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REVIEW

Impact of the educational technology use in undergraduate pharmacy teaching and learning – A systematic review

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Keywords
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Abstract

Background: Educational technology has been increasingly used in recent years in pharmacy education. Its benefit on teaching and learning as well as its intention of use should be determined. **Aims:** To understand the technological approaches used in pharmacy education, and the impact of each approach on teaching and learning. **Method:** Four databases (PubMed, EMBASE, PsycINFO and ERIC) were searched to identify studies that described the use of technology in undergraduate pharmacy teaching and learning. **Results:** Thirty-four papers met the inclusion criteria. Majority of the studies (59%) used simulation technologies adopting a situated learning approach to complement or enhance teaching and learning. Most of the studies reported change in two or more concepts of the Kirkpatrick's model, namely Reaction, Learning, and Behaviour, indicating improvement in learning experience, engagement, and performance. **Conclusion:** Educational technology with design features aligned with effective pedagogical theories seemed more likely to produce positive student outcomes.

Introduction

Online synchronous and asynchronous learning, both in science, technology, engineering, and medicine (STEM) and non-STEM education, have been used in higher education for almost two decades. Asynchronous learning, in particular, is increasingly transforming the way education is being delivered. The development can be attributed to the change in the learning behaviour of the millennial generations, and more importantly, to the findings that blended learning improves learning effectiveness (Crouch, 2009; McLaughlin *et al.*, 2015). The shift of the paradigm, as well as the increased demand of using innovative, advanced, and contemporary educational technology in higher education as a mode of teaching and learning, highlights the needs to ascertain that these technologies help to achieve the learning outcomes that were not achieved previously and that the technology is not developed just to satisfy the quest for its use.

A review by Salter and the authors (2014) on the effectiveness of e-learning in pharmacy education concluded that e-learning effectively increases knowledge and is a highly acceptable instructional format for students. But they also noted there was limited evidence that supports e-learning improves skills or professional practice, and there was no evidence that e-learning increases knowledge in the long term (Salter *et al.*, 2014). Since the review in 2014, there has not been any update or similar systematic review conducted, suggesting a timely review of the subject is necessary. The lack of evidence of the benefit of e-learning on long term knowledge gain could be because this effect is difficult to demonstrate from relatively short interventional studies. However, examining the pedagogical theory or strategy adopted by researchers during the design of their e-learning tools, which was not done in the previous review, may lead the authors to the long term impact of an approach to learning. This paper aimed to review the current use of technology in pharmacy education, specifically on its relevance and effectiveness and attempted to address the limitations noted in Salter and the authors' (2014) review. With the increased abundance, variety, and access to synchronous and

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asynchronous learning tools, the focus of this paper was on technologies that were developed to enhance learning rather than studies that reported the use of e-learning only. The term technology-enhanced learning (TEL) is often utilised to describe a broad field of digital technologies used to support and mediate educational activities. In this review, the term TEL is used to describe totally digitally mediated activities and those that are blended with more traditional educational approaches, as detailed in the study inclusion criteria.

Method

Data sources and search

This review was conducted in accordance with the PRISMA guidelines. The following four databases, PubMed, EMBASE, PsycINFO, and ERIC, were searched from database inception to February 2019 for articles describing the use of technology to complement learning and teaching in the undergraduate pharmacy programme. The full electronic search strategy used was described in Appendix A. Search terms used include: blended, computer-assisted, computer-based, digital, electronic (E), electronic, mobile, information communication technology (ICT), information technology (IT), pharmacy, pharmacy education, and virtual.

Study inclusion

Articles were included if the studies meet the following criteria: 1) described an educational intervention to support and mediate educational activities; 2) used technologies to complement or enhance the learning experience, performance, or self-efficacy; and 3) were published between 2009 to 2019. Studies were excluded if they were non-research articles, discussed curriculum design, were conducted for distance learning programmes, or involved graduate pharmacists.

Article selection, data extraction, and quality appraisal

All records were exported into Endnote X8 (Clarivate Analytics, Philadelphia, PA, USA) and de-duplicated. Articles were screened by title and abstract by two independent reviewers, CYL and SWHL, for eligibility based upon the inclusion/exclusion criteria mentioned above. Any disagreement was resolved through a discussion between the two reviewers. Full text of relevant articles was retrieved and independently extracted using a data extraction form, which has been previously piloted for this review. Data extracted include: 1) the study characteristics such as the authors and the year of publication; 2) the description of the TEL tool; 3) participants; 4) assessment technique and measurement tools used; and 5) outcomes. A meta-narrative approach to synthesis was adopted since there was variation between studies in terms of the study design, intervention, outcomes, and study methods. The studies were described based on the technologies used and the key outcome measured in each study. According to Kirkpatrick's hierarchy model (Kirkpatrick, 1996), these were broadly themed and categorised to yield a concept map (Figure 1).

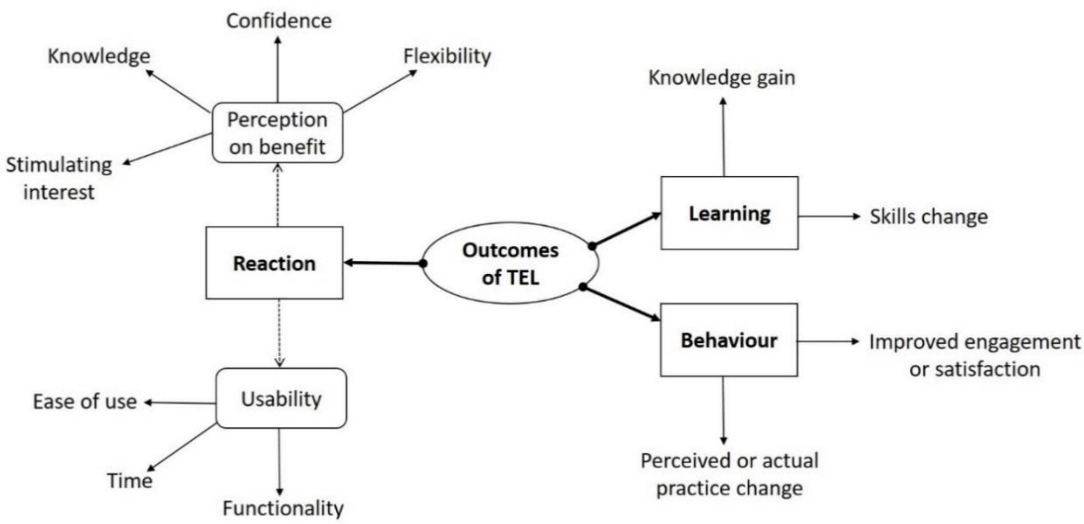

Figure 1: Categorisation of technology-enhanced learning (TEL) outcomes according to Kirkpatrick's hierarchy model

Kirkpatrick's hierarchy model

The model, first introduced in 1959 by Donald Kirkpatrick, aimed to clarify the meaning of evaluation and offer guidelines on how to get started and proceed. It consists of four levels of evaluation, which was described in the following order – 'reaction', 'learning', 'behaviour', and 'results'. The model stood the test of time, as the content has remained unchanged when revisited in 1996.

'Reaction' is a measure of satisfaction to allow management to make decisions about training and to ensure that participants are motivated and interested in learning. 'Learning' is a measure of the knowledge acquired, skills improved, or attitudes changed due to training. 'Behaviour' is a measure of the extent to which participants change their on-the-job behaviour because of training. 'Results' is a measure of the final results that occur due to training (Kirkpatrick, 1996). Although the model was conceptualised for evaluating training programmes in the cooperate world, it shares similarity with the evaluation of a teaching and learning process in education. The purpose of evaluation, i.e. training, and participants of the training, can be referred to as the teaching and learning process, and students, respectively, while the management is the academics.

Results

Characteristics of identified studies

There were 1,105 papers identified from the database search, and 1,005 papers were excluded as they were either not related to the pharmacy programmes, non-research in nature or did not assess the learning outcomes. The full text of the remaining 100 papers was examined, and 66 papers, which did not meet all the inclusion criteria, were further excluded. Thirty-four papers considered suitable for review were analysed for their TEL settings as well as the learning outcomes achieved (Figure 2).

The included studies were from the United States (n=16), Europe (n=9), Australia (n=4), Asia (n=3), Fiji (n=1), and Brazil (n=1) (Table I).

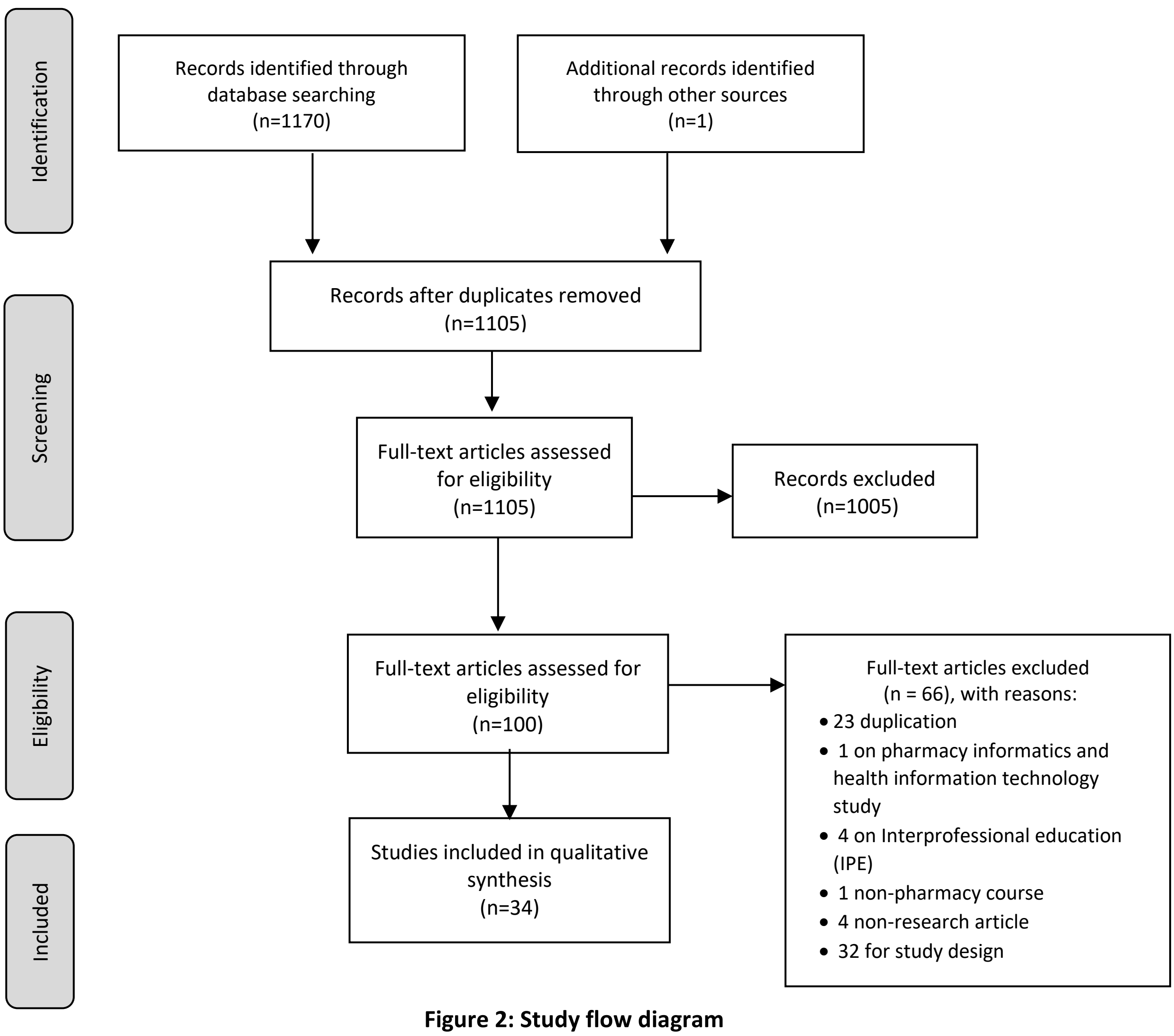

Figure 2: Study flow diagram

Table I: Characteristics of the included studies

First author, Year (Country)	Number of participants, Year of study in Pharmacy course	Topic delivered by e-learning	E-learning intervention	e-learning setting	No of session	Comparator	Kirkpatrick's hierarchy assessed		
							Reaction	Learning	Behaviour
Al-Dahir, 2014 (USA)	119, 4th	Pharmacy practice	Virtual patient cases using DecisionSim software	Online	NR	PBL groups	x		
Alsharif, 2009 (USA)	160, 1st - 5th	Medicinal chemistry	Integrated pre-requisite information electronically using SoftChalk	Online	NR	No integration of information	x		
Ambroziak, 2018 (USA)	85, 1st	Pharmacy practice	Virtual dispensing, MyDispense	Online	NR	NA	x		x
Barnett, 2016 (USA)	134, 3rd	Pharmacy practice	Virtual patient case using Case Scenario/Critical Reader Builder authoring tool	Online	NR	Paper case	x	x	x
Benedict, 2010 (USA)	107, 3rd	Pharmacy practice	Virtual patient case using DecisionSim software	Online	3	NR		x	x
Benedict, 2013 (USA)	106, 3rd	Pharmacy practice	Virtual patient case using DecisionSim software	Online	3	NR	x		x
Berger, 2018 (Switzerland)	70, 5th	Pharmacy practice	Serious game developed using an authoring tool ITyStudio	Online	1	Text-based scenario	x		
Bernaitis, 2018 (Australia)	28, 4th	Oncology pharmacotherapeutics (pharmacy practice)	Virtual patient case using DecisionSim software	Online	NR	Without exposure to DecisionSim		x	x
Bindoff, 2014 (Australia)	33, 3rd & 4th	Pharmacy practice	Simulation of a community pharmacy using Unity3D	Online	2	Paper-based	x	x	x
Bryant, 2017 (USA)	67, 1st	Basic health sciences laboratory	Case studies developed using iSolve for mobile devices (iPad, iPhone, smartphone & tablet computer)	Online	1	NA	x		
Cavaco, 2012 (Portugal)	194, 4th & 5th	Pharmacy practice	Virtual patient technology to simulate and replace real-life clinical scenario	Online	NR	Without virtual patient experience	x		
Coyne, 2018 (USA)	18, 1st	Pharmacy education	Virtual reality (VR) as a platform to provide engaging elements for team-based learning	VR	NR	None	x		x
Ezeala, 2013 (Fiji)	42, 2nd	Pharmacology	Simulated practical sessions with CyberPatient 2007 software and Virtual Organ Bath computer software	In-class	1	NA		x	
Ferrone, 2017 (USA)	241, 3rd	Dispensing (practice skills)	Virtual dispensing, MyDispense	Online	12	NA	x		x
Flowers, 2010 (USA)	79, 4th	Pharmacy practice	Multimedia vignettes on complex drug administration technique	Online	NR	Students who did not access the vignettes		x	
Gustafsson, 2017 (Sweden)	42, 4th	Pharmacy practice	3D virtual world in clinical pharmacy teaching	Online	NR	None	x		x
Hall, 2017 (Australia)	24, 3rd	Medicinal chemistry	3D printed molecular modelling tools	In-class	NR	Non-participants		x	x

First author, Year (Country)	Number of participants, Year of study in Pharmacy course	Topic delivered by e-learning	E-learning intervention	e-learning setting	No of session	Comparator	Kirkpatrick's hierarchy assessed		
							Reaction	Learning	Behaviour
Harrap, 2016 (United Kingdom)	170, NR	Pharmaceutical calculation	Calculations e-package	Online	NR	None	x	x	
Henriksen, 2012 (Netherlands)	56, 1st	Medicinal chemistry	A learning management system to allow distance students to hear and view students on campus and participate in workshop, quizzes, and problem-solving	Online	1		x		
Kurono, 2015 (Japan)	470, 1st - 4th	Communication skills (practice skills)	DocCom - a communication learning tool	Online	NR	before and after intervention	x	x	
Lean, 2018 (Malaysia)	120, 2nd	Pharmacy practice	Web-based online learning module to teach communication skills	Online	NR	NA		x	x
Lee, 2018 (Malaysia)	30, 2nd	Pharmacology	Articulate storyline software for teaching and gamification	Online	1	NA	x		x
Marriott, 2012 (Australia)	34, 1st - 4th	Pharmacy practice	Resource platform consisting of a fictional community of people to augment learning in an undergraduate pharmacy programme and to refine patient contact skills	Online	Variable	NA	x		
Mattsson, 2016 (Sweden)	36, 4th	Drug formulation	Virtual tablet machine	Online	1	NA	x		x
McLaughlin, 2015 (USA)	95, 2nd	Cardiovascular pharmacotherapy	Interactive online module to replace lecture	Online	NR	Did not access all segments of the online module		x	x
Menendez, 2015 (Brazil)	31, NR	Pharmacy practice	A virtual patient system to teach communication skills	Online	NR	NA	x		
Nazar, 2018 (United Kingdom)	53, 2nd	Pharmacy law	Video format of illustrative tutorials, where the audio talked through the element of pharmacy law, whilst a digitalised hand-illustrated visual aids to accompany and support that information	Online	9	NA	x		x
Reinhold, 2010 (USA)	27, 2nd	Substance abuse and drug diversion	Web-based educational module	Online	NR	NA	x	x	
Richardson, 2013 (United Kingdom)	40, 2nd	Medicinal chemistry	Molecular visualisation software PyMol. Images projected using KAVE	In-class	1	3D group vs 2D group		x	x
Smith, 2016 (USA)	102, 3rd	Pharmacy practice	Virtual patient case using DecisionSim software	Online	3		x	x	x
Springer, 2011 (USA)	45, 5th	Pharmacogenomics	Instructional GeneScription software system to teach a new topic	Online	8	None	x		
Taglieri, 2017 (USA)	281, 3rd	Pharmacy practice	Web-based Shadow Health Digital Clinical	Online	NR	VP before and after mock clinic visits	x	x	

First author, Year (Country)	Number of participants, Year of study in Pharmacy course	Topic delivered by e-learning	E-learning intervention	e-learning setting	No of session	Comparator	Kirkpatrick's hierarchy assessed		
							Reaction	Learning	Behaviour
			Experience virtual patient to teach clinical skills						
Zlotos, 2010 (Scotland)	243, 3rd	Pharmacy practice	SCRIPT to compliment classroom teaching of competency-based pharmacy practice	Online	NR	Non-user of SCRIPT	x	x	
Zlotos, 2015 (Scotland)	433, 3rd	Simulated prescription analysis (pharmacy practice)	Computerised randomised interactive prescription tutor (SCRIPT)	Online	NR	Extent of technology integration	x		

NR=not reported; PBL=problem-based learning; NA=not available

In terms of the study design, eight were randomised controlled trials, 22 were quasi-experimental studies, three were case-control studies and one cross-sectional survey. The majority of the studies were from pharmacy practice (n=20), followed by medicinal chemistry (n=4), pharmacology (n=3), and specific therapeutic areas such as pharmacogenetics, drug abuse, pharmaceutics, pharmacy law, pharmacy education, calculations and laboratory science. The total number of participants ranged from 18 to 470, encompassed students from the first year to the fifth year of their study.

Pharmacy practice

Fourteen or 70% of the pharmacy practice studies described the use of virtual patient technology (Benedict, 2010; Cavaco & Madeira, 2012; Benedict *et al.*, 2013; Al-Dahir *et al.*, 2014; Bindoff *et al.*, 2014; Menendez *et al.*, 2015; Barnett *et al.*, 2016; Smith *et al.*, 2016; Ferrone *et al.*, 2017; Gustafsson *et al.*, 2017; Taglieri *et al.*, 2017; Ambroziak *et al.*, 2018; Berger *et al.*, 2018; Bernaitis *et al.*, 2018). The remaining 30% involved the use of simulated prescription (Zlotos *et al.*, 2010; Zlotos *et al.*, 2015), web-based multimedia vignettes (Flowers *et al.*, 2010), learning module (Lean *et al.*, 2018), communication tool (Kurono *et al.*, 2015), and a resource platform consists of a fictional community of people (Marriott *et al.*, 2012).

Pharmacology and medicinal chemistry

The software known as GeneScription that displays patient pharmacogenomics profile was used to enhance the knowledge and skills required in making clinical decisions (Springer *et al.*, 2011). Other approaches used in pharmacology teaching included simulated patient and organ software for practical sessions (Ezeala *et al.*, 2013) and interactive pharmacotherapy module for blending learning of the subject (McLaughlin *et al.*, 2015; Lee *et al.*, 2018). In medicinal chemistry, researchers created online learning modules to evaluate the appropriateness of distance learning of the subject (Alsharif & Henriksen, 2009; Henriksen & Roche, 2012) and used 3-dimensional printing technology to teach drug-receptor interactions (Richardson *et al.*, 2013; Hall *et al.*, 2017).

Other topics

Web-based instructional modules were developed for the teaching of drug abuse and diversion (Reinhold *et al.*, 2010) and pharmacy law (Nazar *et al.*, 2019); virtual reality technology was tested for its effect on learning experience (Coyne *et al.*, 2018); e-calculation tool to teach pharmaceutical calculation (Harrap *et al.*, 2016); virtual tablet machine to teach drug formulation (Mattsson *et al.*, 2016), and mobile devices for solving case studies of basic health sciences (Bryant & Richard, 2017).

Categorisation of papers based upon Kirkpatrick's model

The papers reviewed fall in three of the four levels of Kirkpatrick's model, namely 'reaction', 'learning', and 'behaviour', with 22 or 65% of the studies demonstrated more than one level of Kirkpatrick's model. Specifically, 13 of the 16 studies, which have reported improved experience or engagement (81%, Behaviour level), were also perceived to have benefits on knowledge (four studies, Reaction level) or have led to knowledge gain (nine studies, Learning level).

Overall, 32% of the studies reported students satisfaction with the TEL, perceiving benefits on knowledge (Springer *et al.*, 2011; Cavaco & Madeira, 2012; Henriksen & Roche, 2012; Marriott *et al.*, 2012; Benedict *et al.*, 2013; Kurono *et al.*, 2015; Menendez *et al.*, 2015; Mattsson *et al.*, 2016; Gustafsson *et al.*, 2017; Lee *et al.*, 2018), 41% reported positive outcome on knowledge gain (Benedict, 2010; Flowers *et al.*, 2010; Reinhold *et al.*, 2010; Zlotos *et al.*, 2010; Ezeala *et al.*, 2013; Richardson *et al.*, 2013; Bindoff *et al.*, 2014; McLaughlin *et al.*, 2015; Barnett *et al.*, 2016; Harrap *et al.*, 2016; Smith *et al.*, 2016; Hall *et al.*, 2017; Bernaitis *et al.*, 2018; Lean *et al.*, 2018), which was determined either from measuring the difference in test scores before and after the intervention, or from examination performance, and 47% noted improved learning experience or engagement (Table II).

Table II: Outcomes of studies, themed against Kirkpatrick's four levels model

Study outcomes	Number of studies
Reaction	
• Perceived benefits on:	
○ Knowledge	11
○ Confidence	6
○ Flexibility	4
○ Stimulates interest	10
○ Online discussion	0
• Functionality:	
○ Technology	2
○ Ease of use	8
○ Time	3
Learning	
• Knowledge gain	14
• Increased confidence	0
• Skills change	4
Behaviour	
• Improved engagement or satisfaction	16
• Perceived or actual practice change	3
• Willingness to change practice	0

Discussion

Pharmacy practice was the discipline that has used educational technology the most, and the majority of the studies adopted virtual or simulation technologies. A virtual learning environment is a situated learning approach as it takes learners through the processes to yield the desired knowledge (Rutto, 2017). The virtual patient programmes reviewed enabled students to identify the patient's problem and make a recommendation, and provided feedback to students based on the recommendation that students made. Simulation technologies have also been used in and benefited other pharmacy disciplines. In medicinal chemistry and pharmacology, simulation, which allows visualisation rather than imagination of the molecular structures, has enhanced students understanding of drug-receptor interactions (Richardson *et al.*, 2013). This is expected because simulation offers opportunities for active and engaging learning (Cain & Fox, 2009). Its benefits, therefore, should not be limited to the teaching and learning of complex clinical concepts or professional skills. The majority of the simulation studies reported perceived benefits on knowledge or practice skills, an example of Reaction level based on Kirkpatrick's model, increased knowledge gain (Learning level) and improved learning experience or engagement (Behaviour level). The benefits of simulation are unequivocal, but other TEL tools have generated positive outcomes as well.

In a study by Lee and authors (2018), students who were introduced to an interactive learning software for the learning of pharmacology perceived improvement in their understanding of concepts and principles of the subject and found the TEL interesting and engaging. Four other studies reviewed, which also did not use simulation technologies (Richardson *et al.*, 2013; McLaughlin *et al.*, 2015; Hall *et al.*, 2017; Lean *et al.*, 2018), reported improvement in learning and engagement. Self-directed learning (SDL) is defined by Gibbons (2002) as an increase in knowledge, skill, accomplishment, or personal development brought about by an individual's own effort in any circumstances at any time. A simulation that fosters clinical decision-making skills promotes SDL, and SDL encourages life-long learning (Benedict *et al.*, 2013). In line with the definition of SDL, it is anticipated that if a TEL is successful in achieving its intended outcomes, the knowledge change may be long-term, and the tool may not necessarily be a simulation technology. On this note, whether or not a TEL will encourage SDL may depend on how the technology has changed students' Reaction, Learning and Behaviour, or Reaction and Behaviour, or Learning and Behaviour.

Compared to the educational technologies reviewed previously (Salter *et al.*, 2014), which involved mostly learning management platforms, more advanced and more varieties of technologies are used in pharmacy education. They ranged from highly interactive simulation technologies for patient counselling, tablet production, devices demonstration, and experimental process to technologies that aimed to provide immersive learning experience such as virtual reality.

Studies that focused on improving knowledge of specific subjects or skills have generally been successful. These studies include tablet formulation, pharmacy law, pharmaceutics calculation, pharmacokinetics, and pharmacodynamics. They used strategies consistent with transformed practice and constructivist learning theories. Transformed practice is a pedagogy that enables learners to put learned knowledge into practice or transfer meaning-making to work in a new social context (The New London Group, 1996). This pedagogy was exemplified by Springer and the authors (2011) in their study. They developed a GeneScription software to allow the screening of drug-gene interaction during the prescription filling process, thereby allowing students to make decisions of altering the dose of the drug based on the pharmacogenomics information provided by the system. Meanwhile, constructivist learning theories emphasise the active involvement of the learners during the knowledge construction process (Rutto, 2017). Active learning strategies such as providing an opportunity for interaction with others or an environment are used to engage students in the learning process (Jonassen, 1999). Situated learning, a learning theory categorised under constructivism, is demonstrated more often than other learning theories in the present review. Effective implementation of the strategies of constructivism is able to improve students knowledge and interest (Reaction) and engagement and motivation (Behaviour) in the learning of a multidisciplinary subject such as pharmacotherapy (Lee, 2020). This may explain, in part, the success of the studies in demonstrating outcomes described by Kirkpatrick’s model.

The present study was limited by the inclusion criteria, where only studies that have measured learning outcomes were included. Research that evaluated the usability of new technology but without measuring students’ reaction, learning, behaviour, and performance from the use of the technology was excluded. As the main intention of the present review was to understand if the recent used of technologies has enhanced teaching and learning in pharmacy education, this study excluded approaches that were reviewed before as well as those that have been commonly used, such as recorded lectures and forums. There may be a possibility of overlooking some relevant studies due to the limitation of the search databases and that the search terms were not exhaustive enough to capture all the studies.

Conclusion

This study showed that there were benefits of the rapid advancement of current technologies as there was an improvement in students learning experiences, knowledge, and professional skills. Simulation technologies were used in all pharmacy disciplines and were mostly successful in achieving the above outcomes. Other TEL approaches have also improved students’ performance through increasing the interactive features of the design (for better engagement), addressing the knowledge gaps (between classroom and practice), and increasing access to resources (for better guidance). Regardless of the disciplines, the constructivist learning strategy and the transformed practice strategy are among the pedagogical theories indicated in the above studies.

Conflicts of interest

The authors declare no conflict of interest.

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Appendix A. Sample search strategy

Sample search strategy used in the present systematic review in PubMed. This was adapted for the databases ERIC, EMBASE via Ovid and PsychINFO.

1. electronic
2. blended
3. distance
4. computer assisted
5. computer based
6. digital
7. electronic
8. mobile
9. information communication technology
10. ICT
11. information technology
12. IT
13. virtual
14. #1 OR #2 OR #3 OR #4 OR #5 OR #6 OR #7 OR #8 OR #9 OR #10 OR #11 OR #12 OR #13
15. education
16. education program
17. learning program
18. knowledge
19. #15 OR #16 OR #17 OR #18
20. pharmacy
21. pharmacist*
22. #20 OR #21
23. #14 AND #19
24. #22 AND #23