Effectiveness of online learning interventions on student engagement and academic performance amongst first-year students in allied health disciplines: A systematic review of the literature

S. Kumar[1] & G. Todd[2]

Abstract

Introduction: Online learning has increased in popularity due to its perceived ability to improve access for students. With advancements in technology, traditional barriers such as location, time and space can be readily overcome. However, despite its popularity, there continues to be ongoing debate regarding its effectiveness.

Methods: We searched commercially produced (six databases) and grey literature sources, limiting our search to humans and English language publications. Two reviewers independently screened the search results. Included studies were assessed for methodological quality assessment using the McMaster Critical Appraisal Tool for quantitative studies. Summarised data from the included studies were descriptively synthesised.

Results: We identified a modest body of evidence (19 studies) that indicates that online learning interventions may have a positive impact on student engagement and academic performance for first-year allied health students. This finding should be considered with caution due to methodological concerns about the low-level evidence base arising from lack of adequate and representative sampling, lack of clarity and descriptions regarding the interventions utilised and lack of psychometrically sound outcome measures, just to name a few.

Conclusions: There continues to remain key knowledge gaps in this field, such as who benefits the most, or the least, and the nature of any benefits and limitations, for which ongoing research is required.

Keywords: education; distance; students; health occupations allied health occupations; health personnel; systematic review; academic performance; educational measurement

[1] UniSA Allied Health and Human Performance, University of South Australia
[2] UniSA Clinical and Health Sciences, University of South Australia

Correspondence
Saravana Kumar
Saravana.Kumar@unisa.edu.au

Introduction

Early adoption of active learning approaches in tertiary education can promote deeper understanding of foundation knowledge. Foundation knowledge (e.g., anatomy, physiology and health literacy) is particularly important in medical and allied health degrees that rely heavily on problem-based learning and patient case studies in later courses (Unge et al., 2018). Problem-based learning and case studies help to prepare students to engage with, and care for, patients with individual needs and medical requirements. Failure to engage with, and adequately acquire, foundation knowledge can significantly impair student learning, knowledge transfer and the student's learning experience (Mayer, 2010).

In recent years, there has been a dramatic increase in the number and types of digital learning technologies available to help students to visualise complex anatomical structures, cell processes, pathological changes and/or clinical manifestations of disease (Fernandez-Lao et al., 2016). The factors that influence the selection, design and implementation of specific health-related digital learning technologies are numerous and diverse in nature. For example, pedagogy, cost effectiveness, flexibility, usability, reliability and how to better meet expectations of technology-savvy students are all important considerations (Bates, 2015). However, the success of a given digital resource is highly dependent on whether, and how meaningfully, students engage with the digital resource and if the engagement leads to improvement in the student learning experience and learning outcomes. Identifying specific attributes of digital learning resources that positively influence self-directed online learning (Hammarlund et al., 2015) and strategies that enhance and promote student engagement with digital learning resources could facilitate early adoption of active and collaborative learning behaviours in first-year health students. Early adoption of these skills and behaviours could improve students' learning experiences and performance throughout the remainder of their tertiary education and beyond.

While systematic reviews of online learning interventions in undergraduate and postgraduate courses have been previously reported (Feng et al., 2013; Pei & Wu, 2019; Rowe et al., 2019), there continues to be a paucity of reviews investigating these interventions specifically for allied health disciplines. Previous reviews have investigated online and blended learning approaches for health science students (Cappi et al., 2019; Coyne et al., 2018; Regmi & Jones, 2020) with mixed findings. These studies have highlighted that while online and blended learning approaches may be useful tools to improve students' knowledge and skills, there are also a number of barriers and enablers that impact online learning (such as interaction between learners and facilitator, learners' expectations and motivation, familiar technology and a pedagogical approach that puts learners at its centre). While these findings have a clinical focus and, therefore, could be generalisable to allied health disciplines, there may need to be a hybrid approach

for online teaching strategies in foundational courses such as anatomy, physiology and research. One of the few published examples of a systematic review involving education strategies related to foundational knowledge in allied health programs was conducted by Munn and Small (2017). This review focused on development of information literacy and academic skills of first-year health science students (Munn & Small, 2017), although it did not include any formal critical appraisal of the included literature.

The aim of the current systematic review was to identify evidence for the effectiveness of online learning interventions for first-year students within the allied health disciplines. This includes identifying characteristics of digital teaching resources that positively impact the learning experience and academic performance of allied health students. A novel feature of our systematic review is inclusion of only quantitative research and use of the McMaster Quantitative Critical Appraisal Tool (Law et al., 1998) to formally critique the scientific rigour of previously published studies involving digital teaching interventions. The results of the current systematic review will advance our understanding of the evidence for the effectiveness of online teaching interventions and identify factors that contribute to the successful implementation of digital learning strategies within allied health disciplines. Therefore, this systematic review aimed to address the following question: For first-year students within allied health disciplines, what is the evidence of effectiveness of online teaching on student engagement and academic performance?

Methods

The current systematic review was conducted based on guidelines and previous work involving systematic review methodology in health (Liberati et al., 2009) and higher education (Bearman et al., 2012). The specific inclusion and exclusion criteria for the systematic review are shown in Table 1. Given the nature of the review question with its focus on effectiveness, only quantitative research was included. Given the nature of this research project (systematic review), no ethical approval was required.

Searching the literature

The following electronic databases were searched: Medline, EMBASE, Scopus, Emcare, Web of Science, ERIC and PsychInfo. Pearling (scanning reference lists of included studies) was used to identify any additional publications from the included studies and secondary research (such as reviews). To avoid publication bias, a grey literature search through an internet web engine (Google) was also undertaken. Google Scholar (which contains peer-reviewed literature but access through the internet) was also searched to identify any additional publications. The search was conducted in November–December 2018.

Table 1

Overview of Inclusion and Exclusion Criteria for Participants, Intervention, Comparator, Outcome and Studies (PICOS)

Construct	Summary	Inclusion	Exclusion	Search terms
Participants	Students undertaking undergraduate studies within allied health disciplines in tertiary settings	Students who are enrolled in first-year allied health disciplines, including, but not limited to, the physiotherapy, pharmacy, podiatry, social work, speech pathology, dietetics, optometry, audiology, radiography, and exercise physiology health professions	Students who are enrolled in medical and nursing health disciplines or for postgraduate qualifications in any health-related disciplines (e.g., graduate entry, masters, doctorate)	physiol* or physiotherap* or physical therap* or occupational therap* or podiat* or pharma* or social work* or speech patholo* or dietit* or psychol* or nutritionist or optomet* or audiolog* or radiograph*
Intervention	Strategies to promote student engagement with online learning that are focused on the student, the educator and the environment	Interventions of interest include but are not limited to virtual classrooms, online meetings, problem-based learning, feedback, interaction, support, presence, community	Interventions that have a focus on teaching the use and uptake of digital technologies	digital learn* or online or e-learn* or engage*
Comparator	Students engaged in "usual" learning strategies	Comparators of interest include "routine" or "usual" learning strategies		
Outcome	Students' engagement with digital learning	Outcomes of interest include but are not limited to engagement, satisfaction, perceptions of learning, academic outcomes	Cost, resources	
Studies	Quantitative research	Published in English language; human; all primary quantitative research	Secondary research (such as literature reviews), qualitative research, conference presentations, opinion articles, editorials	

Literature selection

Once the chosen databases were searched and the duplicates removed using Endnote™, the resulting articles were manually screened as part of the literature selection process. As is best practice in the conduct and reporting of systematic reviews, a two-step literature selection process was utilised, whereby first, the titles and abstracts of articles

were screened against the inclusion and exclusion criteria. Subsequently, the full texts of the included articles were assessed against the inclusion and exclusion criteria. During both these steps, the screening of the articles was independently undertaken by the two reviewers (SK and GT), and any discrepancies resolved through discussion.

Risk of bias (methodological quality) assessment

The methodological quality of the included studies was appraised using the McMaster Critical Appraisal Tool (CAT) for quantitative studies (Letts et al., 2007). This tool is suited to appraise a range of different research designs and, hence, selected for this review. As this critical appraisal tool was originally developed for and applicable to health research, it was modified in two ways. First, those criteria that are not specific to educational research were modified (e.g., the criterion on clinical importance was changed to teaching and learning importance). Second, to provide a numerical rating, a simple scoring system was employed. Each "yes" response corresponded to one point and each "no" response corresponded to zero points. In order to ensure consistency in the appraisal process, 10% (n = 2) of the included studies were independently appraised by two reviewers (SK and GT) and scoring compared. Discrepancies between the two reviewers were resolved through discussion, and subsequently, the remaining studies were divided between the two reviewers. Studies were not excluded based on the quality score. However, this information was used to report, analyse and discuss the overall review findings.

Data extraction and synthesis

Customised, comprehensive data extraction forms were developed for this systematic review. A range of data items was extracted, including, but not limited to, origins of the study, the health discipline investigated, sample size, intervention used, parameters of intervention and outcomes reported (including data on statistical precision). Studies were categorised based on the types of online teaching interventions used and the outcomes measured, and the results of these studies were compared. Due to heterogeneity in terms of the populations studied and interventions tested, a meta-analysis was not undertaken following extraction. Instead, the summarised data from the included studies were descriptively synthesised.

Results

The initial search identified 1,842 studies from commercially produced literature and 12 from grey literature sources (which in the PRISMA flow chart are listed as "other sources").

Following the pooling of the search results from these sources and removal of duplicates, 1,733 studies were screened for titles and abstracts. One hundred and twenty-one studies were reviewed as full texts, of which 19 met the eligibility criteria (Figure 1). The most common reason for exclusion was ineligible population of interest, as many studies were conducted with students who were not in their first year of university studies or did

not have a background in allied health disciplines. Other reasons for exclusion included ineligible intervention (commonly a blended strategy) and ineligible design (qualitative research) to that which is of interest to this study.

Figure 1

PRISMA Flowchart of Selection Criteria

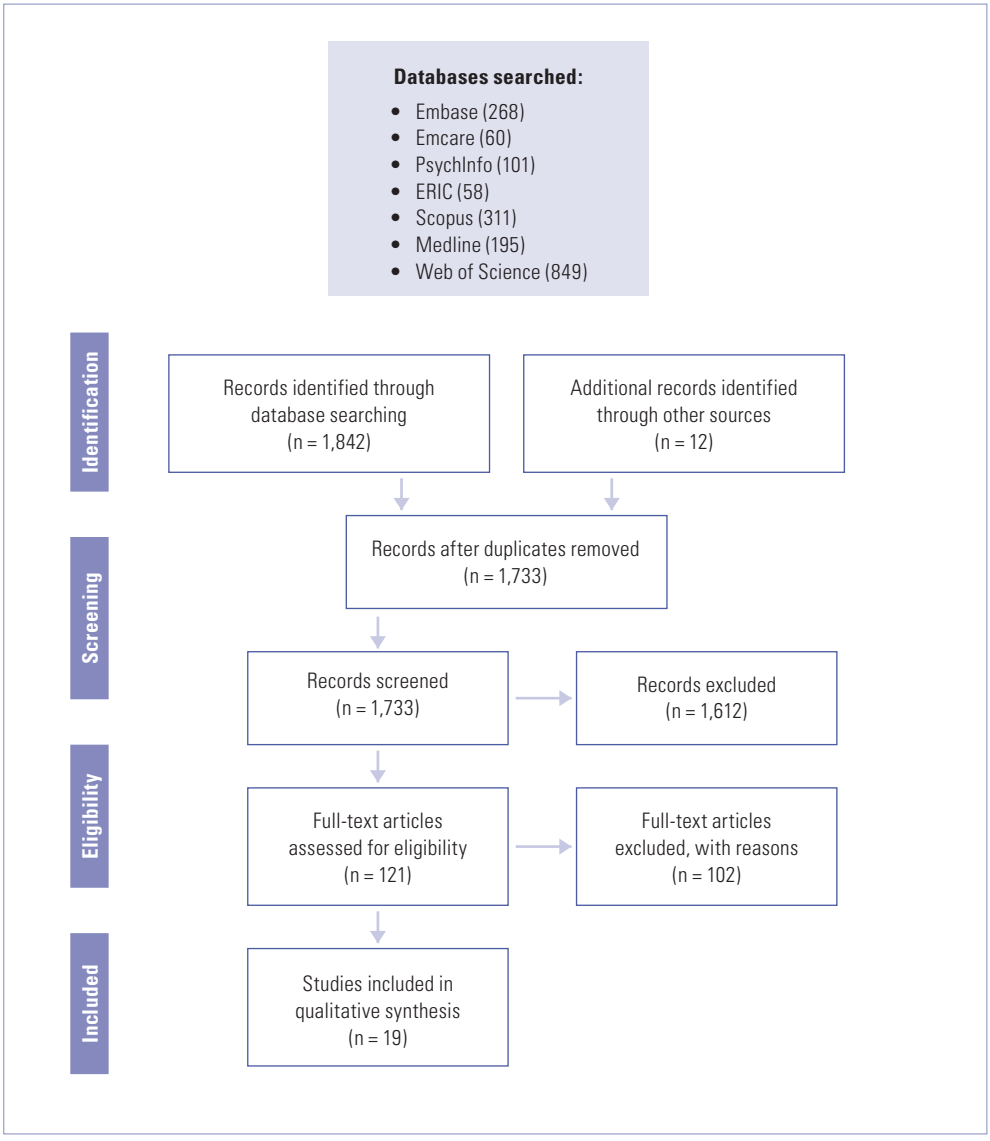

Table 2

Results of the McMaster Quantitative Critical Appraisal of Each Included Study

	Items on McMaster Quantitative Critical Appraisal Tool (Law et al., 1998)																
	Purpose	Literature	Design	Sample			Outcomes		Intervention			Results				Conclusions	
Study	1	2	3	4a	4b	4c	5a	5b	6a	6b	6c	7a	7b	7c	7d	8	Score
Benino et al. (2011)	Y	Y	Cross-sectional	205	N	N	N	N	N	NAD	NAD	N	N	Y	N	Y	4/14 (29%)
Cordier et al. (2016)	Y	Y	Cross-sectional	134	Y	N	N	N	Y	NAD	NAD	Y	Y	Y	N	Y	8/14 (57%)
Curtis et al. (2013)	Y	Y	Cross-sectional	136	Y	N	Y	Y	N	NAD	NAD	Y	Y	Y	N	Y	9/14 (64%)
Delaval et al. (2017)	Y	Y	Cross-sectional	123	N	N	N	N	N	NAD	NAD	Y	Y	Y	N	Y	6/14 (43%)
Gagnon (2015)	Y	Y	Cross-sectional	36	Y	N	Y	Y	Y	NAD	NAD	Y	N	Y	N	Y	9/14 (64%)
James (2016)	Y	Y	Cross-sectional	456	N	N	N	N	N	NAD	NAD	N	N	Y	N	Y	4/14 (29%)
Kalata & Abate (2013)	Y	Y	Cross-sectional	84	N	N	N	N	N	NAD	NAD	Y	Y	Y	N	Y	6/14 (43%)
Lewis & Sewell (2007)	Y	Y	Cross-sectional	132	N	N	N	N	N	NAD	NAD	N	N	Y	N	Y	4/14 (29%)
Lin & Crawford (2007)	Y	Y	Cross-sectional	162	N	N	N	N	N	NAD	NAD	N	N	Y	N	Y	4/14 (29%)
McClean et al. (2016)	Y	Y	Cross-sectional	154	N	N	N	N	Y	NAD	NAD	N	N	Y	N	Y	5/14 (36%)
Moni et al. (2007)	Y	Y	Cross-sectional	1,136	N	Y	NAD	NAD	Y	NAD	NAD	Y	N	Y	N	N	6/14 (43%)
Nallaya et al. (2018)	Y	Y	Cross-sectional	1,802	N	N	N	N	N	N	N	N	N	Y	N	N	3/14 (21%)
North et al. (1998)	Y	Y	Before-After	125	Y	N	NAD	NAD	N	NAD	NAD	Y	Y	Y	N	Y	7/14 (50%)
Nutan & Demps (2014)	Y	Y	Cross-sectional	410	N	Y	N	N	Y	NAD	NAD	Y	N	Y	N	Y	7/14 (50%)
Sando et al. (2018)	Y	Y	Cross-sectional	236	N	N	Y	Y	Y	N	N	Y	Y	Y	Y	N	9/14 (64%)
Soh et al. (2013)	Y	Y	RCT	14	N	N	Y	Y	Y	NAD	Y	Y	Y	Y	N	N	9/14 (64%)
Stamper et al. (2017)	Y	Y	Cross-sectional	306	N	Y	Y	Y	Y	NAD	NAD	Y	Y	Y	N	Y	10/14 (71%)
Suleman (2016)	Y	Y	Before-After	513	Y	Y	Y	Y	N	NAD	NAD	Y	N	Y	N	Y	9/14 (64%)
Vaughan (2009)	Y	Y	Cross-sectional	153	Y	Y	N	N	Y	NAD	NAD	N	Y	Y	N	Y	8/14 (57%)

Table 2 continued

McMaster items:

1. Was the study purpose stated clearly?
2. Was the relevant background literature reviewed?
3. What was the study design?

4a. Sample size
4b. Was the sample described in detail?
4c. Was the sample size justified?
5a. Were the outcome measures reliable?
5b. Were the outcome measures valid?
6a. The intervention was described in detail?
6b. Contamination was avoided?
6c. Co-intervention was avoided?
7a. Results were reported in terms of statistical significance?
7b. Were the analysis method(s) appropriate?
7c. Clinical importance was reported?
7d. Drop outs were reported?

8. Were the conclusions appropriate given the study methods and results?

The total raw and percentage (in brackets) score is reported.

Abbreviations: Y = yes, N = no, NAD = not addressed, RCT = randomised controlled trial

Methodological quality of the included studies

Table 2 provides an overview of the various designs and critical appraisal of the included studies. A large majority (n = 16) of the included studies used an observational (cross-sectional) study design. Two used a before and after design, and one was a randomised trial. Much of the research was undertaken in naturalistic settings, such as at an educational institution during teaching periods. In the studies that had an experimental focus, two studies utilised "before and after" study design, as it is more practical and feasible within the teaching and learning context. Only one study (Soh et al., 2013) was a randomised controlled trial. The main methodological concerns amongst the included studies were lack of a hypothesis; lack of adequate description of the sample and clear justification of sample size; attribution bias (low or failing to report response rate); poor reporting of psychometric properties of outcome measures; lack of clarity and descriptions regarding the intervention utilised (such as insufficient detail about the digital technology used to develop and/or deliver the online learning resource); failure to control for contamination/co-intervention bias (such as failure to consider other factors that may predict or correlate with outcomes); and inappropriate, or lack of clear justification for, analytical methods used.

Study characteristics

The study characteristics are summarised in Table 3. Myriad interventions evaluating the effectiveness of online teaching were reported from a range of countries, including Australia (n = 9), the United States of America (n = 6) and the United Kingdom (n = 2), with France and South Africa each contributing a single study.

Table 3

Study Characteristics

Study	Design (Country)	Discipline (n)	Intervention	Comparator	Outcomes
Benino et al. (2011)	Cross-sectional (Australia)	Pharmacy (205)	Recorded lectures and tutorials	Face-to-face lectures and tutorials and blended	Myriad outcomes, including satisfaction, learning outcomes and experiences, workload, assessment tasks
Cordier et al. (2016)	Cross-sectional (Australia)	Occupational therapy, physiotherapy, speech pathology, diploma of health sciences and dentistry (283)	Child development assessment using PebblePad	None	Students' understanding of psycho-social, physical, cognitive child development, and typical child development
Curtis et al. (2013)	Before-after (Australia)	Psychology (136)	Online academic-integrity mastery module with series of 18 brief online tasks, which were delivered through Blackboard	None	Students' understanding of and attitudes to plagiarism
Delaval et al. (2017)	Cross-sectional (France)	Psychology (123)	Web-based training environment to prepare for the statistics exam consisting of 300 statistics exercises	None	Students' academic performance (final exam grades)
Gagnon (2015)	Cross-sectional (Australia)	Physical therapy (36)	Twitter was used as a platform for asynchronous, out-of-class discussion for this course	None	Student engagement, student social media use and student perceptions of educational use of Twitter in the course
James (2016)	Cross-sectional (Australia)	Psychology (125; 29 undertook the intervention)	Invigilated, online examination facilitated by a proctoring company	N/A	Students' perceptions of and experiences from the invigilated online exam
Kalata & Abate (2013)	Cross-sectional (USA)	Pharmacy (84)	LiveText (LiveText, Inc., La Grange, IL) was used as the platform for the web-based electronic portfolio platform with mentor evaluators	None	Students' academic performance (self-assessment of assignments and number of re-submissions)

Study	Design (Country)	Discipline (n)	Intervention	Comparator	Outcomes
Lewis & Sewell (2007)	Cross-sectional (UK)	Pharmacy and neuroscience (132)	e-learning package in a common pharmacology module was presented with a computer-based summative assessment. The test, based on this learning material, consisted of 30 questions divided into six per section.	None	Students' perceptions of form and method of feedback procedure and style
Lin & Crawford (2007)	Cross-sectional (USA)	Pharmacy (162)	dEbate series using online threaded discussion among paired student groups to facilitate student learning in practising discussion, argument and idea articulation	None	Use (hits) of the resource and students' performance (assessment of posts)
McClean et al. (2016)	Cross-sectional (UK)	Biosciences (biomedical science, dietetics, food and nutrition, human nutrition and biology) (128)	An in-house video-sharing website, YouTestTube.com. Video was recorded during the laboratory session, paying attention to key observations from the experiments conducted, difficulties encountered and conclusions drawn.	None	Students' perceptions of the use of video in practical classes
Moni et al. (2017)	Cross-sectional (Australia)	Pharmacy, human movement, science, engineering, arts, biotechnology, business, commerce, behavioural studies and psychology (1,136)	eConference (called Biohorizons), which was modelled on the structure and activities of a professional scientific conference. Econference delivered by wiki-based LMS.	None	Students' perceptions of organisation, technical support, usefulness of software and usefulness of the conference paper, presentation and discussion
Nallaya et al. (2018)	Cross-sectional (Australia)	Social work (1,802)	Short iSpring video presentations on academic and information literacies	None	Use (hits) of the resource and students' performance (grade distribution)
North et al. (2018)	Before-after (USA)	Physician assistant, physical therapy, occupational therapy (125)	31.6-hour online interprofessional IH course, Foundations in Integrative Health (FIH) consists of six online units	None	Students' knowledge of integrative health concepts in interprofessional practice

Study	Design (Country)	Discipline (n)	Intervention	Comparator	Outcomes
Nutan & Demps (2014)	Cross-sectional (USA)	Pharmacy (410)	Formative assessments completed through online homework assignments in Web CT or Blackboard	Previous year cohort of students	Students' performance (academic grades) and students' preferences
Sando et al. (2018)	Cross-sectional (USA)	Pharmacy (236)	Online spaced-education game on the top 200 medications involving "challenges" consisting of MCQs, which are delivered to students using periodic emails or app notifications	None	Students' engagement and perceptions of game, MCQ performance, self-efficacy to recognise brand/generic names and common indications
Soh et al. (2013)	RCT (Australia)	Medical radiation sciences (14)	The web-based tutorial focused on female breast anatomy, image positioning, mammogram viewing, mammogram analysis, mammographic appearance of the normal breast and appearances of asymmetric density and masses	None	Students' confidence in identifying abnormal images, frequency and duration of lesion identification, total number of fixations per case and time spent per mammographic case
Stamper et al. (2017)	Cross-sectional (USA)	Pharmacy (306)	Online prerequisite review tutorials were delivered (via Moodle)	None	Correlation between quiz scores and final exam scores, students' knowledge, exam preparation, self-directed learning and comprehension of subsequent course content
Suleman (2016)	Before-after (South Africa)	Pharmacy (473)	AIDS Online International (AOI) course	None	Knowledge on HIV transmission, science of the disease and medication
Vaughn (2009)	Cross-sectional (USA)	Pharmacy (153)	Online instruction tools with lecture and email information	Lecture and email information	Use (views) of instruction tools and time spent with librarian

Participant characteristics

The total number of participants from the included studies was 6,457, although in some instances only a subcategory of the original sample undertook the intervention (e.g., James, 2016). There was no consistency in, nor acknowledgement of, how the samples were recruited, with convenience sampling the most likely sampling framework utilised.

The most common research participant group was first-year students from pharmacy (n = 8), followed by research conducted across multiple allied health disciplines (n = 5) and psychology (n = 3), while students from physiotherapy, social work and medical radiation sciences were researched in individual studies as stand-alone disciplines.

Types of online teaching interventions

There was a great deal of variability in the parameters underpinning the use of online teaching interventions in the teaching and learning context. While some studies used online teaching interventions to meet the assessment needs of a course (such as Cordier et al., 2016; James, 2016; Nutan & Demps, 2014), other studies extended the online learning approach to encompass all aspects of teaching and learning (Curtis et al., 2013; Lewis & Sewell, 2007; North et al., 2018; Suleman, 2016). Some studies utilised online learning interventions as targeted strategies to achieve a single outcome as part of the course delivery, such as preparation for the final assessment (Delaval et al., 2017), while other studies used these strategies with a focus on promotion of discussions among the student cohort (Lin & Crawford, 2007). Some studies reported the development and evaluation of bespoke online teaching initiatives that tapped into technologies such as social media (Gagnon, 2015; McClean et al., 2016). While this diversity of online teaching interventions might highlight their fit for purpose nature, it limits the ability to compare and contrast, hence a meta-analysis was not undertaken. However, the findings can be generally grouped under "student engagement" and "student academic performance".

Student engagement

While a large majority of the studies (n = 13) reported on student engagement with regards to the online teaching interventions, how student engagement was measured and evaluated varied greatly between the studies. The most common approach, utilised by five studies (Benino et al., 2011; James, 2016; Lewis & Sewell, 2007; McClean et al., 2016; Moni et al., 2007), was to capture students' perceptions of and experiences about online teaching interventions through routine feedback mechanisms (such as end-of-semester evaluations) or targeted strategies (such as the use of a bespoke survey instrument). Other studies (Cordier et al., 2016; Curtis et al., 2013; Gagnon, 2015; Kalata & Abate, 2013; Suleman, 2016) explored students' experiences with online teaching interventions through their self-reported understanding of the concepts covered, perhaps as a proxy for student engagement. Some studies evaluated other proxy measures of students' experiences of, and engagement with, online teaching interventions through time spent with the resource and how often they accessed or used them (Lin & Crawford, 2007; Nallaya et al., 2018; Vaughan, 2009).

The effect of online teaching interventions on students' perceptions and experiences was mixed. While students expressed positive views about the use of online teaching interventions (as reported by Lewis & Sewell, 2007), there were also concerns and

caution indicated. For example, the research by James (2016) investigated the impact of an invigilated online examination. While students initially expressed a great deal of enthusiasm and willingness (125 students expressed interest due to perceived convenience, efficiency and ease), only 29 students followed through with the option to undertake the invigilated online examination. Of those who did participate, their experience of the initiative was generally poor due to technological and resource issues. Similarly, research by McClean et al. (2016) identified that while a majority of students did enjoy the process of creating and editing videos for chemistry laboratory classes and were satisfied with the process, many participants queried the overall usefulness of the activity and its limited potential for future use (e.g., relevance of video-making skills for science degrees/careers). Similar findings on technological limitations, ease of use and future value were also shared in the research conducted by Moni et al. (2007), who introduced an e-conference modelled on the structure and activities of a professional scientific conference.

Studies that explored students' engagement with online teaching interventions through their self-reported understanding of the concepts covered also presented mixed evidence. For example, Australian research by Cordier et al. (2016) and Curtis et al. (2013) reported positive impacts from online teaching interventions on students' understanding of child development and plagiarism concepts, respectively. Improvements were reported by students in their knowledge and confidence following participation in the AIDS Online International course undertaken in South Africa (Suleman, 2016). The research by Gagnon (2015) also reported increased use of social media (Twitter) following the intervention (use of Twitter to teach, support and model professional online communication in a first-year physical therapy professionalism course). These positive findings should be considered with caution as these impacts were limited to only some domains/measures (see Cordier et al., 2016; Curtis et al., 2013), were mainly short term (see Gagnon, 2015) and required ongoing further investigation.

Similar mixed findings were reported by studies that used proxy measures of students' engagement with online teaching interventions, including how often they accessed and the time spent with the resource. For example, Vaughan (2009) reported reduced reliance on historical face-to-face resources after the introduction of online resources. Pharmacy librarians used to provide, on average, 22.5 hours to assist students with their assignments, and this was reduced to 3.25 hours following implementation of the online teaching intervention (Vaughan, 2009). Analysis of the resource use findings reported by Nallaya et al. (2018) and Vaughan (2009) indicates that such findings were limited to those topics that were linked to assessments. The selective use of topics that were linked to assessments was acknowledged by Lin and Crawford (2007), as some of the topics that were developed as part of an online debate series (called dEbate) for first-year pharmacy students had not been used sufficiently, or at all, by some of the students. This highlights the importance of linking topics and resources to assessments. For students who are time poor, it is likely that assessments will increase motivation for, and the perceived relevance of, using online resources.

Student academic performance

Six of the 19 studies reported on the effect of the online intervention on measures of academic performance. Four of these studies involved online formative learning exercises performed in addition to other study strategies (Delaval et al., 2017; Sando & Feng, 2018; Soh et al., 2013; Stamper et al., 2017). Student performance was primarily assessed with multiple-choice questions (Delaval et al., 2017; Sando & Feng, 2018; Stamper et al., 2017), but Soh et al. (2013) used eye-tracking software to investigate how students visually searched and detected abnormalities on a mammogram image.

The effects of the online formative learning interventions on academic performance are unclear. For example, Delaval et al. (2017) delivered a web-based formative learning intervention in a first-year statistical course for psychology students. Once connected, students received feedback on their performance in two ways—social comparison (their score compared to the mean of all first-year students) and temporal-self comparison (their score compared each week with their previous score). The findings from this research indicate that while temporal self-comparison feedback did not have any effect on performance, social comparison feedback did, especially for students who started the online exam preparation exercises shortly after they became available.

The effectiveness of a voluntary online game to assist first-year pharmacy students to learn key information about 100 common medications on their final exam performance was mixed. Low failure rates were observed on the final exam in 2015 (1/235) and 2016 (11/231), but the preintervention failure rate was not reported, and a high percentage of students reported using other study strategies (e.g., 66% of students used drug study cards 1–2 days per week, and 64% participated in study sessions) (Sando & Feng, 2018). Soh et al. (2013) also administered an online formative learning tutorial. The aim of the 1-hour online tutorial was to improve student recognition of abnormal breast tissue on mammogram images. Fourteen first-year medical radiation science students were assigned to one of two conditions: intervention (training) or no intervention (no training). Eye-tracking software was used to investigate how students visually searched and detected abnormalities on a mammogram image. Students who received the online training intervention improved their performance over time, evidenced by a significant decrease in the average time to first fixation on the lesion. Students who received no training exhibited no change in the average time to first fixation. Decision-making errors also decreased in the intervention (training) group but not in the control (no training) group. The effectiveness of the online formative learning tutorial is difficult to ascertain because the control group did not receive an alternative type of training.

The remaining two studies that reported the effect of an online intervention on measures of academic performance involved replacement of a summative, in-class, multiple-choice quiz with an individualised online multiple-choice quiz for first-year pharmacy students (Nutan & Demps, 2014) and development of an online course to educate first-year students about integrative health, prevention and lifestyle behavioural change

in programs leading to careers as physician assistants, physiotherapists and occupational therapists (North et al., 2018). Statistical comparison of the online and in-class cohort grades yielded mixed results. Performance on the online quizzes in the 2012, 2013 and 2014 student cohorts did not significantly differ to the 2010 and 2011 student cohorts who completed the quiz with pen and paper in class. However, performance on two out of the three online quizzes (2012, 2013) was statistically higher than the 2010 in-class cohort (Nutan & Demps, 2014). However, the results of the statistical analysis should be interpreted with caution because multiple t-tests were used (without *p*-value correction) instead of a one- or two-way analysis of variance (Nutan & Demps, 2014). Very little information about the structure and delivery of the online course on integrative health was provided.

Discussion

With more and more tertiary courses utilising online teaching resources to deliver content and engage with students, it is important to understand their impact and evaluate the evidence base. As there is uncertainty about the effectiveness of online interventions for teaching foundational knowledge to first-year students within allied health disciplines, the aim of this systematic review was to review the literature on this topic. A modest body of evidence, consisting of 19 studies representing a number of research designs, was identified. The summarised findings from this review indicate that the evidence for online learning interventions is mixed, and therefore, while they may have a positive impact on first-year allied health students' engagement and academic performance, an explicit conclusion cannot be made due to lack of clarity and heterogeneity in terms of the interventions delivered and outcomes measured. Therefore, caution is required when interpreting the findings of the included studies.

The mixed findings of this systematic review have been supported by other research in the field of online teaching and learning. In the study by Ni (2013), while student performance, as measured by grade, was found to be independent of mode of teaching (online versus face-to-face), online teaching was considered to be better in terms of quantity and quality of interaction and students feeling less intimidated. In particular, students reported that online interaction increased their comfort level with participation, even though some students expressed frustration about students not participating equally in group work. In order for students to reap the benefits of online teaching and learning, they had to invest more time and effort to be a successful learner in this medium (Shukor et al., 2015).

The answer to the question of how to make online teaching interventions effective is also difficult to extract from the current literature due to significant methodological concerns. For example, two of the studies assessed knowledge before and after completion of the course (North et al., 2018; Soh et al., 2013). Use of this before and after design is surprising given that one would expect student knowledge of a given topic to be poor

prior to commencing a course since students have not yet received instruction. In other instances, studies lacked appropriate control conditions. For example, Delaval et al. (2017), Stamper et al. (2017) and Sando and Feng (2018) did not compare the academic performance of students who received the online learning intervention to students who received an alternative non-digital intervention within the same course (e.g., traditional face-to-face) or students who previously completed the course without the digital learning intervention. Nutan and Demps (2014) did compare academic performance to previous student cohorts, but the mode of administration may not have been comparable (online versus face-to-face quizzes). Two studies (North et al., 2018, Nutan & Demps, 2014) contained inadequate statistical analysis, and the results of studies involving formative learning exercises were likely influenced by contamination (e.g., other information sources and/or modes of learning).

One way to answer the question of how to make online learning effective and achieve better outcomes could be through careful planning and implementation of the online teaching interventions. Lack of such planning could jeopardise the potential benefits from these interventions. This was demonstrated in research by James (2016) on the invigilated online examination initiative. While many students initially expressed interests (due to reasons of efficiency, convenience and resources), only a handful actually went through with the invigilated online examination. The reluctance to engage with the online assessment approach during a high-stakes assessment was supported by the views of some students who did participate and encountered technological and planning barriers (such as internet connection and camera issues). The importance of proper planning to overcome such barriers has been acknowledged in previous research (Jones, 2008; Picciano, 2015).

Limitations

As with any research, there are limitations to this systematic review. While it identified a modest body of research evidence, there were concerns with the methodological quality, resulting in high risk of bias for the evidence base. The areas of concern included stated hypothesis, sample size and sampling approaches, lack of psychometrically sound outcome measures, lack of justification and detail underpinning development and administration of online learning interventions and its parameters (which impacts replicability) and low/no response rates. These concerns, in addition to the fact that the majority of the included studies were observational in nature, indicate that causality should be inferred with caution. Furthermore, given that the majority of the studies originated from first-world, Western countries, generalisability of these results to the wider allied health student population is limited. The heterogeneity of the online learning interventions utilised and the outcomes measured to evaluate their impact may well reflect how broadly online learning interventions are categorised and applied, the local needs of each educational institution and the discipline undertaking the research. However, this does limit a direct comparison of results between the studies.

Conducting systematic reviews is not without its challenges (Leung et al., 2017). Despite a comprehensive search strategy, due to resource and time constraints, only studies published in the English language were included in this systematic review and, hence, language bias should be acknowledged. Furthermore, due to lack of sufficient research in this field, it is unclear which first-year allied health students are most likely to benefit (or not) from online learning interventions. This is an important "black box" that needs to be addressed as targeted strategies could then be implemented for various student groups (such as "at-risk" students).

Conclusion

There is a modest body of evidence to support the widely held view that online learning interventions for first-year allied health students may have a positive impact on student engagement and academic performance. However, while online learning interventions may be useful teaching and learning strategies, the current evidence base is constrained by several methodological concerns. Future research may add to the evidence by adequately defining the outcomes and the underlying mechanisms by which the interventions purportedly influence these outcomes. Such foundational research could then inform the conduct of methodologically sound randomised controlled trials with larger sample sizes using power calculations, psychometrically robust outcome measures and detailed and replicable interventions.

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