analysis without	Comparison between cRCT and RCT could not be made due to heterogeneity of the intervention content.

		(SIRS) comorbidity index (P < 0.0001) and CIRS severity index (P < 0.0001) both at admission and discharge.		covariates in the intention-to-treat population (pg. 55).	
Feng et al. 2013	Unclear	High	High	Low	Unclear
	Information about participant recruitment is inadequately reported.	Baseline comparison between the groups and clusters not reported.	Loss to follow-up of patients reported in Figure 1, pg. 318; however, loss to follow-up of participants by cluster not reported.	The study used a multilevel modelling approach to simultaneously estimate the intervention effects while controlling for the hierarchical nature of data explainable within-clinic correlations and design effects resulting from the stratified cluster-randomised design, (pg. 317).	Comparison between cRCT and RCT could not be made due to heterogeneity of the intervention content.
Hadley et al. 2010	Low	High	High	Low	Unclear
	All hospitals in the region that were responsible for postgraduate medical education were recruited for the trial (pg. 289). Randomisation was performed after	Baseline comparisons between the groups and clusters were not conducted (pg. 292).	After randomisation, 36 participants in the classroom group and 31 participants in the eLearning groups did not complete baseline MCQs, and 7	Analyses were done in an intention-to-treat basis. Between arms comparison was undertaken by means of a generalised estimating equations (GEE)	The study did not specify the specialty of learners; hence appropriate comparisons could not be made.

	recruitment and consent was obtained.		learners in the classroom and 3 learners in the eLearning group did not complete post-test MCQs (Figure 1, pg. 291)	model that accounted for within-cluster (i.e. hospital) correlation of the outcome.	
Hymowitz et al. 2007	Unclear	High	Unclear	Unclear	Unclear
	The study reported residents were nested within residency sites and residencies served as the unit of randomisation (pg. 5).	Baseline comparison of characteristics for standard training and special training are presented in Table 2. Statistical comparison was only done within the two groups not between them and not between clusters (pg. 14).	Loss of clusters not reported in the study.	Generalised linear mixed models were used to adjust for several variables but not between clusters (Statistical analysis, pg. 5).	Comparison between cRCT and RCT could not be made due to heterogeneity of the intervention content.
Kulier et al. 2009	Unclear	High	Unclear	Low	Unclear
	Sixty-one postgraduate trainees were included in the analysis: 28 in the intervention group and 33 in the control group (Figure 1).	Baseline comparison of demographic characteristics between the intervention groups and clusters are not presented.	Loss of clusters not reported in the study; however 3 and 6 trainees dropped out from the control and intervention groups, respectively (Figure 1, pg. 4).	Generalised estimating equations (GEE) were performed. This allowed extending linear models to take into account the correlation between individuals in the same cluster.	Comparison between cRCT and RCT could not be made, as there were no other studies that compared eLearning vs face-to-face learning among obstetricians and gynaecologists.

Kulier et al. 2012	Unclear	High	High	Low	Unclear
	Information about learners' recruitment not reported.	The study compared characteristics for the intervention groups: the two groups were similar in age, year of training, attitudes, and knowledge (Results, pg. 2222, line 16). However, comparisons between clusters were not made.	There was loss of clusters attributable to technical difficulties such as interrupted or limited Internet connection, irregular library or computer access, and other issues (pg. 2224, ln 9).	Mixed-effects models were used allowing inclusion of all available data, consistent with the intention-to-treat approach. Such models account for correlation within clusters and within learners (pg. 2221).	Comparison between cRCT and RCT could not be made, as there were no other studies that compared blended vs self-directed learning among obstetricians and gynaecologists.
Legare et al. 2012	Unclear	High	High	Low	Unclear
	Internet-based software was used to simultaneously randomise all 12 family practice teaching units to either the intervention group (DECISION+2) or control group. However, information regarding randomisation (e.g. whether it preceded recruitment) is not reported.	Characteristics of patients in family practice teaching units before and after the intervention is reported (pg. E729), however statistical comparison was not done for the intervention groups and clusters.	Three of the initial 12 clusters were lost to follow-up (Figure 1, pg. e727).	The study adjusted for potentially confounding variables, baseline scores, and clustering of patients at the level of the teaching unit (pg. e7300).	Comparison between cRCT and RCT could not be made due to heterogeneity of the intervention content.

Little et al. 2013	Low	Low	Low	Low	Unclear
	Physicians and patients were unaware of initial group allocation but the masking of physicians or patients to the intervention was not possible (pg. 1176).	If only 10 patients were recruited from a practice, the network average was used to avoid the imbalance of randomisation by poorly estimated antibiotic prescribing proportions for that practice (pg. 1176).	18 practices did not recruit patients and were lost to follow-up. (Figure on pg. 1177), however an intention-to-treat analysis was done.	Multilevel logistic regression modelling was used to assess the main outcome and controlled for baseline antibiotic prescribing rates with allowance for clustering by physicians and practice (pg. 1178).	Comparison between cRCT and RCT could not be made due to heterogeneity of the intervention content.
Marsh-Tootle et al. 2011	Low	High	High	Unclear	Unclear
	Providers were sent to the intervention or control websites according to a cluster-randomised schedule that was executed on log-in. Providers who completed the log in screen were randomised and considered enrolled. (Methods, pg. 7161).	Table 2 presents demographic and practice characteristics for those who did and those who did not participate in the study (NP), despite being eligible. However, comparisons by clusters were not presented.	Sixty-five providers were enrolled into the intervention arm and 71 into the control arm. For IPs, responses were available from 61 (93.8%) providers at baseline, 57 (87.7%) after the short delay, and 27 (41.5%) after the long delay. For CPs, responses to vision questions were available from 42 providers	Insufficient statistical information.	Comparison between cRCT and RCT could not be made due to heterogeneity in the intervention content.

			(59.2%) after completing all control modules (pg. 7162).		
McLeod et al. 2010	Unclear	Low	High	Low	Unclear
	General surgery training programs in the United States were recruited to participate in the trial. Cluster randomisation was used to allocate the programs to the Internet or moderated journal club format groups (pg. 770).	Baseline characteristics such as number of residents, participation in previous journal clubs, currently teaching appraisal skills, faculty with clinical epidemiology training were reported (Table 2, pg. 772).	In the moderate group, 96% of residents completed at least one package. In the Internet group, only 18% of all residents participated and completed any package (pg. 772). Intention-to-treat was not used for analysis.	Mixed models were used, which allow for the control of putative confounders that might not be addressed in randomisation such as the residency year, age, correlation within the program and training of learners (pg. 771).	Comparison between cRCT and RCT could not be made due to heterogeneity of the intervention content.
Meeker et al. 2016	Low	Low	Low	Low	Unclear
	Recruitment of participants was carried out before randomisation of clusters (mentioned in Figure 1, pg. 566).	No observable difference in participant characteristics from the primary care practice.	No loss of clusters.	The study used logistic and non-linear regression methods, which give more conservative estimates of effect sizes (pg. 569).	Comparison of the cRCT with other cRCTs or RCTs was not possible as there were no other studies that compared online eLearning with similar interventions among primary care practitioners.
Ruf et al. 2010	Low	High	Low	Low	Unclear
	112 practices were	Baseline	The drop-out rate	The clustered	Comparison between

	randomised to the three strategy groups by minimization (pg. 71).	characteristics of the GPs and patients are reported in the study. There were no statistically significant differences on any variables (pg. 72). However, information on clustering was not reported.	of practices was significantly higher in the GP+nurse group, but there were no differences concerning sex, age, population of the town or city, patients seen per quarter and Internet know-how. Intention-to-treat analysis was used.	structure of the data was accounted for by an adjustment for the clustering effect in patient-based analyses (pg. 72).	cRCT and RCT could not be made, as there were no other studies that compared eLearning vs blended learning among primary care practitioners.
Vollmar et al. 2010	Low	Low	High	Low	Unclear
	Cluster randomisation took place at the Quality Circles (QC) level (two arms). Stratified randomisation was performed by a statistician separately for small and large QCs (definition for large QCs: 12 or more participating GPs as reported by the QC moderators) (pg. 4).	The study reported the characteristics of learners and clusters in study arm A, B and the control group (pg. 5). Baseline imbalance of clusters was not reported.	Significant loss to follow-up of clusters (in Figure 1, pg. 3). Intention-to-treat analysis was not performed.	Clustering was taken into account and the authors performed an additional analysis of covariance (ANCOVA) (pg. 4).	Comparison between cRCT and RCT could not be made due to heterogeneity of the intervention content.

	Unclear	High	Unclear	Unclear	Unclear
Yardley et al. 2013	GP practices were cluster randomised to the intervention group (pg. 3); however, information on whether recruitment preceded randomisation was not stated.	Baseline comparison was not undertaken.	Loss of clusters not reported in the study.	No details given to enable judgement.	Comparison between cRCT and RCT could not be made due to heterogeneity of the intervention content.

ARIA: Allergic Rhinitis and its Impact on Asthma; ATS: American Thoracic Society; CDC: Centers for Disease Control; CME: continuing medical education; CPD: continuing professional development; N/A: not applicable

APPENDIX V: EXCLUDED STUDIES WITH REASONS FOR EXCLUSION

Study ID	Reasons for exclusion
Ahmed et al. 2016[279]	Participants received different scenarios and there was a cross-over of interventions.
Boespflug et al. 2015[280]	Not an RCT.
Buijze et al. 2012[281]	A validation study, not an RCT.
Butler et al. 2013[222]	The study included a mixed participant group and the results were not disaggregated for the population of interest.
Carney et al. 2011[282]	No comparison between 'online' and 'non-online'. The study only compared 'consenting and completing' and 'consenting but not completing' radiologists. All learners eventually received the intervention (cross-over study).
Carney et al. 2012[283]	Not an RCT; a randomised wait-list design where both groups were exposed to the intervention. Although the intervention vs control results are mentioned in the study, the results cannot be solely attributed to the intervention. Also, the outcomes (knowledge, skills, attitude and satisfaction) weren't adequately measured (measured on the basis of recall).
Carter et al. 2014[284]	This study is a simulation study.
Casebeer et al. 2003[285]	Not an RCT; describes the development of web-based instruction. A subsequent RCT evaluating this web-based instruction was included.
Danley et al. 2004[286]	Mixed population and the results were not disaggregated for medical doctors.
de Beurs et al. 2015[287]	Mixed population. The results were presented separately for psychiatrists and nurses but the results for psychiatrists and psychologists were combined.
Dimeff et al. 2015[288]	Mixed population and the results were not presented separately for the population of interest.
Dozor et al. 2011[289]	Mixed population and the results were not presented separately for the population of interest.

Feyzi-Behnagh et al. 2014[290]	The study examined the effects of two methods of diagnostic decision paths. Both groups were exposed to Slide Tutor (LMS) and were randomly assigned to one of two scaffolding conditions: metacognitive training in *Playback* or metacognitive training in *Considering Alternatives*. The comparative effectiveness was not between two different forms of eLearning but rather different learning methods (i.e. Playback vs Considering Alternatives), and the emphasis was not on the 'online' or 'e' element of eLearning.
Geller et al. 2014[291]	Not on online eLearning. It compared DVD vs live seminary vs delayed control.
Giudice et al. 2015[292]	Not an RCT.
Hymowitz et al. 2004[293]	The study presented only baseline findings, outcomes between the intervention and the control were not compared. The complete findings of this research were subsequently published in 2007 (Hymowitz et al.[157]).
Kemper et al. 2006[294]	Mixed population and the results were not disaggregated.
Kerfoot et al. 2009[295]	The study made ineligible comparisons. Both intervention groups had access to the same eLearning interventions and the study did not compare the effectiveness of the two modes of intervention.
Kerfoot et al. 2010[296]	The study made ineligible comparisons. Both intervention groups had access to the same eLearning interventions and the study did not compare the effectiveness of the two modes of intervention.
Kerfoot et al. 2010[297]	Mixed population and the results were not disaggregated for the population of interest.
Kerfoot et al. 2012[298]	The study made ineligible comparisons. Both intervention groups had access to the same eLearning interventions and the study did not compare the effectiveness of the two modes of intervention. Further, there was no control group - only the delivery time and the number of questions differed.
Khan et al. 2015[299]	The study made ineligible comparisons, i.e. didactic learning vs computer-based self-learning (offline).
Kim et al. 2008[300]	The study did not include an online component and the content was not delivered online. The only use of online resources was in measurement (using web-based clinical vignettes).
Labrecque et al. 2013[301]	The study did not evaluate an eLearning intervention.

Lanken et al. 2015[302]	Mixed population and the results were not disaggregated for the population of interest.
Lewis et al. 2011[303]	Mixed population and the results were not disaggregated for the population of interest.
Loewen et al. 2003[304]	Mixed population and the results were not disaggregated for the population of interest.
Niazi et al. 2013[305]	The study made ineligible comparisons. Both groups were exposed to the same eLearning intervention (Virtual Spine website; an online 3D teaching resource). The intervention group had access to all three modules of Virtual Spine for 2-weeks, while the control group received limited access to certain modules for a shorter period of time. The study evaluated the time of exposure to a single intervention on improvement in ultrasound imaging.
Olson et al. 2012[306]	The study involved virtual patients.
Rank et al. 2011[307]	The abstract was excluded as the author has published the full-text of the research in 2012 (Rank et al.[308]).
Rank et al. 2012[308]	The study made ineligible comparisons
Satterwhite et al. 2014[309]	A validation study of an online global rating tool (SMaRT). It did not access the effectiveness of the online microsurgery curriculum. The same authors (Satterwhite et al.)[140] reported on the effectiveness of the online microsurgery curriculum in 2012, which was included.
Shariff et al. 2012[310]	This is a duplicate article of the study by Shariff et al. (2015).[175]
Shaw et al. 2011[311]	This is a duplicate article (abstract) of the full-text research published by Gyorki et al. (2013),[135] which was included.
Shenoi et al. 2013[312]	The study made ineligible comparisons. Both cohorts received the intervention (an Advanced Trauma Life Support course); only the order of the module was changed. Cohort 1 answered module A, module B, 4-week rest period followed by module B and module A. Cohort 2 answered module B, module A, 4-week rest period followed by module A and module B. The study did not measure the effectiveness of eLearning compared with traditional learning or other types of eLearning.
Sherwinter et al. 2010[313]	The study assessed psychomotor skills following the use of a laparoscopic box trainer.
Sperl-Hillen et al. 2013[314]	Not an RCT; a review of RCTs on SimCare Diabetes.

Stoner et al. 2014[315]	The study included a mixed population and results were not presented separately by the intervention groups.
Sultana et al. 2010[316]	The study evaluated the effect of a box trainer with instructional training vs an online self-study video (psychomotor domain), which is not within the scope of the review.
Tanoue et al. 2010[317]	The study evaluated the effect of a box trainer with instructional training vs an online self-study video (psychomotor domain), which is not within the scope of the review,
Thompson et al. 2011[144]	This is a duplicate article of the recent full text article by Thompson et al. (2012),[318] which was included.
Triola et al. 2006[319]	Mixed population and the results were not disaggregated for the population of interest.
van Hove et al. 2014[320]	A validation study of Interactive Simulation Module to Train the Use of a Laparoscopic Insufflator.
Wegener et al. 2013[321]	The study investigated the effect of an electronic tutorial for image interpretation in ultrasound-guided regional anaesthesia. This tutorial did not need the Internet to function and hence was not considered a form of online eLearning.
Young et al. 2002[322]	The study did not include an online component: the intervention was a distance learning module containing printed educational materials sent by snail mail.

APPENDIX VI: STUDY III - SURVEY QUESTIONNAIRE

HSOR@NHG
The evidence behind your decisions

National Healthcare Group (NHG) Optometrists and Opticians Survey

Welcome to NHG's Optometrist and Opticians Survey

Dear Sir/Mdm
Thank you for your participation in this short survey. As you know, Singapore's shortage in primary eye care service has impacted care at the ophthalmology specialist outpatient clinics, consequently increasing waiting time for appointments and thus delaying timely care for the acute cases.

The survey aims to understand the role of the optometrist and their readiness for an extended role in primary eye care in Singapore. Your response may have significant influence on future development of optometrist roles in Singapore.

The survey has been reviewed and approved by the NHG Domain Specific Review Board (2015/00549) and University of Adelaide Human Research Ethics Committee (H-2015-237) and should take 20-25 minutes to complete. Be assured that all answers you provide will be kept in the strictest confidentiality. The results of the study will be used for scholarly purposes only.

If you have any questions, feel free to contactus.

Thank you for your valuable time.

Best regards,

Dr Pradeep Paul, ***Health Services and Outcomes Research, NHG.***
Ms Olivia Chng Shih Yun, ***Principal Optometrist, TTSH.***
Ms Kalin Siow, ***Senior Principal Optometrist, SNEC.***
Assoc Prof. Craig Lockwood, ***Faculty of Health Sciences, University of Adelaide.***
Assoc Prof. Josip Car, ***Health Services and Outcomes Research Programme, LKCMedicine, NTU.***

Participation in the survey is voluntary and by clicking on the 'Next" you acknowledge that you have read participant information and agree to participate in this research.

HSOR@NHG
The evidence behind your decisions

National Healthcare Group (NHG) Optometrists and Opticians Survey

Survey questions

1. Age

- ◯ ≤ 30 yrs. old
- ◯ 30 – 39 yrs. old
- ◯ 40 – 49 yrs. old
- ◯ 50 – 59 yrs. old
- ◯ ≥ 60 yrs. old

2. Gender

- ◯ Male
- ◯ Female

3. Ethnicity

- ◯ Chinese
- ◯ Malay
- ◯ Indian
- ◯ Other (please specify)

4. Credentials

- ◯ Diploma
- ◯ BS
- ◯ MS
- ◯ PhD
- ◯ Other (please specify)

5. From which institution did you attain your highest qualification in optometry?

- ◯ Singapore Polytechnic
- ◯ Ngee Ann Polytechnic
- ◯ Institute of Technical Education
- ◯ Other (please specify)

6. I have been in practice for (excluding any significant periods of leave such as maternity leave > 1 year) _____ years. (approximately)

7. My practice postal code is

8. Which of the following best describes the mode of your optometric practice?

- ◯ Govt restructured hospital
- ◯ Academic
- ◯ Private hospital
- ◯ Private optometry clinic
- ◯ Chain (e.g. Capitol, Nanyang optical)
- ◯ I do not practice
- ◯ Private practice (e.g. Single or partner owners)
- ◯ Other (please specify)

9. Which of the following best describes your current designation in your practice?

- ◯ Optometrist
- ◯ Optician (Refraction & Dispensing)
- ◯ Optician (Contact Lens Practitioner)
- ◯ Optician (Dispensing)

* 10. In a typical month, approximately how many patients or clients do you see in your practice?

11. What are your current roles in your practice? (Please tick all relevant boxes)

- ☐ Diagnostic refraction
- ☐ Ultrasound (A and B)
- ☐ Spectacle dispensing
- ☐ Contact lens fitting and dispensing
- ☐ Topography/ pachymetry
- ☐ Specular microscopy
- ☐ Low vision management
- ☐ Tomography
- ☐ Colour vision assessment
- ☐ Electrodiagnostics
- ☐ Ocular photography
- ☐ Visual field analysis
- ☐ Fundus examination
- ☐ Other (please specify)

12. Do you think there is scope for the optometrist to play extended roles* in the hospital, primary eye care setups?

*extended roles could be for e.g screening for eye diseases, co-managing eye conditions with ophthalmologists.

- ◯ Yes
- ◯ No
- ◯ Not sure

If yes, please specify the role(s)

13. On a scale of 1 to 10 (1=very poor; 10=excellent), how would you rate your primary eye care knowledge*?

*primary eye care refers to provision of the following services: patient education for maintaining, promoting healthy vision, performing a comprehensive ocular examination, screening for asymptomatic eye diseases, recognizing ocular manifestations of systemic diseases, performing refractions, fitting and prescribing optical aids, such as glasses and contact lenses, counseling and educating patients about their eye disease conditions, recognizing and managing local and systemic effects of drug therapy, determining when to triage patients for more specialized care and referring to specialists as needed and appropriate, coordinating care with other physicians involved in the patient's overall medical management.

	Excellent 10	9	8	7	6	5	4	3	2	Very poor 1
.	○	○	○	○	○	○	○	○	○	○

14. How confident are you in screening for the following eye conditions in primary eye care set up; rate your confidence level on a scale of 1 to 10 (1=Not confident at all, 10=Very confident)

	Excellent 10	9	8	7	6	5	4	3	2	Very poor 1	Not applicable
Cataract	○	○	○	○	○	○	○	○	○	○	○
Diabetic retinopathy	○	○	○	○	○	○	○	○	○	○	○
Chronic Glaucoma	○	○	○	○	○	○	○	○	○	○	○
Age related macular degeneration	○	○	○	○	○	○	○	○	○	○	○

15. How confident are you in co-managing the following eye conditions in a primary eye care set up with guidance from a hospital ophthalmologist; rate your confidence level on a scale of 1 to 10 (1=Not confident at all, 10=Very confident)

	Excellent 10	9	8	7	6	5	4	3	2	Very poor 1	Not applicable
Cataract	○	○	○	○	○	○	○	○	○	○	○
Diabetic retinopathy	○	○	○	○	○	○	○	○	○	○	○
Chronic Glaucoma	○	○	○	○	○	○	○	○	○	○	○
Age related macular degeneration	○	○	○	○	○	○	○	○	○	○	○

16. Do you feel optometrists/ opticians should undertake regular continuing professional education (CPE)?

○ Yes ○ No ○ Not sure

If yes, specify on what area?

17. Have you had any previous training (excluding on-the-job training) in eye screening, managing or co-managing minor eye conditions*? If no, please skip Q18-20 and proceed to Q21.

*refers to conditions such as red eye, dry eyes, eye irritation and inflamation, sticky discharge from the eye or watery eye, flashes and floaters, painful eye, ingrowing eyelashes and foreign body in the eye

	Yes	No	Not sure
Eye screening	◯	◯	◯
Managing or co-managing minor eye conditions	◯	◯	◯

If yes, please specify

18. In terms of location, timing and cost how accessible was the training venue?

	Extremely satisfied 5	4	3	2	Very dissatisfied 1
Location	◯	◯	◯	◯	◯
Timing	◯	◯	◯	◯	◯
Cost	◯	◯	◯	◯	◯

19. Has being away from your practice during training negatively impacted on your day-to-day working practice?

◯ Yes ◯ No ◯ Not sure

20. Have you had any previous on-the job training in eye screening, managing or co-managing minor eye conditions*?

*refers to conditions such as red eye, dry eyes, eye irritation and inflamation, sticky discharge from the eye or watery eye, flashes and floaters, painful eye, ingrowing eyelashes and foreign body in the eye

	Yes	No	Not sure
Eye screening	◯	◯	◯
Managing or Co-managing minor eye conditions	◯	◯	◯

If yes, please specify

21. Are you aware of any continuing professional education (CPE) courses available to increase optometrists knowledge on screening for eye conditions such as cataract, age related macular degeneration, glaucoma and diabetic retinopathy in SG?

◯ Yes ◯ No ◯ Not sure

If Yes, please list the CPD, CME courses

22. Approximately how many hours of CPE have you undertaken in the past year?

- ◯ <10 hours
- ◯ 10 to <20 hours
- ◯ 20 to <40 hours
- ◯ 40 to <60 hours
- ◯ 60 or more hours

23. Please briefly indicate where you have undertaken most of your CPE training in the past year.

- ◯ Optometrists and Opticians Board (OOB)
- ◯ Singapore Optometric Association (SOA)
- ◯ Other (please specify)

24. My most preferred mode of delivery for CPE would be: (Please tick one box only)

- ◯ Didactic lectures organized by restructured hospitals/polyclinics
- ◯ Online eLearning course
- ◯ Blended learning course (mix of eLearning and didactic learning)
- ◯ Other (please specify)

25. If you have opted for didactic training as you most preferred mode for CPE, pleaserank the barriers listed below for online eLearning, blended learning in your setting in order of their importance. If no, please skip Q26.

	1 (Most important barrier)	2	3	4	5	6	7	8 (Least important barrier)
Lack of personal motivation	◯	◯	◯	◯	◯	◯	◯	◯
Lack of access to instructor / expert	◯	◯	◯	◯	◯	◯	◯	◯
Significant interruption during study at home / work	◯	◯	◯	◯	◯	◯	◯	◯
Insufficient time to learn online courses	◯	◯	◯	◯	◯	◯	◯	◯
Lack of internet access	◯	◯	◯	◯	◯	◯	◯	◯
Needed technology (hardware, software) not available	◯	◯	◯	◯	◯	◯	◯	◯
Lack technical skills (typing, navigating the internet..)	◯	◯	◯	◯	◯	◯	◯	◯
Lack of interaction	◯	◯	◯	◯	◯	◯	◯	◯
Other	◯	◯	◯	◯	◯	◯	◯	◯

Other (please specify)

26. If you have opted for eLearning as you most preferred mode for CPE, please rank the enablers listed below for online eLearning in your setting in order of their importance. If no, please skip Q26 and proceed to Q27.

	1 Most important enabler				5 Least important enabler
Flexibility, training could be taken from work / home	○	○	○	○	○
Cost, lower cost than didactic training	○	○	○	○	○
Other	○	○	○	○	○

Other (please specify)

27. If you have opted for blended learning as you most preferred mode for CPE, please rank the enablers (listed below) for blended learning in your setting in order of their importance. If no please skip Q27 and proceed to Q28.

	1 Most important enabler		2 Least important enabler
Better efficiency, uses a combination of digital instruction and face-to-face training	○	○	○
Cost, lower cost than didactic training	○	○	○
Other	○	○	○

Other (please specify)

28. What are your priority topics for CPE course to improve primary care ophthalmology knowledge?

	First	Second	Third	Fourth
Glaucoma	○	○	○	○
Diabetic retinopathy	○	○	○	○
Age related macular degeneration	○	○	○	○
Other	○	○	○	○

Other (please specify)

* 29. What would be the maximum you would be willing to pay (S$) for a short course (24 hour) "online eLearning course on primary eye care in SGD", if the course

a. Was not recognised as professional development (ongoing learning) points

b. Had been subsidized 50% by your employer (you are indicating the pre-subsidized total cost)

c. Was recognised your profession as a professional development (ongoing learning) points

d. Was recognised as prior learning (of approximately 5%-10%) towards a university postgraduate qualification, eg. master's degree

30. Do you refer patients to General practitioners (GPs) or Ophthalmologists in specialist outpatient clinics (SOCs) for treatment?

- Yes
- No
- Not applicable

31. What are the conditions for which you refer?

- Cataract
- Chronic Glaucoma
- Age related macular degeneration
- Diabetic retinopathy
- Acute Glaucoma
- Other (please specify)

32. During the past month, how many patients have you referred to the GPs, Ophthalmologists?

GPs

Ophthalmologists at SOCs

33. Do you receive feedback on your GP's and Ophthalmologists referrals?

- Yes
- No

34. How do you receive feedback?

- e-mail
- Phone calls
- Short message through phone (SMS)
- Other (please specify)

35. If you do not receive feedback for your referrals, will you continue to refer patients?

- ◯ Yes
- ◯ No

36. If you have any additional comments or questions on primary eye care or about the survey, please feel free to write them here.

Thank you very much for participating in this survey! Have a pleasant day ahead.