# Characteristics and efficacy of digital health education: an overview of systematic reviews.

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**Abstract**

**Objective**: The primary aim of this overview was to synthesise the results of studies of digital education in terms of: knowledge or learning outcomes, student satisfaction, student enrollment, attendance rate, course completion rate, clinical practice, health outcomes for patients and cost-effectiveness. A secondary aim of this overview was to report on effective instructional design strategies, and barriers or contextual factors influencing the effectiveness of online learning course delivery in health care education.

**Method**: We developed an overview of Systematic Reviews (SRs) for digital education interventions delivered to students and practitioners of health care.

**Results**: We scanned 848 titles, reviewed 247 abstracts, and assessed 49 full-text articles against pre-determined inclusion and exclusion criteria. This overview includes data collected from 31,730 participants across 16 SRs. The quality of evidence included in the SRs ranged from very low (n=2), low (n=6) to moderate (n=8). The best available SRs were of moderate quality (7.4 of 11 AMSTAR). SR authors did not report other teaching methods as being superior to digital learning. In most cases (n=9), digital education when used in addition to traditional methods augmented the primary outcomes of knowledge acquisition. Other SRs (n=7) did not show statistically significant differences across interventions including digital education as a replacement, or additive resource to traditional intervention.

**Conclusion**: Student enrollment, attendance rates, course completion rates, cost-effectiveness, and changes in clinical outcomes for patients are underreported in the existing evidence. Although the quality and quantity of data are limited, evidence-based instructional design for digital education is becoming more possible, especially as educators establish learning activities that track to learning objectives for knowledge acquisition in health care.

**Keywords**

Review, systematic, health education, digital, online, healthcare, courses.

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## Background

Technological advance has improved access to information and increased the speed and efficiency of communication in education. Beyond this basic communication and information flow, educational institutions have developed a mix of online and in-person (blended) learning environments, digitalised lectures with in-person workshop sessions (flipped classrooms), webinars, chat forums and live digital discussions, alongside new automated learning applications.

Educational offerings in the current digital era comprise at one extreme, independent, automated, self-guided digital courses (downloadable or available online) and at the other end individual attention through private tutorial, face-to-face sessions. Educational media and approaches vary considerably in terms of accessibility, individualised attention, scalability, flexibility, responsiveness, replicability and cost. Often, their relative impact on health education in terms of learning outcomes remains unclear (Curran and Fleet et al. 2005; Consorti et al. 2012).

Continuing medical education (CME) among health care professionals (HCPs) in general leads to the acquisition and retention of knowledge, attitudes, skills, behaviours and clinical outcomes (Marinopoulos et al. 2007). Medical conferences, workshops or traditional in-person classes often show an increase in physician knowledge and in some instances, health outcomes. However, the degree to which didactic learning approaches, or non-experiential learning translates into better health care practice are more uncertain (Davis et al. 1999). Digital media for health care education, especially for working professionals, provide a potentially convenient and cost-effective method to deliver training to improve knowledge and patient outcomes. This systematic overview, therefore, seeks to understand the type of interventions and outcomes that may be expected to improve not only HCP student knowledge, but also healthcare practice.

The primary aim of the overview was to synthesise results from studies of digital education in terms of knowledge or learning outcomes, student satisfaction, student enrollment, attendance rate, course completion rate, clinical practice, health outcomes for patients and cost-effectiveness. A secondary aim of this overview was to report effective instructional design strategies, and list barriers or contextual factors that influence the effectiveness of online learning course delivery in health care education. In addition, we sought to explore different types of student or teacher-specific characteristics that might improve either the quality, satisfaction or performance in digital learning in health care.

## Methods

We conducted an overview of Systematic Reviews (SRs) for digital education interventions delivered to students and practitioners of health care.

### *Inclusion Criteria*

Systematic reviews (SR) synthesising data from at least one randomised controlled trial (RCT) of digital health education intervention were included. To qualify as an SR, each article needed to satisfy five Oxman Criteria (Oxman 1994), including: statement of a replicable search method; authors adequately attempted to retrieve all relevant data; data collected in a systematic way; authors analysed and presented results appropriately; and authors considered sources of bias and quality of evidence.

Included participants were adult (18 years or older) students of health care subjects, or health care professionals who received education or training through a digital medium for the medical treatment of humans or animals. Only SRs conducted with at least one 100% online, digital intervention to improve knowledge or services in healthcare of humans or animals were included. Part-time, short units and full courses were included, provided the descriptions of the intervention included subject details and a description of the medium. Multi-media classes including online video, text, or audio files via computers or personal devices were included. Studies using comparison groups that did not include 100% digital-based education - including waitlists, in-person, or blended learning styles - were included as adequate comparisons.

***Exclusion Criteria***

Case series, business reports, market analyses or opinion articles, or SRs that sought to address health behaviour or education of patients (as opposed to students of a health-related field or healthcare professionals) were excluded from the overview. Interventions that did not include a digital medium (such as paper-based or using textbooks) were not included. Also, specialised surgical simulations of procedures were excluded.

***Search Strategy***

An information specialist (NR) designed and conducted a search of the following online databases: Cinahl, Cochrane Database of Systematic Reviews, Database of Abstract of Reviews of Effects, Embase, Epub Ahead of Print, In-Process & Other Non-Indexed Citations, Ovid MEDLINE(R) Daily and Ovid MEDLINE, ERIC and British Education Index, Science Citation Index and Social Science Citation Index and PROSPERO for SR protocols. Additional online databases were searched for relative studies including: The Campbell Collaboration Online Library, Best Evidence Medical and Health Professional Education, JISC e-learning programme and Google Scholar. For a comprehensive list of free-text terms and search dates, please see online Appendix A. The search for evidence was originally performed in December 2016, and an updated search was performed in June 2017.

***Outcome Measures***

This overview collected data from research that sought to measure change or differences in the aspects of health education in the context of Kirkpatrick's four levels of evaluation (Kirkpatrick 1998): learning outcomes (knowledge or skills); student satisfaction; student enrollment; attendance rate; course completion rate; clinical practice (of HCPs only); health outcomes for patients (of HCPs); and cost-effectiveness (including administration, logistics for teacher or student).

In addition, quantitative or qualitative data that described any of the following outcomes were collected: strategies of course design or delivery that increase student learning, satisfaction, or retention rates in health care education; barriers or contextual factors influence effectiveness of online learning course delivery in health care education; and type of student or teacher-specific characteristics (i.e. personality, learning style, socio-demographics) thought to improve either the quality, satisfaction, or performance of online learning for health care education.

### ***Data Management and Analysis***

The first reviewer (MM) scanned all titles and abstracts for exclusion based on the pre-determined inclusion and exclusion criteria. See Figure 1 for the article flow diagram. Full-text articles (n=49) were assessed by two reviewers (ES,HO) with consultation by an additional reviewer (MM) to resolve any differences. The quality of each SR was assessed by two reviewers (ES, HO) using the 11-point AMSTAR tool (Shea et al. 2009). The quality of evidence contained within each SR was assessed by two reviewers (ES,HO) using the GRADE tool as a guide (Guyatt et al. 2011).

Figure 1 about here

#### *Subgroup analyses*

We planned for sub-group analyses in the population, intervention and comparators of SRs. Lack of consistent reporting on interventions prevented a sub-group analysis for the difference in short versus long online courses. Excessive heterogeneity in data reporting for comparisons across SRs prevented a sensible meta-analysis of effect size differences between different comparators.

#### *Qualitative analysis*

One reviewer (MM) analysed the qualitative data for keywords, themes, and characteristics according to our primary and secondary research questions. Two reviewers (ES,HO) verified the selection of supporting qualitative data and its analysis. NVivo 10 for Mac (QSR International) software was used to code qualitative data from which we were able to extrapolate themes.

## **Results**

### ***Search Results***

We scanned 848 titles and 247 abstracts based on the pre-determined inclusion and exclusion criteria, and assessed 49 full-text articles (see Figure 1). Of these we excluded 33 with reasons (see Table 1). The primary reason for exclusion was that studies did not satisfy the criteria for a systematic review (n=15), or the intervention did not match our set criteria (n=8). One article focused on Internet-based interventions only and did not provide an adequate comparison to non-digital based interventions (Cook et al. 2010a); however, it includes relevant information on instructional design for health care education. Therefore, we included findings from this systematic review for discussion purposes only. In the full analysis of this overview, we consider data from 16 systematic reviews.

### ***Quality of Systematic Reviews***

The quality of the 16 included SRs assessed using the AMSTAR tool ranged from low (5.5) to satisfactory (9), average 7.4 points of a possible maximum 11 (see online Table 2). Review quality was consistently downgraded due to the lack of provision of a list of included and excluded studies, poor listing of the characteristics of included studies, and lack of sufficient assessment of publication bias.

The quality of evidence using the GRADE parameters ranged from very low (n=2), low (n=6) to moderate (n=8) (see online Table 3). The quality of evidence was downgraded most frequently due to perceived limitations in the authors' consideration of risk for potential bias, including lack of allocation concealment, and lack of blinding. SR authors note the considerable inconsistency of reporting, lack of confidence in quantitative analyses, excessive heterogeneity in terms of study design and methods, while existing reports often included a small number of RCTs. Our analysis, therefore, was limited to descriptive reporting and qualitative analyses due to this inconsistent reporting across reviews.

#### *Duplicate Data*

This overview identified 278 RCT references included across SRs (n=16), of which 44 RCT were duplicates across SRs. We did not reject any SR with an RCT from a duplicate source. Instead, we note this duplication as a limitation of an overview, reported where relevant in quantitative and qualitative syntheses, and analysed for differences in the SR qualitative reporting of results.

### ***Characteristics of Participants***

This overview includes data collected from 31,730 participants across 16 systematic reviews (see online Table 4). The SRs included health care professionals (n=12), students in undergraduate (n=9) or graduate training in health care (n=5). Research findings were most prevalent for nurse training (n=10), followed by education of SRs including general physicians (n=6). Other listed participants were dentists, orthodontists, paramedics, physical therapists, surgeons and educators in health care.

In the reporting SRs, digital health education studies have been conducted primarily in the USA and the UK, with other contributions from Brazil, Taiwan, and China. We are unable to provide a subgroup description or analysis of the population characteristics such as age, gender, language, geographical region, socioeconomic characteristics, education status or perception of technology due to lack of data.

### ***Characteristics of Interventions***

Digital education in this review includes the use of technology to communicate information for the purposes of knowledge or skill transfer. Of the included SRs, all reviews included digital education that included the use of a computer and a multimedia component. For a summary of the types of digital education identified in this overview, (adapted from Maertens et al. 2016) see Box 1.

Insert box 1 about here

The term e-learning was cited (n=5) as equivalent to Internet-based learning, or website supported education.

Virtual patients and case-based scenarios were implemented in four SRs (Cook et al. 2010b; Consorti et al. 2012; Härkänen et al. 2016; Lam-Antoniadeset al. 2009).

Computer-assisted learning (CAL) was described in instances (n=5) where the computer was used to enhance, or blend in, with traditional in-person methods. CAL included web-based material, as well as multimedia components such as CD-ROMs, videos and text files.

Digital interventions varied substantially in the amount of delivery time: from a minimum of 15 minutes (Consorti et al. 2012) to a maximum duration of 8,760 hours over 12 months (Maertens et al. 2016). Due to lack of consistent reporting, we were unable to determine an average or median time of duration or intervention for digital education. Insufficient data reporting for intervention characteristics by SR authors was identified in 13 of 15 reviews.

***Characteristics of Comparisons***

From the available data, studies within the SRs used in-person teaching (traditional method) comparison groups (n=127), no intervention or waitlisted participants (n=88), or a mix of either in-person, digital, or another unspecified intervention (n=61). The detailed characteristics of comparison groups, including description of teaching styles, session duration and physical location were not sufficiently reported in several systematic reviews.

***Outcomes***

Six systematic reviews performed quantitative data-analysis to compare digital learning with other education methods. Excessive heterogeneity, including differences in outcome measures and the type interventions across these reviews prohibited further meta-analysis. Instead, the SR quantitative summaries are reported according to result direction of primary outcome (as first stated by SR authors). Three of the SRs favour digital education over various comparison groups.

*Favours digital education*

One review (Al Jewair et al. 2009) included undergraduate, post-graduate, pre-clinical, clinical, and educators of orthodontics to examine differences in knowledge acquisition, learning efficiency, learner, education attitudes, cost and labour of delivery. In terms of knowledge gain, results favoured computer-assisted learning (CAL) with a weighted mean difference (WMD) 9.78% (CI 95% 2.89 to 16.67; p=0.005). Three sources were included in this synthesis (Clark et al. 1997, Aly et al. 2003 Rosenberg et al. 2008). Results were heavily weighted from one study (Rosenberg et al. 2008) that accounted for 67.47% of the measured outcome. The other two studies did not show statistically significant results, and indicated no mean difference between computer use and traditional learning.

In the Consorti et al. (2012) review, undergraduate and graduate medical education students of general medicine were evaluated for changes in clinical reasoning following training using virtual patients (VPs) in blended learning. Clinical reasoning skills improved using VPs as an additive resource, Odds Ratio (OR): 2.39 (CI 95% 1.364 to 4.791; p=0.003), and as an alternative to traditional teaching OR: 2.190 (1.059 to 4.527; p=0.034). Five RCTs (Vash et al. 2007, Kerfoot et al. 2006, Schittek et al. 2004, Triola et al. 2006, Wahlgren et al. 2006) were synthesised in this review to analyse effects of VPs as an additive resource, and 7 RCTs (Botezatu et al. 2010, Deladisma et al. 2007, Fleetwood et al. 2000, Fleming et al. 2009, Kandasamy et al. 2009, Kumta et al. 2003, Youngblood et al. 2008) were synthesised to analyse effects of VPs as a replacement to traditional methods.

Härkänen et al.'s (2016) review compared Internet-based and computer-assisted learning (CAL) with traditional methods and no intervention for effects on medical administration and safety skills of practising nurses. The pooled effect size (Hedges' *g*) of 1.06 (CI 95% 0.44-1.69; p=0.001) favoured digital learning from four studies whose quality was evaluated as moderate or strong (Sung et al. 2008, Lu et al. 2013, Tsai et al. 2008, Simonsen et al. 2014).

*No significant difference for digital education*

In Feng et al.'s (2013) meta-analysis, the digital learning group demonstrated a statistically significant positive effect on knowledge with a Cohen's Standard Mean Difference (SMD) of 1.66 (CI 95% 0.97 to 2.42; p<0.0001) when compared to no other learning programme. However, when combined with studies using traditional methods as the comparator, the overall effect was not significant on knowledge acquisition SMD of 0.24 (CI 95% -0.15 to 0.62; p<0.0001). Eight RCTs were included in Feng's knowledge data analyses Hugenholtz et al. 2008, Elgie et al. 2010, Gega et al. 2007, McDonough and Marks 2002, Smits et al. 2012, Truncali et al. 2011, Vash et al. 2007, Wenk et al. 2009 (n=638).

Lahti et al. (2014) review included practising nurses as well as nursing students. The review included computer-assisted (CAL) and Internet-based learning, and compared this intervention with traditional methods in its meta-analysis for differences in knowledge level. Results indicated no statistically significant differences in knowledge acquisition for digital learning: Mean Difference (MD) 0.44 (CI 95% -0.57 to 1.46; p=0.39) across four studies (Gega et al. 2007, Horiuchi et al. 2009, Paladino et al. 2007, Tsai et al. 2004).

One systematic review (Cook et al. 2010b) investigated learning efficiency of 100% Internet-based learning compared to traditional and other computer-assisted learning (CAL) interventions of health professionals in training or practice. In their random effects meta-analysis of eight studies (Bell et al. 2000, Cook et al. 2005, Dennis et al. 2003, Friedl et al. 2006a/b, Grundman et al. 2000, Leong et al. 2003), the pooled effect size was -0.10 (CI 95% -0.51 to 0.31; p=0.63) for Internet-based learning when compared to non-Internet instruction. These data suggest no significant difference in time spent learning on Internet courses and non-internet courses.

*Sub-group analyses*

In the population subset, we sought to examine any differences in primary outcomes of health care students versus working professionals. One study provided quantitative results (Feng et al. 2013) and found significant improvements in skill performance following digital education in medical and nursing students, not in practising clinicians, (Cohen's) SMD=0.30 (CI 95% 0.02 to 0.57; p=0.038).

**Cost Information for Digital Education**

Aspects of cost for digital education were reported in five SRs (Al Jewair et al. 2009, Du et al. 2013, George et al. 2014, Jayakumar et al. 2015, Rasmussen et al. 2014). In general, the literature suggests upfront investment in software, hardware, and faculty time are the most expensive aspects of digital education implementation. Al Jewair et al. (2009) indicated 300 hours of administration time is needed to create a 60-minute lecture on a computer-assisted medium.

Two SRs provided estimate costs of developing a digital course, including initial hardware and software investments, as well as faculty time. In Al Jewair et al. (2009), the direct design and set-up costs of a computer-assisted website costs range from $1,850 USD. George et al. estimated an initial investment requirement of $10,000 USD for a digital course, with additional $2,200 USD investments required for video cases.

For cost-effectiveness of digital education compared to traditional teaching methods, one SR reports digital learning required 50% less faculty time and incurred less expense by both students and faculty in its implementation (Jayakumar et al. 2015). Three additional SRs sought to analyse data on cost-effectiveness, but their included RCTs did not provide sufficient data (Al Jewair et al. 2009, George et al. 2014, Rasmussen et al. 2014).

**Learner Preferences in Digital Education**

Fifteen of the included SRs presented data on some aspects of learner preferences. Many of the reviews reported high satisfaction with digital education, especially when used as an additional resource to in-person teaching. Students of health care education may prefer digital education for its "flexibility (asynchronous design), learner independence, and time efficiency" (Du et al. 2013). In addition, the multiple components of digital education provide an extensive variety of content delivery (text, video, animation, and games) to arouse and retain the attention of the learner. Highly interactive courses are desirable for students, especially in the absence of in-person teaching. Ease of accessibility, affordability, self-pacing, and repetition of material are important advantages of the digital education interventions.

**Evidence-based Instructional Design**

All included SRs (n=16) reported aspects of effective instructional design for healthcare students or professionals. Three central themes regarding instructional design were highlighted in these reviews, including the nature and complexity of learning requirements; efficiency trade-offs with interactive learning; and general design preferences.

**Matching Learning Requirements**

The qualitative analysis across SRs suggest that capable learners benefit more from online (asynchronous learning). The independent, self-paced nature of digital learning may be more suitable for students who are experienced in knowledge acquisition. Virtual or case-based scenarios delivered appear more applicable to produce and monitor learning outcomes in contextual knowledge. "Situated e-learning platform provides learners with photographs, videos, or multimedia on an individual basis… (it) provides opportunities for students to interact with a virtual client within the programme as in a real-life situation, and emphasise perception and action in various contexts rather than memory of knowledge" (Feng et al. 2013: 181). To ensure a positive learning outcome, the learning environment and learning objectives must match the instructional method (Sinclair et al. 2016). SR authors were not more explicit about which learning objectives are best matched with digital learning activities.

**Facets of Interactive Design**

The benefits of highly interactive designs, where the learner engages more in-depth with the course content (its platform, components and/or peers and faculty), allows for a potential increase in communication and feedback during the learning process. An increase in interaction is associated with an increased time spent on learning activities. Learner satisfaction can be increased, or decreased with a highly interactive design, depending on the expectations of the student. In comparison, students enjoy a greater amount of privacy, independent learning, and time-efficiency in digital courses with a low-interactive design.

**General Design Preferences**

Instructional activities do not facilitate learning with equal effectiveness or efficiency (Cook et al. 2010b: 766), or elicit the same amount of satisfaction across subjects or students. In general, however, the following elements of general design appear in existing literature to support a positive digital learning experience. First, to encourage participation and prevent student drop-out, SRs "suggest a goal-directed curriculum that adheres to principles of educational psychology, including focused and immediate feedback" (Maertens et al. 2016: 1435). Intermittent evaluations of student progress can assist in arousing the participant to learn. Click and drag evaluation tools benefit the learner, and have shown benefits in knowledge and skill acquisition (Rasmussen 2014).

Second, courses split into small units of material have higher satisfaction, and are easier for students to track and maintain progress. In addition, short video clips have led to students spending more time on learning, and are associated with higher knowledge test scores (Cook et al. 2010b). Furthermore, providing content so that a student may repeat specific material, and replay videos at their own pace also shows greater knowledge gains (George et al. 2014).

Third, course components should be based on student-centred principles, and include a variety of activities that tend towards visual or auditory stimulation. Interventions consisting of “flat text are of limited value and should be avoided if possible” (Lam et al. 2009: 50). In terms of lecture style, poor quality videos should be avoided, “students prefer online lectures of power point slides with audio narration” (George et al. 2014: 11). Clarity, motivating exercises and real-world examples were especially appreciated by students (Santos et al. 2016).

**Barriers for Digital Education**

All included SRs (n=16) reported on contextual barriers or limitations to digital education. Negative themes of digital education related primarily to technical issues, including lack of equipment and support, poor Internet connection, poor infrastructure, and anxieties about fairness, security and cheating” (Webb et al. 2017: 167) In addition, lack of faculty interest or training in learning tools for online education. Finally, this emergent theme points towards a misconception of the need or lack of resources to develop high-quality multimedia components (administration time, money, professional expertise).

**Discussion**

***Summary of main findings***

Of the included reviews in this synthesis, no SR authors reported other teaching methods as being superior to digital learning. In most cases (n=9), digital education when used in addition to traditional methods augments the primary outcomes of knowledge acquisition. Other SRs (n=7) did not show statistically significant differences across interventions including digital education as a replacement, or additive resource to traditional intervention.

*Does digital education change clinical practice?*

Three systematic reviews (Feng et al. 2013, Lahti et al. 2014, Sinclair et al. 2016) report changes in clinical practice of nurses and physicians following an e-learning intervention. Their findings suggest digital education methods are at least as equivalent to traditional learning approaches, or superior to no instruction at all. Durmaz et al.’s (2012) study reported that e-learning was more effective ($p = 0.04$) than skill laboratories alone for second year undergraduate nursing students in teaching pre-operative patient admission skills. However, in the same cohort’s post-intervention deep breathing and coughing exercises, e-learning was not found to be more effective than clinical laboratory instruction ($p = .867$). The effectiveness of e-learning compared to no training at all was demonstrated in three studies (Elgie et al. 2010, Gordon et al. 2011, Smeekens et al. 2011). Gordon et al. (2011) was the only study to include a longitudinal element in its design and reported that e-learning was superior to no intervention at all ($p < 0.0001$), and that paediatric prescribing skills outcomes were maintained three-months post intervention ($p < 0.0001$). As expected, the strengths of results to favour digital education increase when compared to a waitlist or no comparison intervention.

*What is evidence-based instructional design for digital healthcare education?*

Instructional material delivered in clear, small, sub-sections of multiple components using audio, video, hypertext, graphics or case-based simulations can improve learning outcomes and student satisfaction. Regular evaluations, feedback, and opportunities for student interaction tend to motivate learner participation. The cost-effectiveness of digital education is an area for further exploration, especially as it relates to behavioural outcomes and skill performance of HCPs trained using traditional in-person methods. Adequate faculty training, equipment and available resources (time, money) to design the course are significant barriers that need to be addressed for implementation of digital education. Although the quality and quantity of data are limited, evidence-based instructional design for digital education is becoming more possible, especially as educators establish learning activities that track to learning objectives for knowledge acquisition in health care.

***Overall completeness and applicability of evidence***

This overview includes quantitative and qualitative data gathered from 16 SRs (278 RCTs and 31,730 participants). The quality of SRs was moderately good. In general, insufficient reporting of interventions and comparison groups prevented further meta-analysis. Nursing students and practitioners are well-represented in existing literature (included in 10 of 16 reviews). Data from the included SRs did not sufficiently report on cost-effectiveness, learner characteristics or effective digital design elements. Questions of behavioural outcomes of HCPs and downstream patient outcomes were raised, but have not been adequately answered in existing research.

***Potential biases and discussion of heterogeneity***

The quality of evidence from the RCTs was graded as low, the body of evidence risking high exposure to bias from lack of adequate randomisation, lack of blinding, and lack of adequate control groups. SR reported concerns about evidence from other study designs that did not provide a baseline measure, and lack of clear methods for detecting outcomes, subjecting the results to confounding and measurement bias (Al Jewair et al. 2009, Sinclair et al. 2016). Evidence of publication bias was considered but not found in several SRs (n=5) (Al Jewair et al. 2009, Maertens et al. 2016, Härkänen et al. 2016, Sinclair et al. 2016, Webb et al. 2017); although an overrepresentation of positive studies from other SRs may have affected results.

Weak quality ratings of RCTs were consistent across all SRs. Poor descriptions of interventions and comparison groups may have led to misinterpretation or wrong classification of some results (Consorti et al. 2012). An additional limitation is the overlap in RCTs for the synthesis, although we have disclosed two instances where the individual RCTs impacted the quantitative description of the SR results. This body of literature has an additional bias towards English-language studies.

The effect sizes of digital education are affected by a significantly heterogeneous set of interventions and comparison groups. In several SRs (n=4), the comparison groups also included an aspect of digital intervention (blended learning). The interventions often included blended learning and 100% digital interventions to compare with traditional methods. The information was not provided as a clear subset and therefore limited subgroup analyses or extraction of 100% online digital interventions. A future SR may consider a more limited definition of what constitutes digital learning, and seek to eliminate hybrid or other digital learning components from control groups.

### *Implications for practice and future research*

Given the rise of online education services for health care students and professionals, it is clear the evidence needs to be strengthened to understand how, and what type of digital education is most suitable for specific learning objectives. In terms of systematic review methodology, we strongly recommend future reviewers follow the Cochrane guidelines (Green et al. 2008) to ensure data can be used in an overview synthesis. Future randomised controlled studies should report detailed intervention characteristics (duration, features, prototypes) and comparison characteristics. It is important for future studies to explore cost-efficacy, learning efficiency, as well as the impact of HCP digital education on clinical outcomes for patients. Future research would also seek to evaluate specific instructional design components, assessing for relative effects or cost-benefits of video versus audio with slides or animated graphics and other customised interactive games or platforms on learning.

## Conclusions and recommendations

The digital education interventions analysed are at least equal to traditional methods in terms of knowledge outcomes and learner satisfaction. Student enrollment, attendance rates, course completion rates, cost-effectiveness and changes in clinical outcomes for patients are underreported in the existing evidence. The barriers for implementing digital education include skills training for faculty, technological glitches, and lack of resources (time, money) to invest in the course. At this time, evidence suggests effective instructional design strategies (i) communicate in clear, short segments of varied student-centred learning activities (audio, video, graphics, text and hypertext, animation, simulations, evaluations) that are tracked to learning objectives; (ii) use adequate real-world examples and (iii) include an appropriate level of interactivity and feedback through course delivery.

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*Box 1*

**Types of Digital Education**

- Multimedia components (videos, images, animations, audio files, text and hypertext)
- Interactive sessions (conference, chats, forums, messaging)
- Virtual reality (simulations, case-based learning
- Automated assessments (multiple choice, short answer)
- Gaming (learning through structured play)
- Applications (downloaded to personal device for decision tools, reminders, information)

**Figure 1.**

**Article Flow Diagram**

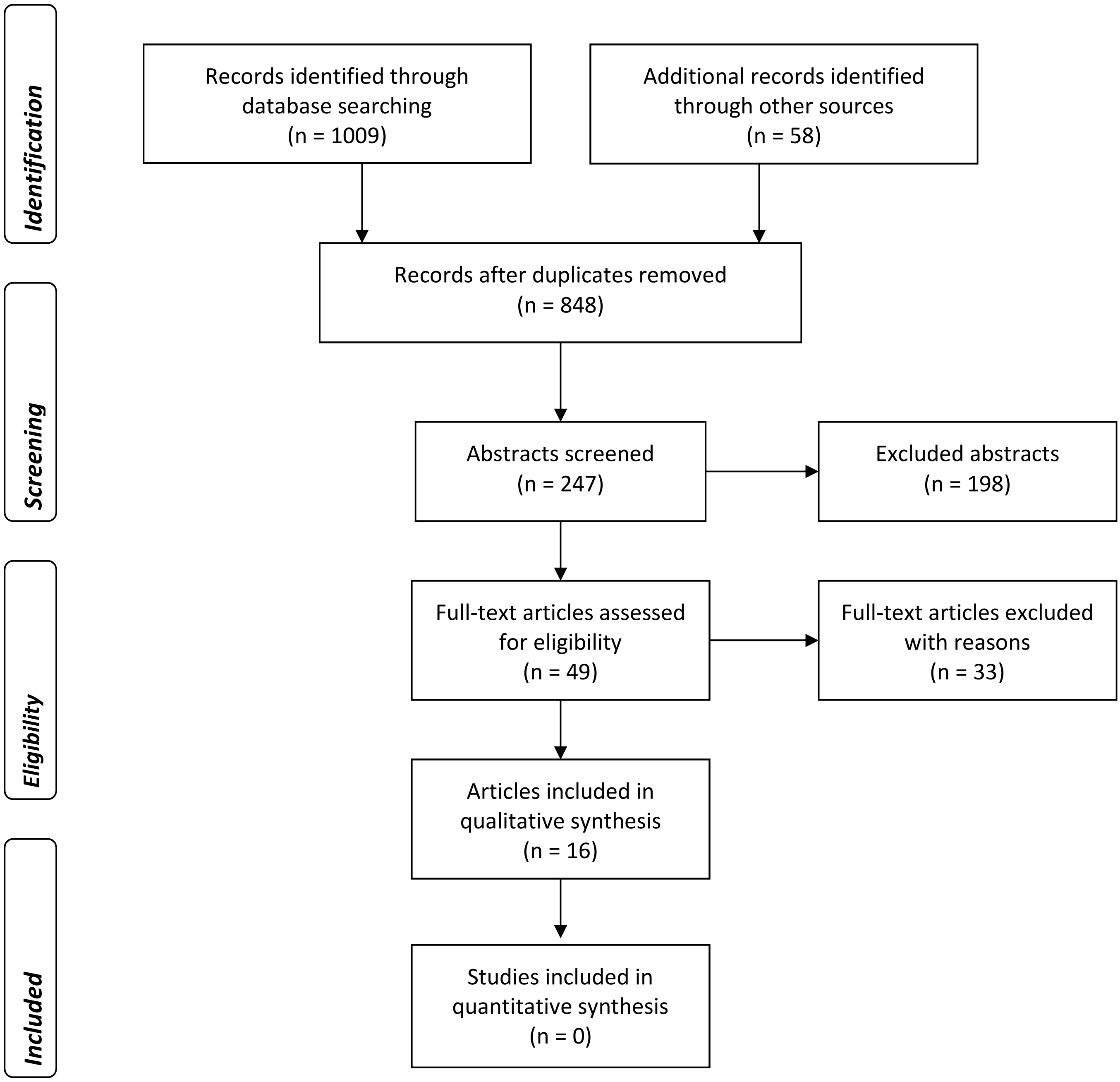

**Table 1.**

**Summary of included reviews**

| First Author, Year | Population | Taught Subject | Type of Intervention | Primary Outcomes | Comparisons | Meta-analysis | Direction of Results |
|---|---|---|---|---|---|---|---|
| Al Jewair, 2009 | Undergraduate or post-graduate, pre-clinical, clinical students, and educators of orthodontics | Orthodontics | Computer-assisted learning* | Efficacy of computer-assisted learning (knowledge acquisition, learning efficiency, learner and education attitudes, cost and labour) | Traditional methods | X | Favours digital education (+) |
| Consorti, 2012 | Undergraduate and graduate medical education | General Medicine | Virtual patients and blended learning | Clinical reasoning (including history taking and differential diagnosis) | Traditional methods | x | Favours digital education (+) |
| Cook, 2010b | Health professionals in training or practice | Specialised and General Medicine (i.e. cardiovascular, ambulatory care, examination of eye and ear, back pain, psychotherapy, women's health, health screening, hygiene) | Internet-based learning | Learning efficiency (time on task to acquire knowledge) | Traditional methods and other computer-assisted learning intervention | x | No difference (o) |
| Du, 2013 | Nursing students and practitioners | Nursing | Internet-based and blended learning | Knowledge acquisition and skill performance | Traditional methods and no intervention | | Favours digital education (+) |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Feng, 2013 | Undergraduate, graduate students and professionals in nursing and medicine | General Medicine and Nursing | Computer-assisted learning | Knowledge acquisition and skill performance | Traditional methods and no intervention | x | No difference in knowledge of students and clinicians (o); slightly favours digital education for student performance only (+) |
| George, 2014 | Undergraduate and graduate students of medicine dentistry, nursing, physical therapy, pharmacy | General Medicine and Allied Health (including dentistry, midwifery, physical therapy, diagnostic technology, pharmacy) | Internet-based iand blended learning | Knowledge acquisition, skill performance, learner satisfaction and attitude | Traditional methods and no intervention | | No difference (o) |
| Härkänen, 2016 | Nurses | Medication administration skills in hospital | Internet-based learning, computer-based learning and traditional methods | Increasing medical administration and safety skills | Traditional methods and no intervention | x | Favours digital education (+) |
| Jayakumar, 2015 | Medical, dental students, residents and practising surgeons | Surgical education | Internet-based and blended learning | Identify current modalities of e-learning~ | Traditional methods and no intervention | | Favours digital education (+) |
| Lahti, 2014 | Nurses and nursing students | Nursing skills, hygiene, ergonomics | Computer-assisted and internet-based learning | Knowledge acquisition and skill performance | Traditional methods, blended learning, and no intervention | x | No difference (o) |
| Lam-Antoniades, 2009 | Health professionals in practice | Continuing education (clinical guidelines, ergonomics, patient management, nursing skills, supplementation) | Computer-assisted and internet-based learning | Knowledge acquisition and skill performance | Traditional methods and no intervention | | Favours digital education (+) |
| Maertens, 2016 | Medical students or surgeons in training or practice | Surgical training (including general, trauma, orthopedic, pediatrics, obstetrics, nursing, plastics, cardiovascular) | Computer-assisted learning | Knowledge acquisition and skill performance | Traditional methods and no intervention | | Favours digital education (+) |

| | | | | | | |
|---|---|---|---|---|---|---|
| McCutcheon, 2015 | Undergraduate nurses | Nursing skill, communication, and epidemiology | Internet-based and blended learning | Knowledge acquisition and skill performance | Traditional methods, blended learning, and no intervention | No difference (o) |
| Rasmussen, 2014 | Undergraduate students | Medicine, Dentistry, Nursing, Psychology, Physical Therapy | Computer-assisted, internet-based, and blended learning | Knowledge acquisition, skill performance, learner satisfaction and attitude | Traditional methods and blended learning | Favours digital education (+) |
| Santos, 2016 | Predoctoral dental students | Oral radiology | Computer-assisted learning | Knowledge acquisition, skill performance, and learner satisfaction | Traditional methods and no intervention | No difference (o) |
| Sinclair, 2016 | Health professionals in practice | Patient screening, medical assessments, emergency preparedness | Computer-assisted learning | Effect on health care professional behaviour and patient outcomes | Traditional methods | No difference (o) |
| Webb, 2017 | Pre-registration nurses | Nursing | Computer-assisted, internet-based learning, and blended learning | Deliver and efficacy of pre-registration nurse education | Traditional methods | No difference (o) |

**Limitations and Comments**

| **Review ID** | **SR Author Comments of Results Favouring Digital Education** | **SR Author Comments with No Difference / No Significant Results** | **SR Author Comments of Results Favouring Traditional Methods** |
|---|---|---|---|
| Al Jewair, 2009 | Confounders including level of motivation and prior knowledge, uncertain about knowledge retention | | |
| Consorti, 2012 | Unable to discern best practice in digital formats due to poor description of studies, uncertain about knowledge retention | | |
| Cook, 2010b | | Poor description of interventions and outcomes | |

| | | |
|---|---|---|
| Du, 2013 | Learner preferences for flexibility, independence and time efficiency, and some used interactive web-based mediums | |
| Feng, 2013 | | Lack of computer skills for some participants, learning needs of a clinician are different than a student (i.e. problem solving of their patient, application of knowledge for clinician) |
| George, 2014 | | High risk of bias, authors suggest that online learning is possibly superior to traditional learning, as studies show mixed results (i.e 12 of 50 studies favoured online learning; 27 found no significant differences; 11 studies did not test for differences), subjective outcome measures primarily based on survey recall questionnaires |
| Härkänen, 2016 | | Five of 14 studies used digital learning as an additive (n=1) or alternative (n=4) to traditional classroom learning; the most effective of these studies was the blended learning model see Fig 2 of SR) |
| Jayakumar, 2015 | Small samples in 18 studies including data from six randomised-controlled trials, unclear about pre-existing knowledge, slow internet connection and technical issues were listed as the largest impediments, one study at a 54% completion rate (Cochran et al. p.1150 of SR) | |
| Lahti, 2014 | | All studies were randomised-controlled trials, only four of 11 used in meta-analysis due to poor reporting of numerical data |
| Lam-Antoniades, 2009 | Effects of multi-component (blended learning) are longlasting (up to 12 months), flat-text information on screen is of limited value and to be limited, risk of publication bias | |

| | | | |
|---|---|---|---|
| Maertens, 2016 | Limited evidence to support digital education over traditional methods, stronger evidence for comparison with no interventions, serves as an adjunct and can assist in cognitive phase of skill acquisition | | |
| McCutcheon, 2015 | | | Mixed results, where digital education is "no less effective than traditional means" in all but three studies (where traditional method was favoured), students felt 'disadvantaged' having only online learning, those in traditional method reported wanting more online learning |
| Rasmussen, 2014 | Findings suggest that "offline eLearning is at least equivalent, possibly superior to traditional learning, favourable because it offers a "more convenient, and more cost-effective, alternative to facilitate competency development and the training of health care professionals around the globe" | | |
| Santos, 2016 | | Digital education may be more properly used as a support to traditional education and not as a substitute for it, students are positive about digital learning material, may be cost and time-effective for instructors | |
| Sinclair, 2016 | | No papers reported the effectiveness of digital education | |
| Webb, 2017 | | Many studies highlight concerns for staff training, support, and perceived external pressures, lack of technical competence among teachers and students, personal motivation is key to engagement | |