American Journal of Pharmaceutical Education **2014; 78 (4) Article 83.**

REVIEWS

Effectiveness of E-learning in Pharmacy Education

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Submitted October 21, 2013; accepted December 16, 2013; published May 15, 2014.

Over the past 2 decades, e-learning has evolved as a new pedagogy within pharmacy education. As learners and teachers increasingly seek e-learning opportunities for an array of educational and individual benefits, it is important to evaluate the effectiveness of these programs. This systematic review of the literature examines the quality of e-learning effectiveness studies in pharmacy, describes effectiveness measures, and synthesizes the evidence for each measure. E-learning in pharmacy education effectively increases knowledge and is a highly acceptable instructional format for pharmacists and pharmacy students. However, there is limited evidence that e-learning effectively improves skills or professional practice. There is also no evidence that e-learning is effective at increasing knowledge long term; thus, long-term follow-up studies are required. Translational research is also needed to evaluate the benefits of e-learning at patient and organizational levels.

Keywords: pharmacy education, e-learning, knowledge assessment, computer instruction, Internet

INTRODUCTION

The fundamental purpose of pharmacy education is to provide pharmacy students with the knowledge and skills to become pharmacists, and then to enable pharmacists to remain competent in the profession. The traditional pedagogy involving face-to-face instruction has evolved alongside the maturation of the Internet. Increasingly, pharmacists, pharmacy students, and pharmacy educators encounter teaching and learning opportunities beyond the classroom, with more and more content delivered online.[1-5] Historically, online learning (using information and communication technologies) represented one facet of e-learning, while computer-based learning (using standalone multimedia such as a CD-ROM) represented another. Now e-learning is defined as learning conducted through an Internet process.[6,7]

E-learning programs are truly ubiquitous, and for this reason they offer attractive solutions to educating large numbers of geographically diverse populations. They allow standardized educational content to be easily distributed and updated. Learners gain control over time and place of learning, while programs provide automated real-time feedback for teachers and learners. Moreover, rather than move away from teacher-centered pedagogy, educators enhance and extend existing curriculums with e-learning opportunities, and learners embrace this.[4,7-10] However as e-learning becomes a common feature in pharmacy education, the need to demonstrate its effectiveness increases.

Measuring and defining effectiveness of complex interventions, such as e-learning is difficult.[11-13] In 1959, Donald Kirkpatrick proposed a 4-level model for evaluation of training programs.[14] Further in 2009, the Best Evidence Medical Education (BEME) Collaboration adopted (and termed the levels) "Kirkpatrick's hierarchy," as a grading standard for literature reviews.[15] In both instances, the levels may be simply defined as (1) reaction, (2) learning, (3) behavior, and (4) results. Reaction is a measure of program satisfaction. Learning is a measure of attitudes, knowledge, or skills change as a result of the program. Behavior is represented by the transfer of learning to the workplace. Finally, results are a measure of how the learning has changed organizational practice or patient outcomes.

Several reviews have evaluated the effectiveness of e-learning in the health professions, some with and others without applying the concepts of Kirkpatrick's hierarchy.[8,9,16-22] However, there are no reviews of the effectiveness of e-learning in pharmacy education. We conducted a systematic review to identify and evaluate the literature on effectiveness of e-learning in pharmacy

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education. We used Kirkpatrick's hierarchy to guide outcome measures. Our primary aim was to determine effectiveness in terms of learning, behavior, and results. Our secondary aim was to assess effectiveness as reactions to e-learning programs.

METHODS

This systematic review was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Statement.[23] The protocol for the review is published elsewhere.[24] We defined specific criteria to allow a focused review of the effectiveness of e-learning in pharmacy education (Table 1). We included any effectiveness research that evaluated e-learning programs in undergraduate, postgraduate, and continuing professional development pharmacy education. We did not set limits on study design, language, or year of publication.

A senior reference librarian at The University of Western Australia's Medical and Dental Library with expertise in conducting systematic literature reviews was consulted as part of the process to develop a comprehensive search strategy (Table 2). Databases were searched from inception to June 4, 2013. The review was conducted using the Web-based systematic review software, DistillerSR (Evidence Partners Incorporated, Ottawa, Canada). All identified citations were uploaded to DistillerSR and duplicates were removed. We developed forms for title/abstract and full-text screening according to the stated eligibility criteria, and pilot tested them before implementing them in study selection. Two reviewers independently and in duplicate screened all titles and abstracts. Potentially eligible abstracts, abstracts where reviewers disagreed, or abstracts with insufficient information were retrieved for full text review. Two reviewers then assessed the eligibility of each study in duplicate, and a final list of studies was determined. Agreement between reviewers was measured using Cohen's kappa (weighted kappa for title/abstract screen was 0.75, and for full text screen, 0.88, estimated using DistillerSR). Conflicts were resolved by consensus. Reasons for exclusion were documented and are presented in Figure 1.

Two reviewers independently abstracted data using a series of dedicated forms we developed based on the Evidence for Policy and Practice Information and Coordinating Centre (EPPI-Centre) data extraction and coding tool for education studies.[25] These forms were piloted and refined prior to data abstraction, and applied through DistillerSR. We assessed reviewer agreement in data abstraction using Cohen's kappa, where 0=no agreement and 1=complete agreement. We abstracted data on study characteristics (study aims, location, participants, intervention topic, and assessment; kappa range 0.53-1); study design and methodology (sampling and recruitment, blinding, power, funding; kappa range 0.43-1); data collection and analysis (how data were collected, use and reliability of tools, statistical analysis; kappa range 0.48-1); and outcomes. As the focus of this review was on effectiveness, we sought information for outcomes that measured change after the e-learning intervention was delivered. The form for learning outcomes identified knowledge or

Table 1. Definitions Used in Conducting a Systematic Review of eLearning in Pharmacy Education

E-learning program	Educational program accessed through the Internet.
Participants	Pharmacists, intern (or trainee) pharmacists, preregistration pharmacists, pharmacy students. Studies evaluating any other person or population receiving or using a pharmacy e-learning program were excluded.
Intervention	Any pharmacy e-learning program. Hybrid interventions were defined as a combination of face-to-face and e-learning components in one course. Blended interventions were defined as a combination of multiple training methods, including e-learning, in one course.
Comparator	1. 'No training': no other learning activity. 2. 'Traditional learning': Same topic delivered as face-to-face teaching or through books. This evaluated the effectiveness of e-learning technology. 3. 'Traditional learning': Different topic delivered as face-to-face teaching or through books. This evaluated the effectiveness of the e-learning education program. Studies without comparator groups were also included.
Primary Outcomes	1. Learning: change in attitudes, knowledge or skills after training. 2. Behaviour: transfer of learning to the workplace (includes willingness to apply learning in the workplace). 3. Results: Changes in organisational practice (e.g. in delivery of care) and patient outcomes as a result of the program.
Secondary Outcomes	1. Reaction: learners' views about the e-learning program, including experiences and satisfaction with the topic and e-learning technology.

Table 2. Search Strategy Used in Conducting a Systematic Review of eLearning in Pharmacy Education

Search Databases	
Scholarly online indexing and abstracting databases	MEDLINE, EMBASE, Web of Knowledge, ERIC, PsycINFO, Science Direct, CINAHL, IPA, and Google Scholar
Review databases	Evidence Based Medicine, Joanna Briggs Institute
Grey literature databases	Mednar, Open Grey, Scirus
Reference list pearling	All included studies
Search Terms	
Participants	Pharmacist, intern pharmacist, internship nonmedical, pharmacy, preregistrant,[a] preregistered, preregistration, trainee, pharmacy student, pharmacy, professional
Intervention	E-learning, e-training, learning, education, blended, virtual, web-based, education pharmacy continuing, computer assisted instruction, computer assisted learning, computer, Internet, online, distance education, flexible, program
Outcomes	Knowledge, skills, practice, change, acceptability, satisfaction
Evaluation	Effectiveness, comparative effectiveness research, evaluation, outcome assessment, test, assessment, educational measurement

Medical subject heading (MESH) terms and keywords were searched in accordance with database indexing practices.
Searches were iteratively refined to suit different databases and to improve accuracy within each database.
[a] Preregistrant, preregistered/preregistration refers to graduate pharmacists who held provisional registration as a pharmacist with the Pharmacy Board of Australia and who were undertaking supervised practice hours under the direct supervision of a registered pharmacist.
Database-specific searches are available from the authors upon request.

skills change, and problem-solving ability (kappa range 0.55-1). The form for behavior and results outcomes identified willingness to change behavior or practice change, and organizational change or patient benefit (kappa range 0.64-1). The form for reaction outcomes identified satisfaction, attitudes and opinions (kappa range 0.48-1). Finally and where relevant, we contacted authors by e-mail to request missing data.

We expected the studies to be diverse, to include both qualitative and quantitative designs, to consist in the majority as noncomparative studies, and by the very nature of e-learning interventions, to be limited in their ability to conceal the intervention from the participant. Further, acknowledging that quality assessment of education intervention studies is complex,[12] we considered no single published quality assessment tool to be appropriate

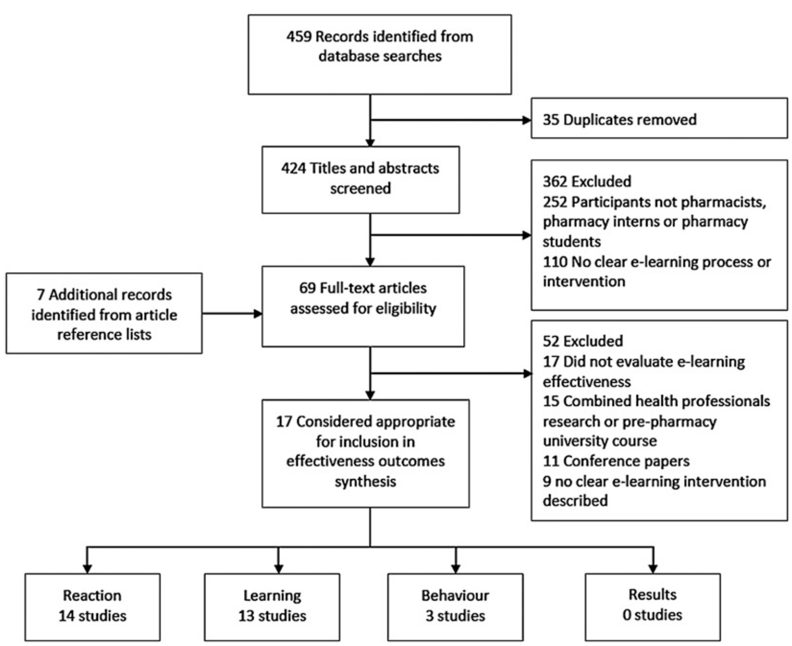

Figure 1. Systematic review flow. Studies may have contributed more than one effectiveness outcome measure. Reaction=satisfaction and course opinions. Learning=change in attitudes, knowledge or skills (including perceptions of these). Behavior=practice change (actual or willingness to change). Results=organizational change and patient benefit.

for this review. However, aspects of 3 published tools were considered relevant to quality: the Cochrane Risk of Bias Criteria for Effective Practice and Organisation of Care reviews tool,[26] the NICE quality appraisal checklist,[27] and the EPPI-Centre data extraction and coding tool for education studies.[25] In order to develop a more robust assessment of quality, we developed a quality assessment tool that included relevant aspects from each of the published tools as well as additional criteria, and embedded the assessment within the data abstraction forms in DistillerSR (Appendix 1).

We concurrently assessed the impact of each intervention in terms of Kirkpatrick's hierarchy, and strength of findings for each study in terms of the BEME weight of evidence rating scale (strength 1=no clear conclusions can be drawn, not significant; 2=results ambiguous, but there appears to be a trend; 3=conclusions can probably be based on the results; 4=results are clear and very likely to be true; 5=results are unequivocal).[15]

There was significant variation between studies, in terms of design, intervention, duration, assessment method, and outcome. There were few controlled studies, and every study assessed a different topic within pharmacy education. Few studies reported sufficient data to enable calculation of a combined effect size, and there was limited response to requests for data. Given contextual limitations on methodology in education research (and the associated complication of interpreting education outcomes),[13] the risks associated with evidence from uncontrolled studies and from imputing data, it was not possible or appropriate to conduct a meta-analysis for any outcome.

We adopted a modified meta-narrative approach to synthesis.[28,29] We considered how e-learning effectiveness was conceptualized, using key outcome measures and how they were assessed in each study. To start, outcomes were broadly themed according to the 4 levels of Kirkpatrick's hierarchy. Depending on how the outcome was defined (eg, perceived confidence, actual knowledge) and measured (eg, rating scales, formal test), we then iteratively categorized the results of each study to yield a detailed map of e-learning effectiveness in pharmacy education.

RESULTS

Our search strategy identified 459 records from database searches. After adjusting for duplicates, we screened 424 records, and excluded 362 because they did not assess e-learning interventions or because the participants were not pharmacists or pharmacy students. We identified a further 7 citations from reference lists and examined the remaining 69 records in detail. Of these, 17 studies met the criteria for review.

Table 3 summarizes the characteristics of pharmacy e-learning effectiveness studies. Every study assessed a different learning topic, although 3 studies included diabetes within their focus.[30-32] Six studies (35%) assessed effectiveness of e-learning in pharmacists;[32-37] 10 studies (59%) assessed pharmacy students (of which 1 included preregistration pharmacists),[31,38-46] and 1 study assessed both pharmacists and pharmacy students.[30] The number of participants in each study ranged from 17-190.

Fourteen studies (82%) delivered e-learning in more than 1 format. The most common interventions were online modules, with or without simultaneous audio. Online reading materials, synchronous and asynchronous lectures, virtual patients, compulsory discussions (with peers or teachers), online feedback systems, and multimedia vignettes were also presented. Six studies (35%) included traditional methods, such as face-to-face lectures, workshops or small-group activities, as part of a blended or hybrid approach.[31,38-40,43] Five studies (29%) included a comparator group (non-Internet teaching on the same or different topics, or no training). There was significant variation in setting, including mode of delivery (continuing education, distance learning, university core and elective units, university courses, and pre-registration training), and duration of the intervention (range: 25 minutes to 1 academic year of education).

Effectiveness was measured using a variety of objective and subjective assessments, including pre-post knowledge tests, curriculum tests, mock patients, rating scales, semi-structured interviews, and written or online surveys. All objective assessments were analyzed quantitatively; while subjective assessments were analyzed qualitatively and/or quantitatively. We identified 3 effectiveness outcomes based on Kirkpatrick's hierarchy, which were reaction, learning, and behavior, with 13 studies (76%) reporting more than 1 of these outcomes. A further 19 effectiveness themes emerged through the iterative process. These were refined and presented as a thematic map of e-learning effectiveness in pharmacy education (Figure 2).

Reaction was assessed subjectively, with different instruments and scales in each study. E-learning programs were considered beneficial in improving knowledge and confidence, and stimulating interest.[30,31,35,37,39,40,44-46] Courses were evaluated in terms of their functionality, which was measured as time taken to complete the course,[35,38,39] online navigation (programs were easy to use and user-friendly),[32,33,35,37,39,44] course presentation (courses were acceptably designed and integrated),[31,35,37,40,46] and technical issues (online access, and quality of recordings).[31,33,43,44] The majority of pharmacists and pharmacy students considered their e-learning

Table 3. Description of Studies Included in a Systematic Review of eLearning in Pharmacy Education

First Author,[ref] Year, Country	E-Learning Topic	Participants	E-Learning Intervention	E-Learning Setting	Comparator Intervention	Outcomes[a]
Erickson,[41] 2001, US	Asthma inhaler technique	PS: 42	Online video streaming and text with animations for demonstration	One hour lecture from a university core unit that included respiratory medicine	Didactic lecture on the same topic, or no training	K, S
Elliott,[40] 2004, Australia	Pharmaceutical calculations, pharmacy law	PP: 108	Online modules, online reading materials, online asynchronous discussions as part of a blended course (included 8 days of FTF education)	23-26 weeks of online distance education in a Pharmacy Preregistration Course	NC	R, PB
Lust,[45] 2004, US	Veterinary therapeutics	PS: 17	Online images and text	Two elective-credit hours in undergraduate pharmacy	NC	PC, PK, PB
Freeman,[44] 2006, US	Drug information	PS: 124	Online asynchronous lectures with supplementary oral narration or written descriptive captions, and learning quizzes, delivered as part of a blended program	Four one-hour lectures as part of a first year Pharm D program	NC	PB
Hall,[31] 2006, US	Diabetes	PS: 109	Online modules, online asynchronous lectures	Twelve modules as a standalone university elective course	NC	PB, K, WP
Sweet,[32] 2006, US	Diabetes medicines	P: 29	Online modules, Internet-based feedback system	Three one-hour modules as part of a CE program	NC	R, K
Congdon,[38] 2007, US	First-year doctor of pharmacy (PharmD) program	PS: 132	Online asynchronous lectures, synchronous videoconferencing as part of a hybrid course (including small-group FTF activities)	Full year of a university course conducted at a newly opened satellite campus	The same course delivered by traditional methods at the main campus	R, K

(*Continued*)

Table 3. (*Continued*)

First Author,[ref] Year, Country	E-Learning Topic	Participants	E-Learning Intervention	E-Learning Setting	Comparator Intervention	Outcomes[a]
Hughes,[34] 2007, Canada	Laboratory values	P: 25	Online reading materials, online asynchronous discussions as part of a blended learning course (also included a 2 day FTF workshop)	12-week CPD course, including three distance learning sessions	NC	R, PC, K, PRAC
Flowers,[42] 2008, US	Over-the-counter eye and ear drops; inhaler devices	PS: 79	Online modules with simultaneous synchronized scrolling text (presented as 5 vignettes)	One month Advanced Community Pharmacy Practice Experience	No training	K
Crouch,[39] 2009, US	Advanced cardiovascular pharmacotherapy	PS: 158	Online modules, online synchronous lectures, online reading materials, online discussion boards as part of a blended course (25% online)	Eight 35-minute drugfocussed lectures and six 25-minute introductory presentations in a university elective unit	NC	R, K
Lancaster,[43] 2009, US	Over-the-counter medicines: gastrointestinal conditions; obesity	PS: 97	Online modules, online asynchronous lectures; as part of a hybrid lecture model including in-class active learning	Six lectures of a university core unit	Didactic lectures on a different topic; previous year's scores	R, K
Tsugihashi,[36] 2009, Japan	Core competency in clinical research	P: 42	Online synchronous lectures, Internet-based feedback system	Twenty-three 60-minute lectures in a DL program	NC	R
Battaglia,[30] 2010, US	Medication therapy management and diabetes care	P: 42, PS: 80	Online modules, online reading materials, online virtual patient, "drop box" for documentation	Four virtual patient interactions in a CE program or university pharmacotherapy core unit	NC	PB, K, WP
Legris,[35] 2010, Canada	Pharmacotherapy assessment in chronic renal disease	P: 52	Online virtual patient – interactive clinical vignettes	60 minute CE program	No training	R, K, S

(*Continued*)

Table 3. (*Continued*)

First Author,[ref] Year, Country	E-Learning Topic	Participants	E-Learning Intervention	E-Learning Setting	Comparator Intervention	Outcomes[a]
Walters,[37] 2010, New Zealand	OST for the management of opioid dependence	P: 190	Online modules with simultaneous audio, online reading materials	Three 45 minute modules in a DL program	NC	R, PK, PA
Buxton,[33] 2011, US	12 different continuing education clinical topics	P: 97	Online modules, online synchronous lectures, online synchronous discussion	90 minute CE webinars in a 12-month CE program	NC	R
Ruehter,[46] 2011, US	Health assessment and general medicine as part of IPPE	PS: 190	Online modules, online videos, online quizzes as part of an IPPE	2 hours per week, until completed 20 online modules, over the IPPE period (3 years)	NC	K, PRAC, PC, PB

Abbreviations: US=United States of America; OST=Opioid Substitution Therapy; IPPE=Introductory Pharmacy Practice Experience; PS=Pharmacy Students; P=Pharmacists; PP=Preregistration Pharmacists; FTF=face-to-face; CPD=continuing professional development; CE=continuing education; DL=distance learning; NC=no comparator.

[a] Outcomes: K=knowledge; S=Skills; R=Reaction (participation, satisfaction, opinions); PB=perceived benefit of the course; PC=perceived change in confidence; PK=perceived change in knowledge; WP=willingness to change practice; PRAC=practice change (perceived or actual), PA=perceived change in attitude to patients.

course to be relevant and practical.[30,32,33,35,37,39,45,46] One study reported dissatisfaction with online lectures in pharmacy students.[44]

Learning was assessed objectively and subjectively. Of 11 studies assessing knowledge change, all reported a significant improvement in knowledge immediately after e-learning.[30-32,34,35,38,39,41-43,46] However, the magnitude of the gain varied considerably from study to study (range 7% to 46%). Comparative studies assessing knowledge change demonstrated e-learning to be equivalent to lecture-based learning and superior to no training.[35,38,41-43] One skills assessment reported significant gains (24% increase after training; adjusted compared to control),[35] while another reported superior skills after e-learning in a posttest compared to control.[41] Significant gains in self-perceived confidence or knowledge after e-learning varied in magnitude, depending on whether a 5- or 7-point rating scale was used. Most ratings improved by 1-2 points on each scale, representing a change between 14% and 40%.[34,37,45,46]

Behavior was assessed subjectively, as direct application of knowledge or skills to the workplace,[34,46] or willingness to change practice.[30,31] Although intended behavior change was reported, the intention varied across studies, depending on the educational topic.

The quality of each study was rated as low (0-4), moderate (5-7), or high (8+), with a maximum score of 10 points. The mean quality for all included studies was 5.7 (Table 4).

For all studies, the most common flaws in methodology were selection bias and associated poor external validity (narrow sampling frame, convenience sampling, self-selection, use of financial incentives, lack of randomization). Lack of validated tools[30,33,34,36,38,40,43] and/or no control group[30-34,36,37,39,40] limited the quality of 11 of the 17 studies. Only 4 studies reported research questions or hypotheses. [30.33,41,45] Two studies had significant loss (40% or greater) at follow-up (posttests).[31,37] Almost all studies included self-report (subjective) data; in uncontrolled studies, confounders affecting opinions were not identified or considered in study design or analysis. Most studies did not clearly explain analyses or fully report results of analyses (eg, significant differences claimed based on pooled data, where pooled results were not reported).

When compared to quality scores, there was no apparent relationship between the impact of e-learning interventions and quality, based on Kirkpatrick's hierarchy. Conversely, BEME strength of findings for each study showed a trend, with higher-quality studies receiving higher ratings on the BEME scale.

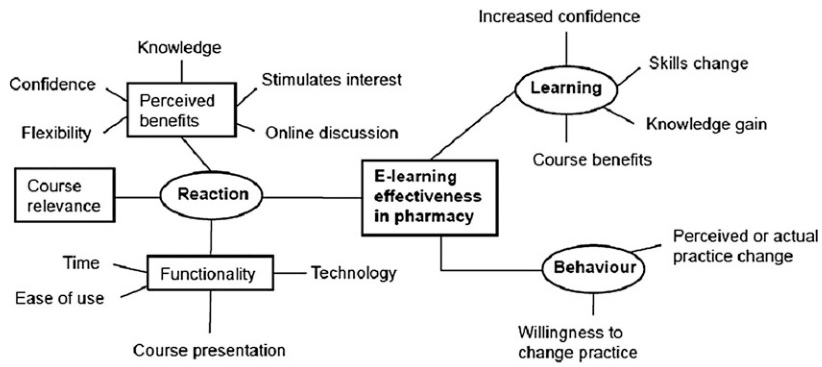

Figure 2. Thematic map of e-learning effectiveness concepts in pharmacy education.

DISCUSSION

This review is the first to comprehensively examine the effectiveness of e-learning in pharmacy education. Effectiveness is a complex, theoretical construct; here we used Kirkpatrick's hierarchy to guide the development of a detailed e-learning effectiveness map in pharmacy education. Our primary interest was effective learning. Eleven studies evaluated knowledge change. Ten studies conducted pre- and post-intervention tests only, and 1 study conducted an additional 2 follow-up tests.[39] All reported a significant improvement in knowledge after e-learning, although the magnitude of the gain varied widely (7% to 46%). This confirms that e-learning in pharmacy education is effective at increasing knowledge immediately after training. Additionally, in comparisons, e-learning was as effective as traditional learning and superior to no training. These results concur with the breadth of literature demonstrating effectiveness of e-learning in developing knowledge, in other professions.[8,9,16-22] However, long-term knowledge change as a result of e-learning remains unknown.

Table 4. Quality of Studies Included in a Systematic Review of eLearning in Pharmacy Education

First Author, Year[ref]	Reporting/3	Design And Methodology/6	Analysis/1	Overall Quality Score/10	Kirkpatrick's Hierarchy (Impact of Intervention)[a]	BEME Rating (Strength of Findings)[b]
Congdon, 2007[38]	1	2	1	4	1, 2b	4
Crouch, 2004[39]	1	2	1	4	1, 2b	3
Elliott, 2004[40]	2	2	0	4	1, 2a	2
Tsugihashi, 2007[36]	2	2	0	4	1	1
Buxton, 2010[33]	2	3	0	5	1	2
Freeman, 2006[44]	2	3	0	5	1	3
Hughes, 2007[34]	2	3	0	5	1, 2a, 2b, 3	2
Sweet, 2006[32]	2	2	1	5	1, 2b	3
Battaglia, 2010[30]	2	3	1	6	2a, 2b	3
Flowers, 2008[42]	2	3	1	6	2b	3
Hall, 2006[31]	2	3	1	6	2a, 2b, 3	3
Walters, 2010[37]	2	4	0	6	1, 2a	3
Rheuter, 2012[46]	2	4	0	6	1, 2a, 2b, 3	3
Lancaster, 2010[43]	2	4	1	7	1, 2b	3
Erickson, 2001[41]	3	4	1	8	2b	5
Legris, 2010[35]	2	5	1	8	1, 2b	4
Lust, 2004[45]	3	5	0	8	2a	4

Overall quality score: 0-4: low; 5-7: moderate; 8+: high. Mean (SD) quality for all studies: 5.70 (1.40); for comparator studies: 6.60 (1.67); for noncomparator studies: 5.33 (1.15); for studies evaluating stand-alone e-learning: 6.20 (1.40); for hybrid/blended courses: 4.83 (1.17).

[a] Levels: 1=satisfaction or opinions; 2a=modification of attitudes; 2b=measured knowledge or skills change; 3=practice change. No studies measured level 4 concepts.

[b] BEME rating: 1=no clear conclusions; 2=results ambiguous; 3=conclusions probably based on results; 4=results are clear and likely to be true; 5=results are unequivocal.

Attitudinal change (assessed as pre and post e-learning ratings) evaluated professional confidence in performing tasks and perceived knowledge. The evidence, while significant was realistically limited. In all cases assessment was subjective, gleaned through questionnaires with rating scales and survey instruments. Improvements in attitude were seen immediately after e-learning. However, the results need to be interpreted with caution: scale format data should not be analyzed on an item-by-item basis, and ordinal data is at risk of distortion when reported as mean scores, as occurred in 4 studies.[30,33,34,37,47,48] There was no evidence of long-term change in attitude.

We also primarily defined effectiveness as change in skills or practice. The evidence for effectiveness in these terms was limited and generally based on self-report data from small groups.[30,31,34,41] Only 1 study employed sufficient methodological rigor to objectively report a positive change in skills after e-learning.[35] To conduct objective skills or practice assessments is costly and time consuming, and requires greater dedication than objective knowledge assessments. However, the goal of quality education must be to improve skills and practice, and research should be directed to address this. There were no e-learning effectiveness studies for organizational change or patient benefit – the highest level in Kirkpatrick's hierarchy. Translational research is required to determine the benefits of e-learning at this level.

Our secondary aim was to assess effectiveness as reactions to e-learning programs. Effectiveness measures for reactions included perceived benefits of e-learning, relevance of the specific e-learning course, and e-learning functionality. Most pharmacists agree that e-learning formats stimulate interest, provide flexible alternatives to traditional methods, and are easy to use. There is limited evidence for acceptance of technology used in e-learning, although technology is central to the process. This may be because the Internet is so inherently a part of everyday life that the details of technology are overlooked in research. Poor recordings or difficult access can lead to bad learning experiences. Further, as students (as part of the millennial generation) embrace other e-learning opportunities such as social media applications or massive open online courses (MOOCs), continued evaluation of e-learning technology will be essential. Finally, courses were presented in a myriad of formats, and satisfaction with course design and educational content was generally high.[31,32,35,37,39,40,44-46]

Overall, the findings of these studies show that learners consider e-learning a highly acceptable instructional format in pharmacy education. However, we acknowledge the risk that ratings may have been subject to response bias and that respondents' impressions may have changed over time after completing the e-learning course. Opinions may be affected by external factors, especially in times of stress (eg, pharmacy students may score ratings differently after examinations compared to usual coursework); however, this is true for any instructional format. Finally, what we observed is missing from e-learning satisfaction research is the impression of the educator.

Our study has several limitations. We limited the eligibility criteria for inclusion in the study to those studies that reported evaluations of the effectiveness of e-learning in pharmacy education. Other research evaluating effectiveness alongside different constructs may have been overlooked. Although 2 reviewers independently abstracted the data, differences in study interpretation may have impacted the data obtained, as evidenced by the low to moderate agreement within some of the data extraction levels. Although overall quality was moderate, study methodological quality was generally low. Three particular flaws stood out: selection bias, lack of control groups, and lack of validated tools. Most studies were conducted within a narrow sampling frame, did not employ appropriate control groups, and used only partially validated or non-validated tools, thus limiting internal and external validity. We attempted to synthesize results for a group of studies that held only 2 commonalities: pharmacy and e-learning. Interventions, topics, duration, and setting were different for every study. However, while this may have affected combination of results, the fact that e-learning was effective in different environments may support generalizing these results. Further, we acknowledge that all included studies reported significant (and positive) effects, and that publication bias was likely to exist. Lastly, we synthesized the evidence for pharmacists and pharmacy students as one. We recognize each have distinct learning needs, motivations, and environments. As pharmacy students progress to pharmacists, learning styles may change. Future reviews should identify specific aspects of effective e-learning for each population.

In the context of the broader literature, our review adds e-learning as an effective instructional method in pharmacy education, to the evidence that it is effective for other health professions.[7,9,19,22] Individual e-learning programs should continue to be evaluated for effectiveness, not to answer the question of whether e-learning works in pharmacy, but to inform educators and decision makers that the program itself is effective. There are 2 key reasons why this matters. First, e-learning programs are often developed for large-scale distribution; thus, confidence that the program will effectively teach (often complex) pharmacy topics is essential. Second, e-learning programs may not always be subject to the same scrutiny that traditional programs undergo, especially those developed by smaller organizations specifically for a target audience.

Finally, 13 of the 17 studies reviewed evaluated more than 1 effectiveness measure, in some cases using multiple methods. Problems with reporting, methodology, and thus quality may stem from this multiple outcome approach, suggesting that effectiveness studies of e-learning in pharmacy education are trying to address too many questions at once. Now that we know e-learning is effective in the short-term, it may be more useful to see well-conducted research that reports the long-term effectiveness of e-learning in pharmacy education (defined by 1 or 2 measures only) rather than broad snapshots of immediate impact.

CONCLUSIONS

E-learning has been studied as an instructional format across a range of pharmacy education topics and contexts for decades, yet until now there have been no reviews on the effectiveness of e-learning in pharmacy education. In this review, we found e-learning to be effective at increasing knowledge immediately after training for all topics and in all contexts. Therefore, we can generalize that e-learning in any context should improve knowledge. E-learning in pharmacy education was a highly acceptable instructional format for pharmacists and pharmacy students, although this measure of effectiveness, by its nature was assessed subjectively and is open to criticism. There is little evidence that e-learning improved skills or professional practice and no evidence that e-learning is effective at increasing knowledge long term. There is room for improvement in the quality of e-learning effectiveness research in pharmacy. Properly validated tools, follow-up research, and translational research are required to answer new questions about the effectiveness of e-learning in pharmacy education.

ACKNOWLEDGEMENTS

Sandra Salter is the recipient of a University Postgraduate Award and UWA Top-Up Scholarship, provided by The University of Western Australia. There were no other funding arrangements for this study.

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Appendix 1. Criteria for Quality Assessment of Included Studies

	Reporting	Design and Methodology	Analysis
Quality criteria	Study context and aims clearly stated	Type of study (eg, RCT, ITS, crosssectional) and rationale clearly stated	Analyses conducted clearly stated
	E-learning and control interventions (including their delivery) clearly stated	Measurements timed appropriately for stated outcomes	Rationale for analyses explained
	Intervention and control participants clearly stated	Sampling frame, recruitment and sample selection clearly stated and appropriate	Analysis control for confounding/bias
	Completeness of follow up stated	Design control for bias (incentives, ethics approval, allocation method, blinding, power and sample size calculation, funding)	Unexpected outcomes reported
	Prespecified outcomes fully reported	Use and validation of tools clearly stated	
Bias assessed	Reporting bias, attrition bias	Selection bias, detection bias	Reporting bias, performance bias
Maximum designated points	15 points	30 points	4 points
Calculated maximum score[a]	3 points	6 points	1 point

[a] Scoring was embedded in DistillerSR, with designated points scored for each criterion. Total designated points were converted to a maximum of 3 points for reporting, 6 points for design and methodology, and 1 point for analysis.