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Offline and computer-based eLearning interventions for medical students' education (Protocol)

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Offline and computer-based eLearning interventions for medical students' education.
Cochrane Database of Systematic Reviews 2016, Issue 4. Art. No.: CD012149.
DOI: 10.1002/14651858.CD012149.

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Offline and computer-based eLearning interventions for medical students' education

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Editorial group: Cochrane Tobacco Addiction Group.

Publication status and date: New, published in Issue 4, 2016.

Citation: Hervatis V, Kyaw BM, Semwal M, Dunleavy G, Tudor Car L, Zary N, Car J. Offline and computer-based eLearning interventions for medical students' education. *Cochrane Database of Systematic Reviews* 2016, Issue 4. Art. No.: CD012149. DOI: 10.1002/14651858.CD012149.

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ABSTRACT

This is the protocol for a review and there is no abstract. The objectives are as follows:

The primary objective of this review is to assess the effects of offline, computer-based eLearning compared with 'traditional' learning and other types of eLearning interventions for medical students' knowledge as well as changes in skills and attitude towards the intervention. Additionally, as secondary objectives, this review will assess the economic impact (cost-benefit, cost-utility or cost-effectiveness), unintended adverse effects, and medical students' satisfaction with using offline and computer-based educational interventions.

BACKGROUND

Description of the condition

The world is facing a chronic shortage of well-trained healthcare workers, with an estimated need for 7.2 million worldwide. This number is expected to reach 12.9 million by 2035 (Campbell 2013). Low- and middle-income countries (LMICs) are the most affected, and migration of healthcare workers from these countries furthers the existing problems of inadequate infrastructure and a scarce healthcare workforce. The World Health Organization

(WHO) has warned that the health of billions of people will be affected with serious complications if this problem is not addressed now (WHO 2013). The shortage and disproportionate distribution of doctors is also aggravated by the inadequacy of training programmes available worldwide (Chen 2010). The content, organisation, and delivery of current medical programmes often fail to equip healthcare workers (medical doctors, nurses, pharmacists, allied health professionals, etc.) with the skills, competencies, experience and expectations needed to meet the changing health needs of the world (Frenk 2010). In such a context, it becomes essential to enable, develop and promote educational programmes

which increase not only the number of healthcare workers, but also the quality and relevance of their training, to meet these new challenges (WHO 2011). For the purpose of this review, we will focus on medical students' education programs (those that lead to them becoming medical doctors), and we will examine other health professionals' education in a separate review.

Description of the intervention

Medical schools prepare future doctors. Hence, the quality of health care depends (in part) on the quality of medical education. Through medical training programs, future doctors learn the theoretical knowledge and practical skills, and develop the professional attitudes, needed in their day-to-day work. Medical practice is changing constantly in the following ways:

- basic theoretical knowledge changes with new scientific discoveries, new theories and evidence;
- rapid technological development requires new practical skills, e.g. the use of new clinical tools; and
- new working concepts, e.g. greater emphasis on patient responsibility for self-management of their diseases, require new attitudes.

Medical education has to adapt and evolve to prepare current students to face these changes. Of particular importance is developing the ability of medical students to search for available knowledge, along with the capacity and willingness to engage in critical reasoning and collaborative practice (Frenk 2010). The increased use of information and communication technologies (IT) is recognised as one of the key strategic platforms to build strong education and training systems (Crisp 2008). The application of IT in the educational context is referred to as eLearning, which is 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 for improving access to training, communication and interaction and that facilitates the adoption of new ways of understanding and developing learning" (Sangrà 2012).

eLearning is a growing field due to the advances in modern technology and current applications of use, accentuated by the increased volume of and access to information (Frenk 2010). If eLearning is used in a mixed delivery mode (i.e., in combination with traditional education strategies such as classroom face-to-face discussion), we will refer to it as "blended learning".

eLearning consists of many different types of interventions that can be categorised according to their tools, content, learning objectives, pedagogical approaches and delivery settings (Chua 2004). The current and potential users of eLearning have different needs and there are different resources available. We will categorise eLearning according to the resources required for the eLearning intervention to work, but also according to pedagogical aspects. Alternative approaches are likely to make evidence

synthesis very difficult, if not impossible. eLearning includes, but is not limited to, offline and online computer-based eLearning, Digital Game-Based Learning (DGBL), Massive Open Online Courses (MOOCs), Virtual Reality Environments (VRE), Virtual Patient Simulations (VPS), Psychomotor Skills Trainers (PST) and mLearning. Each of these types of eLearning has its own specificities, and related advantages, limitations and challenges. This Cochrane review is part of a series of Cochrane reviews evaluating the efficacy of different types of eLearning in improving skills, knowledge and attitudes of pre- and post-registration health professionals during formal education (Paul 2016; Saxena 2016; Tudor Car 2015; additional protocol publications pending). This review will focus on offline computer-based eLearning for pre-registration (i.e. undergraduate) medical students' education.

Offline computer-based eLearning was one of the first forms of eLearning, used before the internet became available on a global scale. Unlike online eLearning, offline computer-based eLearning requires no internet or local area network connection. Offline computer-based eLearning can be delivered through media including CD-ROM, external hard disc, and USB stick. Offline eLearning is likely to play an important role in medical students' education in the next decades owing to the limited availability of and challenges to a reliable internet connection that still persists in LMICs (International Telecommunication Union 2013). In areas with limited teaching facilities, knowledge, equipment, infrastructure and/or resources available, this type of eLearning may be particularly efficient in increasing the quality, affordability and availability of medical education, especially as eLearning content can be multi-media rich and thus require high-volume data transfers at high speed.

How the intervention might work

eLearning is recognised as an opportunity for a significantly different mode of learning from traditional learning, including increased self-directedness, independent learning and variability of the design to suit the learners' needs and preferences. It also helps to improve accessibility in terms of depth and breadth of content, flexibility to transcend geographical boundaries and time zones, time of learning and its pacing, opportunities for economies of scale, and reduced education-related expenses.

Offline eLearning accommodates scenarios with limited internet access, teaching workforce, and operating systems necessary for traditional learning. Moreover, offline eLearning allows for learning at one's own pace.

For students, offline computer-based eLearning solves geographical and temporal obstacles they may face. Firstly, students can take a course anywhere, which cuts down on the time and cost of transportation to and from class. Secondly, offline computer-based eLearning allows students to choose a course from a wide range of schools. Thirdly, a course supported by traditional education is "only one time" exposure for students. However, courses provided

by offline computer-based eLearning can be reviewed, repeated, interrupted, and resumed at will, so students can complete the course on their preferred schedule.

With offline eLearning, core educational material can be delivered to the students during clinical placements in rural and remote settings. Therefore, offline eLearning can assure that all remote students, regardless of location and internet access, will have the same access to learning and materials as urban-based colleagues. Since offline computer-based eLearning removes the geographical and temporal constraints on students and academic staff, collaborating schools may share the same offline eLearning courses which may eventually lead to the awarding of a degree that is universally recognised across institutions (Greenhalgh 2001). Therefore, schools could expand student numbers and reduce costs for academic educators and equipment.

Possible disadvantages and risks of the Intervention

It is important to take into account the potential disadvantages and risks of offline eLearning interventions for medical students, such as potential feelings of depression and loneliness, drop-out risks and computer anxiety (Rasmussen 2014).

The use of offline eLearning needs infrastructure (such as electricity and cost) as well as digital literacy. A lack of either could result in increased drop-out rates and poor performance.

Why it is important to do this review

Past reviews have underlined the need for further research and reviews on the topic of offline computer-based eLearning, due to the limited scope of existing evaluations, in terms of outcomes (user enjoyment and satisfaction towards eLearning), duration (short term rather than long term), professional field (medical education) and educational context (mostly high-income countries) (George 2014; Greenhalgh 2001; John 2013; Rasmussen 2014). Furthermore, two of the reviews that investigated the effect of offline eLearning used search strategies that may have missed relevant studies, and were published over a decade ago (Greenhalgh 2001; Rosenberg 2003). Our review will investigate offline computer-based eLearning interventions for medical students' education and will address the existing gaps through:

- updating the fast growing body of evidence on the effectiveness of the intervention;
- focusing on offline computer-based eLearning interventions for medical students' education;
- focusing on the intervention as a tool for delivering medical education, and as a means for assessment and group examination;
- evaluating the impact of the intervention on medical students' theoretical knowledge, practical skills, professional attitudes, and satisfaction with offline computer-based eLearning;
- including evidence from LMICs;

- being integrated in a series of reviews and a final overview, which will provide a systematic, comprehensive picture of the multiple applications of eLearning.

OBJECTIVES

The primary objective of this review is to assess the effects of offline, computer-based eLearning compared with 'traditional' learning and other types of eLearning interventions for medical students' knowledge as well as changes in skills and attitude towards the intervention. Additionally, as secondary objectives, this review will assess the economic impact (cost-benefit, cost-utility or cost-effectiveness), unintended adverse effects, and medical students' satisfaction with using offline and computer-based educational interventions.

METHODS

Criteria for considering studies for this review

Types of studies

We will include randomised controlled trials (RCTs), cluster RCTs (cRCTs) and quasi-RCTs. We will exclude cross-over trials due to the high likelihood of carry-over effect.

Types of participants

We will include studies with participants who are medical students enrolled in a pre-registration, university medical degree. We have defined pre-registration education as any type of study leading to a qualification that: (i) is recognised by the relevant governmental and professional bodies of the country where the study was conducted; and (ii) entitles the medical degree qualification-holder to apply for entry level medical doctor positions in the healthcare workforce.

Participants will not be excluded on the basis of age, gender or any other socio-demographic characteristic. If a study includes both pre- and post-registration students and presents their data separately, then we will include the information relating to pre-registration students. If it is impossible to distinguish data from these two groups of students, the study will be excluded. We will also exclude trials of individuals undertaking studies of traditional and complementary medicine.

Types of interventions

We will include studies in which offline computer-based eLearning interventions were used to deliver the learning content of the course. This includes studies where offline computer-based eLearning methods are the sole means by which the interventions are delivered, or where offline computer-based eLearning methods are part of a complex, multi-component intervention (i.e. blended learning). Blended learning studies will be included in formal synthesis only if the contribution of offline eLearning to overall learning has been assessed. If this is not the case, studies will not be synthesised in the review. In cases where the offline computer-based eLearning intervention could fit into multiple categories of eLearning intervention (e.g. both offline and digital game-based) then the studies will be excluded and will be reported in the other review (e.g. digital game-based learning). We will only include studies published from 1990 onwards, because the use of IT in medical education was uncommon before this year.

We will exclude studies that compare offline computer-based learning to other forms of eLearning interventions (online, VRE, VPS, DGBL, psychomotor, mLearning), as these studies will be reported separately in focused reviews.

Therefore, the included studies will be of offline, stand-alone software applications, where internet/intranet connections are not required for the learning activities. The main tasks of the eLearning software will be performed on a personal computer or laptop (with hard keyboard). The delivery channel of the computer-based intervention will typically be via CD-ROM, DVD, hard disc or USB memory stick. The focus is not on the delivery mode of the software but on the learning activities, which do not have to rely on any online connection. Interventions where an internet connection is essential in order to provide its full functionalities will be excluded from this review.

Types of outcome measures

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

Primary outcomes

- Medical students' knowledge, measured using any validated or non-validated instrument to measure difference in pre- and post-test scores. If several post-test results are available, data as to when those tests were conducted will be recorded and the difference between the pre-test and the first post-test will be used for the analysis. When applicable, the difference between the pre-test and the last-test available will be used for the sensitivity analysis (see [Sensitivity analysis](#) below).
- Medical students' skills, measured using any validated or non-validated instrument (e.g. pre- and post-test scores, time to perform a procedure, number of errors made whilst performing a procedure).

- Medical students' professional attitudes towards patients (e.g. awareness of moral and ethical responsibilities involved in patient contact) and/or towards new clinical knowledge or skills measured using only validated instruments.

Secondary outcomes

- Educational economic aspects of the intervention (e.g. cost-effectiveness, implementation cost, return on investment).
- Changes in accessibility and/or availability of education (including measures relating to geographical dispersion of students, student/teacher contact time and duration of access to educational resources).
- Adverse and/or unintended effects, such as feelings of depression and loneliness, drop-out risks and computer anxiety.
- Medical students' satisfaction with the intervention, measured using any validated or non-validated instruments (e.g. retention rates, drop-out rates, survey satisfaction scores).
- Patient-related outcomes (for interventions delivered to medical students in clinical settings, or if measured long term after students' graduation when they become doctors and assume direct clinical care responsibilities).

Search methods for identification of studies

Electronic searches

We will search the following databases:

- MEDLINE (Ovid)
- EMBASE (Elsevier)
- Cochrane Central Register of Controlled Trials (CENTRAL) (Wiley)
- PsycINFO (Ovid)
- Educational Research Information Centre (ERIC) (Ovid)
- Cumulative Index to Nursing and Allied Health Literature (CINAHL) (Ebsco)
- Web of Science Core Collection (Thomson Reuters)

We will use the MEDLINE strategy and keywords presented in [Appendix 1](#). This will be adapted to search the other databases. Databases will be searched from and including the year 1990 to present. The reason for selecting 1990 as the starting year for our search is because prior to that year, the use of the computers and the internet was limited to very basic tasks. We will search for and include papers in any language.

We will define and use a common search strategy for all of the Cochrane reviews in our series on eLearning for health professional education, as mentioned in the '[Types of interventions](#)' section. We will screen references in multiple steps to ensure maximum sensitivity and specificity. Two independent authors will conduct all steps of the screening. In the first step of screening titles and

abstracts, references will be sorted into defined groups e.g., offline eLearning, online eLearning, virtual patients, massive open online courses (MOOCs), mLearning, psychomotor skills trainers and VRE. For any references where authors are unsure of categorisation or whether the study meets inclusion criteria, we will obtain a full-text article to aid decision making and ultimately use a third author as an arbiter where uncertainty remains.

Searching other resources

We will search reference lists of all studies that we deem eligible for inclusion in our review, and relevant systematic reviews. We will also search the International Clinical Trials Registry Platform Search Portal and Current Controlled Trials metaRegister of Controlled Trials to identify unpublished trials, and contact the relevant investigators for further information. We will also contact key experts (as identified by publications that meet inclusion criteria) and will enquire what work in this area has been done and not published.

Data collection and analysis

Selection of studies

We will implement the search strategies, as described in the 'Electronic searches' section, and import all the references identified to reference management software. The search results from different electronic databases will be combined in a single library and we will remove duplicate records of the same reports. Two screeners will independently screen titles and abstracts to identify potentially-relevant studies. We will retrieve full-text copies of those articles deemed potentially relevant. Finally, two screeners will independently assess the full text of the retrieved articles for compliance with the reviews' inclusion and exclusion criteria. Any disagreements will be resolved through discussion between the two screeners. If no agreement can be reached, other authors will act as arbiters. Studies that initially appeared to be relevant, but are excluded at this stage will be listed in the 'Characteristics of excluded studies' table, where a reason for exclusion will be noted. Two review authors will verify the final list of included studies. The selection procedure will be calibrated on 500 citations.

Data extraction and management

Two review authors will independently extract and manage the data for each of the included studies using a structured data recording form. We will pilot the data extraction form and amend it according to the received feedback. In addition to the usual information on the study design and participants' demographics, we will extract data on other relevant fields, including the type of device used, delivery channel/method (CD-ROM, external hard

disc, USB stick etc.), type of content (video, text, images, etc.), and mode of offline eLearning (active or passive, linear or dynamic). We plan to contact study authors in any cases of unclear or missing information. Disagreements between review authors will be resolved by discussion. A third review author will act as an arbiter in cases where disagreements cannot be resolved.

Assessment of risk of bias in included studies

Two review authors will independently assess the methodological quality of RCTs and cRCTs using Cochrane's 'Risk of bias' assessment tool (Higgins 2011). We will pilot the 'Risk of bias' assessment, comparing results between authors, and contact study authors in any cases of unclear or missing information. RCTs will be assessed for risk of bias using the following domains: random sequence generation; allocation sequence concealment; blinding (participants, personnel); blinding (outcome assessment); completeness of outcome data, selective outcome reporting; and other sources of bias.

For cluster RCTs, we will also assess the risk of these additional biases: recruitment bias; baseline imbalance; loss of clusters; incorrect analysis; and comparability with individually randomised trials. Judgements concerning risk of bias for each study will be classified using 'yes', 'no' or 'unclear' indicating high, low or unclear risk of bias, respectively. We will incorporate the results of the 'Risk of bias' assessment into the review using 'Risk of bias' tables, a graph and a narrative summary.

Measures of treatment effect

For continuous outcomes, we will calculate the mean difference (MD) and 95% confidence intervals (CI) for individual studies. For dichotomous outcomes, we will calculate the risk ratio (RR) and 95% CI. We will inflate the variances for clustering in cRCTs when the cluster size, number of clusters and the intra-class correlation coefficient (ICC) (or estimate equivalent) will be attained for a study.

If more than one study measures the same outcome using different tools, the MDs for each study will be recalculated into a standardised mean difference (SMD), by dividing the study MD between groups by the standard deviation of outcome among participants.

Unit of analysis issues

For cRCTs, we will attempt to obtain data at the pre-registration student level. In cases where the statistical analysis of the cRCT has already been adjusted for clustering of data, we will simply extract the reported effect estimates and use them directly in our analysis. In those cases where the individual data are not available in the study report, we will start by contacting the author(s) to request the required information and then include it in the meta-analysis using the generic inverse-variance method in Review Manager 5

(RevMan 2014), which accounts for the clustering of data. If access to student-level data is not possible, a summary effect measurement will be extracted for each cluster. The number of clusters will be considered as the sample size and the analysis will proceed as if the trial was individually randomised. It must be noted that this technique will, however, reduce the statistical power of the analysis.

Dealing with missing data

In the case of missing data, we will contact the original investigators for clarification or to request missing information. If we are unable to obtain the missing data, we will use data available from the studies and assess the risk of bias through the criterion 'incomplete outcome data'. We will not impute any missing outcome data. We will discuss in the review all assumptions and subsequent procedures used to deal with missing values. We will, where possible, conduct analyses on an intention-to-treat basis.

Assessment of heterogeneity

We will decide if it is appropriate to pool our measures of effect by assessing if the included studies are similar enough (in terms of their population and intervention characteristics, and their reported outcomes) to result in meaningful conclusions. If a meta-analysis of the included studies is indicated, we will assess statistical heterogeneity by visual inspection of the scatter of effect estimates in the forest plot and by calculating the I^2 statistic (Higgins 2011). In cases of high degrees of heterogeneity (I^2 greater than 0.5), we will explore possible reasons for variability by conducting subgroup analyses.

Where we detect substantial clinical, methodological or statistical heterogeneity across included studies, we will not report pooled results from meta-analyses, but will instead use a narrative approach to data synthesis. In this event we will attempt to explore possible clinical or methodological reasons for this variation by grouping studies that are similar in terms of populations, intervention features, methodological features, or other factors to explore differences in intervention effects.

Assessment of reporting biases

Reporting bias will be assessed qualitatively in the first instance, based on the characteristics of included studies (eg. if only small studies that indicate positive findings are identified for inclusion), and if information that we obtain from contacting experts and authors of studies suggests that there are relevant unpublished studies. If we include at least 10 studies, we will assess reporting bias using a funnel plot regression, weighed by the inverse of the pooled variance. A regression slope of zero will be interpreted as absence of small study bias.

Data synthesis

Data will be reported using Review Manager 5 (RevMan 2014). Extracted data will be entered into tables grouped by study design and type of intervention to create a descriptive synthesis.

Using Miller's classification of clinical competence (Miller 1990) the different types of tests for students' knowledge and skills will be grouped and analysed together. For example, multiple choice questions assessing knowledge (i.e. 'knows') will be analysed together and essay questions assessing competence (i.e. 'knows how') will be analysed together. The focus will therefore be on the testing method rather than the delivery method (i.e. if skills were assessed by a knowledge test, it would be categorised as knowledge).

For students' professional attitudes the different types of assessment will be grouped and analysed as cognitive attitudes, behavioural attitudes or affective attitudes as described by Martin 2002. Students' satisfaction will include the satisfaction and attitudes towards the learning intervention they were exposed to. Students' professional attitudes and satisfaction will only be assessed narratively, as preliminary work conducted by the Global eHealth Unit (George 2014; Rasmussen 2014; WHO 2013) suggests that there is a high level of heterogeneity in the operational definition of these outcomes across different studies.

Where studies report more than one measure for each outcome the primary measure as defined by the primary study authors will be used in the analysis. Where no primary measure has been reported, a mean value of all the measures for the outcome will be calculated and used in the analysis.

We will decide whether to pool data quantitatively depending on statistical, methodological and clinical heterogeneity, to ensure meaningful comparisons. If meta-analysis is feasible, we will use a random-effects model. We will use MD (for outcomes measured using the same scale) and SMDs (for outcomes measured with different scales) for pooling and summarising continuous outcomes, and RRs for pooling and summarising dichotomous outcomes, as measures of treatment effect (along with their 95% CIs). The Mantel-Haenszel meta-analytic method (Mantel 1959) will be used for analysis of dichotomous outcomes, and for the analysis of continuous outcomes we will use the inverse variance meta-analytic method, using Review Manager 5 (RevMan 2014). Where possible, we will conduct analyses on an intention-to-treat basis.

We will include all RCTs regardless of their sequence generation bias rating, if the meta-analysis of all included studies is feasible and appropriate.

Subgroup analysis and investigation of heterogeneity

We will perform the following subgroup analyses (i.e. stratified analyses) in this review:

- stratified by countries' income (LMICs versus high-income countries);

- stratified by number of repeated interventions (one-off versus repeated interventions);
- stratified by blended eLearning versus solely offline computer-based eLearning;
- stratified by categories of duration of exposure to the intervention;
- stratified by types of devices used for delivery of the intervention.

We acknowledge that there are many other subgroup analyses that could be performed, for example comparing interventions according to learning objectives and interactivity of interventions. Future reviews conducted after completion of our series of initial reviews will be in the best position to do this, because such comparisons would be most meaningful from the perspective of an educator if multiple methods of eLearning were to be compared.

Sensitivity analysis

Sensitivity analyses will be considered to explore the impact of the 'Risk of bias' dimensions on the outcomes of the review. We will purposefully exclude studies according to the following filters:

- high risk of bias studies (as specified above);
- grey area studies (i.e. those categorised as both web-based and computer-based);
- smallest studies;
- time lapse between end of intervention and first post-test (quartiles), as well as last post-test;
- unpublished studies;
- source of funding, divided into:
 - industry sponsorship (solely industry funded),
 - mixed sponsorship (public and industry funded, including free provision of study material only),
 - non-industry sponsorship (solely publicly funded and no free provision of material),
 - not described.

If studies compared more than one offline eLearning or blended learning intervention to traditional learning, we will perform a

sensitivity analysis to assess the impact of successively replacing the results of each intervention group on the measure of effect. Additionally, we will average the mean scores for each intervention group and use this average in the meta-analysis. We will then compare the difference between the two approaches.

'Summary of findings' table

We intend to prepare a 'Summary of findings' table to present the meta-analysis results, based on the methods described in chapter 11 of the Cochrane Handbook for Systematic Reviews of Interventions (Schünemann 2011). We will present the results of meta-analyses for the major comparisons of the review, for each of the major primary outcomes, as well as potential adverse effects, as defined in the 'Types of outcome measures' section. Two authors will use the GRADE criteria to rank the quality of the evidence using the GRADEprofiler (GRADEpro) software (Schünemann 2011). We will provide a source and rationale for each assumed risk cited in the table(s). If meta-analyses are not feasible, we will present results in a narrative 'Summary of findings' table format, such as that used by Chan 2011 (Chan 2011; CCCRG 2014).

ACKNOWLEDGEMENTS

This review is conducted in collaboration with the World Health Organization (WHO) Department of eHealth, Knowledge Management and Sharing. We thank the Cochrane Tobacco Control Group, and in particular Dr Nicola Lindson-Hawley and Ms Lindsay Stead, for their support and guidance as well as the UK Cochrane Centre for their workshops in Oxford. We also thank Mr Carl Gornitzki, Ms GunBrit Knutssön and Mr Klas Moberg from the University Library, Karolinska Institutet for developing and executing our search strategy, and the peer reviewers for their comments. We gratefully acknowledge funding from Nanyang Technological University and National Healthcare Group Polyclinics (NHGP), Singapore for this project.

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* Indicates the major publication for the study

APPENDICES

Appendix I. MEDLINE (Ovid) search strategy

1. exp education, professional/ not education, veterinary/
2. Education, Predental/
3. Education, Premedical/
4. exp Students, Health Occupations/
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 psychiat* 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. or/1-5
7. Computer-Assisted Instruction/
8. exp Internet/
9. Computer Simulation/
10. Patient Simulation/
11. software/
12. Mobile Applications/
13. User-Computer Interface/
14. Video Games/
15. Web Browser/
16. Education, Distance/
17. Computers/
18. exp Microcomputers/
19. exp Cell Phones/
20. Games, Experimental/
21. exp Models, Anatomic/
22. Audiovisual Aids/
23. Educational Technology/
24. Electronic Mail/
25. exp Telemedicine/
26. Telenursing/
27. Telecommunications/
28. Webcasts/
29. exp Videoconferencing/
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. or/7-56
58. 6 and 57
59. Education.fs.
60. Education/
61. Teaching/
62. Learning/
63. exp Inservice Training/
64. Curriculum/
65. educat*.tw,kf.
66. learn*.tw,kf.
67. train*.tw,kf.
68. instruct*.tw,kf.
69. teach*.tw,kf.
70. or/59-69
71. Health Personnel/
72. exp Allied Health Personnel/
73. Anatomists/
74. "Coroners and Medical Examiners"/
75. exp Dental Staff/
76. exp Dentists/
77. Health Educators/
78. Infection Control Practitioners/
79. Medical Laboratory Personnel/
80. exp Medical Staff/
81. exp Nurses/
82. exp Nursing Staff/
83. Personnel, Hospital/
84. Pharmacists/
85. exp Physicians/
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. or/71-120
122. Health Occupations/
123. exp Allied Health Occupations/
124. Biomedical Engineering/
125. Chiropractic/
126. exp Dentistry/
127. exp Evidence-Based Practice/
128. exp Medicine/
129. exp Nursing/
130. Dietetics/
131. Optometry/
132. Orthoptics/
133. exp Pharmacology/
134. exp Pharmacy/
135. Podiatry/
136. Psychology, Medical/
137. Serology/
138. Specialization/
139. exp Surgical Procedures, Operative/
140. exp Radiography/
141. or/122-140
142. 121 or 141
143. 57 and 70 and 142
144. Psychomotor Performance/
145. motor skills/
146. ((psychomotor or procedural or technical) adj3 skill*).tw,kf.
147. (psychomotor adj3 performance).tw,kf.

148. or/144-147
149. 6 and 148
150. 58 or 143 or 149
151. limit 150 to yr="1990 -Current"

CONTRIBUTIONS OF AUTHORS

JC conceived the idea for the review. VH and BMK wrote the protocol. LTC provided methodological guidance, drafted some of the methodology-related sections and critically revised the protocol. MS, GD, LTC, NZ and JC provided comments on the protocol.

DECLARATIONS OF INTEREST

None

SOURCES OF SUPPORT

Internal sources

- Imperial College London, UK.
Salary of LTC
- NTU Lee Kong Chian School of Medicine, Singapore.
Salary of BMK, GD, MS and JC
- Karolinska Institutet, Sweden.
Salary of VH and NZ
- National Healthcare Group Polyclinics (NHGP), Singapore.
- Nanyang Technological University, Singapore.

External sources

- No sources of support supplied