DEVELOPMENT AND EVALUATION OF COMPUTER-ASSISTED LEARNING (CAL) TEACHING TOOLS COMPARED TO THE CONVENTIONAL DIDACTIC LECTURE IN PHARMACOLOGY EDUCATION

Abdullah Karaksha, Gary Grant, Andrew K. Davey, Shailendra Anoopkumar-Dukie

School of Pharmacy, Griffith University, Queensland (AUSTRALIA)
akarakshe@hotmail.com

Abstract

Objective

Develop and compare the educational benefit of an interactive pharmacology computer assisted learning (CAL) tool, designed according to educational theory, versus the conventional lecture in a pilot study. Evaluate student satisfaction with the tool, identify its place in pharmacology education, and evaluate the educational benefit it may have on student performance using a short-term recall assessment.

Methods

A computer-based flash animation describing two gastrointestinal drug mechanisms of action was developed. The study group comprised 75 third-year pharmacy students at Griffith University. Ethical approval was granted by the Griffith University Human Ethics Committee. Participants were randomly allocated into four groups, Lecture + CAL (N = 23), CAL (N = 22), Lecture (N = 13) and No intervention (N = 17). Performance was assessed using multiple choice questions. Time taken to answer each question and the quiz as a whole was also compared between the four groups. Participants satisfaction with the tool was also measured using a 5-point Likert scale. Data were analysed statistically by ANOVA testing using GraphPad InStat software (version 3.10). Probability (p) values of less than 0.05 were considered statistically significant.

Results

Performance as measured by mean test scores was significantly different ($p < 0.05$) in two comparisons only: the Lecture + CAL versus Lecture groups and the Lecture + CAL versus No intervention groups with the Lecture + CAL group outperforming the other groups in both cases. No significant difference ($p > 0.05$) was found by comparing the time to undertake the quiz between the four groups. In addition no significant difference was discovered by comparing the time spent to finish each question between the groups. The majority of participants were satisfied with the CAL and found it easy to use.

Conclusion

The results of the present study suggest that these self-developed CALs supplement lectures and have the potential to improve students' performance and improve knowledge transfer.

Keywords: Computer assisted learning, CAL, E-learning, blended learning, performance assessment.

1   INTRODUCTION

Innovative teaching methods, embracive of technology and responsive to individual student needs, are essential to help academics manage increasing pressures (including an increasingly diverse student cohort) and facilitate student learning in the face of competing interests.[1] The last period of the 20th century has seen a rapid expansion of the pharmacology knowledge-base, an increased understanding of the mechanisms of drug action, and an increase in therapeutic classes and drugs available for the treatment of disease.[2] It is essential to add this new knowledge into existing pharmacology curricula because of its relevance to contemporary clinical practice; however, no additional time is usually allocated for its inclusion.[3] It is likely that these aforementioned factors, in part, hinder student learning, prevent true comprehension and understanding, and restrict integration of the knowledge into students' existing knowledge-base.[4] It is proposed, therefore, that

technological advancement can assist academic educators overcome challenges and meet the growing needs and expectations for improving education quality, whilst encouraging student-focused learning and developing independent life-long learners.[4]

E-learning educational materials, which include computer-assisted learning (CAL), are rapidly growing in both quantity and quality.[3] Many of these and other self-developed CALs have been implemented and evaluated in dental, health science and nursing curricula and in the continuing professional education settings.[3, 5-6] Although the general consensus is that CAL is valuable for improving students' knowledge, many authors claim that CAL provides no clear educational benefit.[7-9] Lewis et al (2005) reviewed 25 evaluation studies of CAL packages and concluded that their findings often yielded ambiguous results. In addition, they stated that many of these reports were of a qualitative nature and some could at best be described as anecdotal.[10] Few studies have effectively demonstrated the efficacy of knowledge transfer or the concept of knowledge retention following the use of CAL.[10]

Despite these negatives and unknowns, CAL provides many advantages to student learning. CAL allows students to direct their own learning by providing flexible learning opportunities.[10-11] They allow students to learn when, how (learning style, collaborative or independent learning), what (content) and where (place) they want.[12] Moreover, some studies conclude that the use of CAL provides an exciting addition to the teaching and learning arsenal at a time of financial constraint.[8] The development of CAL is principally a one-off investment of time for a method of instruction that may be used repeatedly.[7] Therefore, such a delivery method is likely to be more cost-effective than employment of teachers and tutors to do the same work.[7-8, 13-14]

This study was undertaken after attempts to source a commercially available or free access CAL, which conformed to our educational needs, proved difficult. Commercial CALs had dated significantly at the time of review and presented a considerable amount of content which deviated from the course learning objectives. The majority of these products had been developed overseas and did not accurately reflect local practices. In addition, these CALs were developed and presented in a format (Flash) which made it difficult to update or specifically tailor content to our continuously evolving teaching needs. Similar concerns have previously been raised by other investigators.[15]

In order to ensure that sufficient emphasis was placed on sound educational principles in the construction of our self-developed CALs, literature was reviewed to identify relevant teaching theories. These principally related to cognitive load theory and Mayer's dual channel assumption.[16-17] Cognitive load theory is based on information processing assumptions and refers to the total amount of mental activity imposed on working memory at an instant in time.[16, 18-19] Cognitive load theory suggests that when large volumes of information are presented simultaneously, the learner can experience overload in their working memory, owing to limited capacity.[16] In effect, the learner becomes overwhelmed with what is presented, resulting in a loss of direction and focus.[16, 20] With respect to CAL, the main factors influencing cognitive overload are designs incorporating text and animation.[21] Although these might focus the learner on the exciting aspects of the topic, the learner often bypasses thoughtful analysis of the underlying meaning.[21] According to cognitive load theory, too many distractions may impede learning.[22] These were problems identified in many of the commercially available CALs. In the same context, Mayer's dual coding (channel) theory suggests that the working memory consists of two distinct processing systems, auditory (verbal) and visual (nonverbal). The auditory system processes narrative information while the visual system processes images (animation).[17] Fletcher (1990) found that students retain 20% of what they hear and 40% of what they see, but 75% of what they see, hear, and interact with.[23]

Additional teaching theories considered relevant, together with description and evidence, are provided in table 1.

Table 1: Teaching theories and principles relevant to CAL development

Teaching Theories and Principles	Description and Evidence
Multimedia Principle: Students learn better from words and pictures than from words alone.[17]	Mayer and Anderson (1992) concluded in their study that when animations were presented concurrently with narration, students demonstrated large improvements in problem-solving transfer over the no instruction group.[24] Problem-solving transfer relates to 'factual /procedural knowledge' within Bloom's revised taxonomy.[25] Mayer and Moreno (1998) also concluded that students who received both animation and narration outperformed those who received animation and on-screen text in retention testing.[26]
Spatial Contiguity Principle: Students learn better when multiple source of information are integrated rather than separated.[27]	The designed CAL eliminates the need to collate information from different disciplines. Mayer and Moreno (1998) stated that students preformed significantly (p<0.05) worse in the retention test when they had to refer to different sources of information compared to the students who had to refer to only one information source.[26]
Temporal Contiguity Principle: Students learn better when corresponding words and pictures are presented simultaneously rather than successively.[27]	Moreno and Mayer (1999) demonstrated in their study that students who watched the animation concurrently with the narration, performed significantly better (p<0.05) in retention and problem solving tests from those who had them separately.[28]
Coherence Principle: Students learn better when extraneous words, pictures, and sounds are excluded rather than included.[17]	Presentations that add 'bells and whistles' or extraneous information impede student learning and disrupt the process of organizing the material.[22] Cooper (1998) showed that modifying the presented materials to obtain a lower level of extraneous cognitive load will aid learning if the resulting total cognitive load falls to a level that is within the bounds of mental resources.[18]
Modality Principle: Students learn better from animation and narration than from animation and onscreen text.[17]	Moreno and Mayer (1999) confirmed in their study that students who watched the animation and listened to the narration performed significantly better (p<0.05) in retention, matching and problem solving tests than those who watched the animation and read the on-screen text.[28]
Individual Differences Principles: Design effects are stronger for low-knowledge learners than for high knowledge learns.[17]	Miclea et al (2008) suggested that novices (learners with low prior knowledge) may benefit more from CAL than experts (learners with high prior knowledge).[29]
Interactivity: Students learn better when they interact with learning materials rather than by receiving direct instruction.[17]	Moreno (2005) explained that students learn better when allowed to interact with CAL.[30]

iSpring Pro 4.3.0 and Question Writer 3 (Professional) were identified as the most suitable software packages for the development of CALs. iSpring Pro produces quality Flash movies, which incorporate animations and transition effects. Generated Flash files allow the viewer to control the progression of the animation, thereby avoiding cognitive overload, and permit the student to easily revisit specific content, thereby providing sufficient student interaction. iSpring Pro 4.3.0 also enables the addition of voiceovers with a process that is streamlined and simple. Narration can be modified for an individual slide or animation without the need for re-recording the entire presentation. Question Writer 3 (professional) is quiz software allowing generation of Flash quizzes which are easily combined with generated Flash animations for delivery. This software package allows the inclusion of multiple choice, multiple responses, true/false, fill in the blank, matching, sequencing, and essay questions. Test results of quizzes created and delivered through Question Writer 3 (Professional) can be viewed online, emailed directly to instructors or downloaded in spreadsheet format. This allows investigators to track the origin of results (i.e., randomisation group), whilst retaining anonymity if required. The program also monitors the time taken to answer each question and to finish the quiz.

The use of these resources negates the need for complex programming and generates a tool that can be easily updated without the need for advanced programming skills.

Because of a distinct lack of suitable commercial tools pertaining to their pharmacological action, two gastrointestinal (GIT) drug classes, namely Histamine 2 (H2) receptor antagonists and proton pump inhibitors (PPIs) were chosen for CAL development and evaluation.

Therefore, the aim of this pilot study was to evaluate the educational benefit of interactive GIT CAL, developed using the educational theories and software packages described above, in pharmacology education. The investigation aimed to evaluate student satisfaction with the tool, identify its place in pharmacology education, and evaluate the educational benefit it may have on student performance using a short-term recall assessment.

2 METHOD

This investigation was conducted at the School of Pharmacy, Griffith University, Gold Coast campus, Australia. Ethical approval was granted by the Griffith University Human Ethics Committee.

Images provided by Servier Medical Art [31] were used for the construction of illustrations in Microsoft PowerPoint 2007. The main aim of the CAL was to educate students on the pharmacodynamic mechanisms of these two drug classes. To achieve this, illustrations met the following learning objectives: (1) Describe the normal physiological processes regulating the release of hydrochloric acid (HCl) from parietal cells. (2) Describe the pharmacological mechanism by which H2 receptor antagonists and PPIs reduce the secretion of HCl from the parietal cells. (3) State the main indications and adverse drug reactions for H2 receptor antagonists and PPIs. Custom animations were sequenced in Microsoft PowerPoint 2007. Narration was added using iSpring Pro 4.3.0. Taking into account cognitive load theory, Mayer's dual channel assumption and the multimedia and modality principles, the GIT CAL was developed with narration, rather than excessive written text, to accompany custom animations, leaving the visual channel available to process images and expand the working memory capacity.[16-17] The text screen was only used to conclude key points after each animation and accompanying narration. Narration accompanied specific animation to comply with the temporal contiguity principle.[27] Based on the spatial contiguity principle, the CAL integrated content relating to anatomy, physiology, cellular biology and pharmacology.[27] After initial construction, the tool content was reviewed and unnecessary words, pictures and narration were removed to adhere to the coherence principle.[17] iSpring Pro 4.3.0 was used to then convert the animation into a Flash format for ease of delivery and access through Blackboard. Participants could easily control the speed of the final CAL, skip content and move forward and backward as needed to revisit specific concepts. After the assessment the CAL was made available to all students to access.

Question Writer 3 (professional) was used to generate the quiz, which contained five multiple choice questions (MCQs) ranging in complexity. Questions were carefully developed to assess stated learning objectives and attempted to evaluate both factual and procedural knowledge, as defined by Bloom's and Bloom's revised taxonomy.[25, 32] Four different student groups (described below) undertook the quiz to evaluate student performance within the specified time frame. The developed CAL and quiz were copied to CD for delivery. Students from CAL groups were given access to both CAL and assessments. Students from the Lecture only and No intervention groups had restricted access to the assessments only. The study was initiated and completed within a 24 h timeframe. The quiz included two additional questions relating to student satisfaction. The total question number in the quiz was seven. Five questions were used to assess the participant performance and two to obtain their feedback. The first qualitative question simply evaluated student satisfaction with the CAL by way of a 5-point Likert scale (strongly agree, agree, no comment, disagree and strongly disagree). The second was an open-ended question asking students for specific comments or suggestions to improve the animation. The time taken to answer each question and total time taken to complete the quiz were compared between the four groups. This variable was considered important to examine the claim that CAL stimulates quicker information recall than the normal didactic lecture [33].

Students were recruited from the School of Pharmacy at Griffith University, Australia. Third year pharmacy students enrolled in a pharmacology course (n=139) were identified as suitable participants, having low prior knowledge of the GIT content presented in the CAL.

During the GIT lecture, the study was described to students, which was then repeated in the workshop session to recruit those that had not attended the lecture. Students were given the opportunity to

decline participation at any point. No extra credit was given for participation. Seventy five students voluntarily participated in the study.

Subgroups then self-selected depending on whether the students turned up to the GIT lecture or not. The subgroups were then randomly allocated to either the CAL or no CAL group as shown in Figure 1. Results and feedback were anonymously obtained. Results were automatically emailed to investigators by Question Writer 3 (Professional) together with unique identifiers. Questions were also included in the quiz to elucidate whether or not students had participated in either the lecture or CAL. Student responses indicated that 36 students had attended the GIT lecture and 39 were absent. This generated the following four intervention groups: Lecture + CAL (N=23), CAL only (N=22), Lecture only (N=13) and No intervention (no lecture or CAL) (N=17).
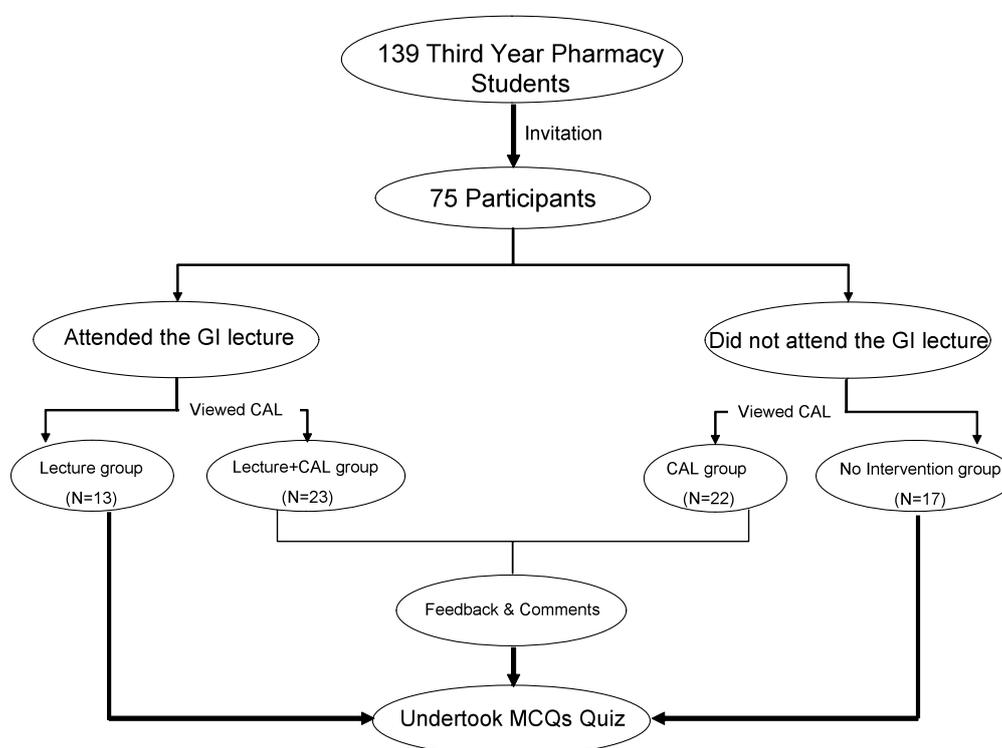

Figure 1. Study design. 75 Pharmacy students participated in the study. The study, using MCQs quiz, compared between four groups: Lecture + CAL, CAL only, Lecture only and No intervention (no lecture or CAL)

Data analysis was performed using GraphPad InStat software (version 3.10). Descriptive data and Kruskal-Wallis test with Dunn's Multiple Comparison post-hoc test were used to compare performances between the four study groups. One-way Analysis of Variance (ANOVA) test was used to compare the time to complete the quiz between the groups. Probability (p) values of or less than 0.05 were considered statistically significant.

3 RESULTS

The final developed CAL, using iSpring Pro 4.3.0, was a flash animation which illustrated and described the mechanisms of action of two GIT drug classes, namely (H2 receptor antagonists and PPIs). A summative quiz, that automatically recorded student responses and delivered results to a designated email address, was successfully embedded into the CAL using Question Writer 3 (professional). The resultant flash animation allowed students to easily control the pace and progress of the presentation. An example screen capture of the developed animation is presented in Figure 2. The chosen software packages proved ideal for the self-development of CALs. No technical difficulties were experienced in any of the CAL groups.
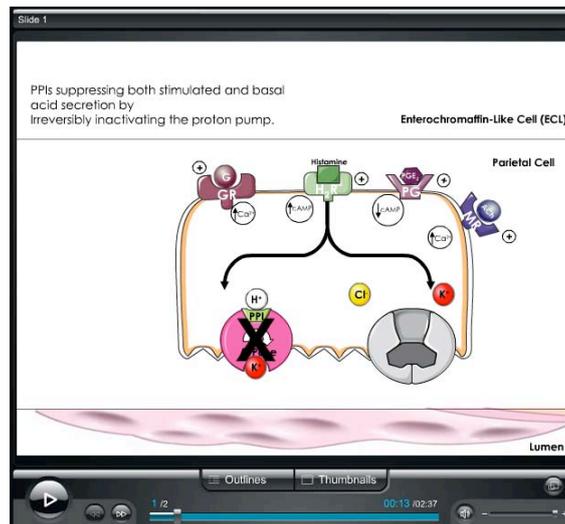
Figure 2. Example screen capture of developed CAL describing mechanism of action of proton pump inhibitors drugs (PPIs)

A total of 75 students participated in this study. All students completed the five question MCQ quiz to assess performance. ANOVA test was performed to compare the time to finish the quiz between the groups. The mean (± SD) in seconds was: Lecture + CAL group 27.5 (± 10); CAL 25 (± 11.5); Lecture 29 (± 13); and finally No intervention group 26 (± 13). No significant difference was found in any comparison ($p > 0.05$)

Sample descriptive data are presented in table 2. The highest percentage of correct answers was achieved by the Lecture + CAL group 67% (± 23.82) with a minimum of 20% and a maximum of 100%. This was significantly better than students in either the Lecture only or the No intervention groups. The lowest overall percentage was obtained by the Lecture only group 41.5% (± 22.3) with a minimum score of 0% and a maximum score of 80% (Table 2).

Table 2: The table represents the MCQ performance of the various intervention groups. (* = $p < 0.05$ compared to Lecture + CAL group)

(n)	Mean	SD	Minimum %	Maximum %
Lecture+CAL (23)	66.96	23.82	20	100
CAL (22)	54.55	26.32	0	100
Lecture (13)	41.54 *	22.30	0	80
No intervention (17)	45.88 *	18.39	20	80

Figure 4A shows student performance (% correct answers) for individual answers. Performance for the first two questions was approximately the same in all groups. The third and fourth questions were deemed to be more complex (i.e. testing conceptual knowledge). Students in the lecture + CAL group performed considerably better in these questions. Figure 4B provides a mark distribution of student performance on the quiz. Mark distribution was comparable between the groups. Lecture and No intervention groups' mark distributions were below 50% whereas Lecture + CAL and CAL groups were over 50%. Performance, however, tended to be higher in the Lecture + CAL group. The highest test scores of 100% were achieved by three students in this group. In comparison, only one student obtained 100% in the CAL group. Furthermore, the highest percentage achieved by the participants in Lecture and No intervention groups was 80%. Similarly, the lowest score 0% was obtained by two participants, one from the CAL and the other from the Lecture groups. In comparison, the lowest score obtained in the Lecture + CAL group was 20% by two students only.

As shown in table 3 the majority of the students (40 out of 45) in Lecture + CAL and CAL groups reported satisfaction with the CAL. Overall participants comments demonstrated satisfaction with the CAL quality and found the information it provided useful for their learning. The remaining five students were neutral regarding the CAL.
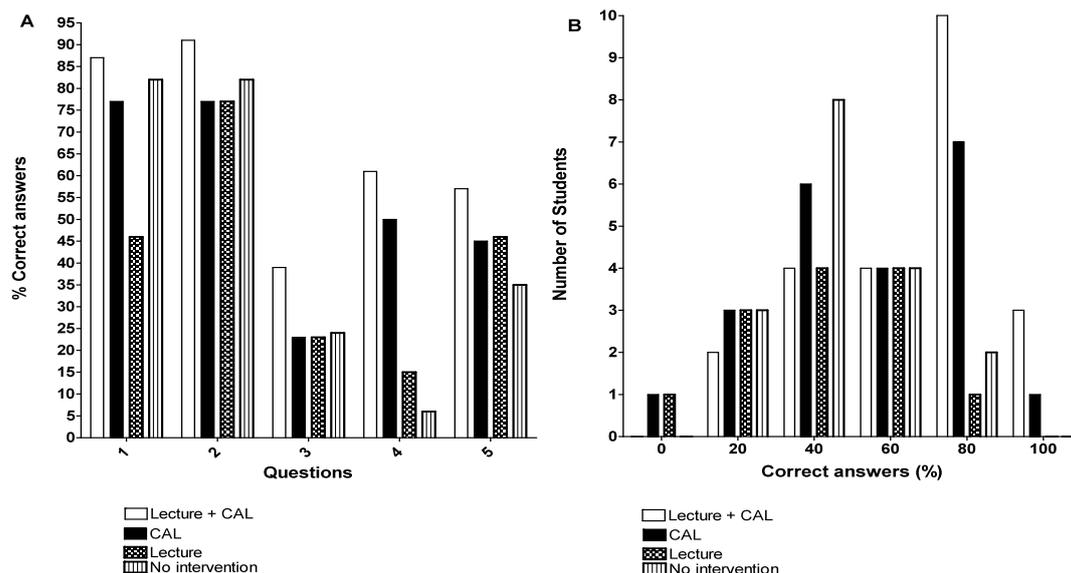
Figure 4. (A) Students' performance in the quiz. MCQs were used to estimate participants' performance and compare it between the groups. All groups (Lecture + CAL N=23, CAL N=22, Lecture N=13 and No intervention N=17) received the same questions and allocated the same timeframe for completion. Bars represent the percentage of correct answers for each of the four groups. (B) Mark distribution for each of the study groups. Bars represent the number of students for each overall score

Table 3. Participants' response regarding satisfaction of the CAL.

Students' satisfaction	Positive (N)	Neutral (N)	Negative (N)
Lecture + CAL Group (N =23)	22	1	0
CAL Group (N =22)	18	4	0

The Likert scale used was from 1= strongly disagree to 5 = strongly agree. Numbers reported here were obtained by combining responses of 1 and 2 (strongly disagree and disagree are reported in as negative) and responses 4 and 5 (agree and strongly agree are reported in as positive).

4   DISCUSSION

Due to the complexity of pharmacology as a discipline, it is important to develop innovative methods to improve student performance.[2] The main aim of this preliminary study was to evaluate the educational benefit of a self-developed pharmacology CAL tool which focussed on drug mechanisms. This study highlights relevant teaching theories which proved useful in the development of these CALs. By using commercially available software packages such as iSpring Pro 4.3.0 and Question Writer 3 (Professional), we were able to successfully self-develop CALs. We propose that these processes can be easily replicated by other pharmacology and pharmacy educators. The advantage of these self-developed CALs is that educators can easily update content to match evolved course learning objectives or changed practices, unlike those tools developed by trained programmers using complex software packages. By adhering to relevant teaching theories during construction, these self-developed CALs were shown to not only attract high student satisfaction, but also increase student performance in a short MCQ assessment compared to lectures alone.

Students that completed both the Lecture + CAL interventions significantly outperformed all other intervention groups in the MCQ assessment. This would imply that these self-developed CALs have the potential to facilitate transfer of factual knowledge, particularly in relation to drug mechanism of action, when added to traditional lectures. This study therefore confirms that there is added educational value in combining self-developed CALs with conventional lectures as part of a blended learning approach in pharmacology teaching and learning. This notion is supported by the findings of Allen (2008), who showed that adding web-based interactive instructional techniques, which supplemented traditional lectures, significantly improved student performance. [33] The uniqueness of this current study is that the same educational benefit can be obtained with self-developed CALs directed at the education of drug mechanisms in pharmacology. Comparing students' performance

between the CAL only and Lecture only groups showed no significant difference. This was an encouraging observation. Student performance in the quiz was at least as effective in the CAL only group to the Lecture only group. This would suggest that these carefully constructed CALs, which were developed in parallel to course learning objectives, may prove invaluable for students to acquire the crucial factual knowledge if they were unable to attend lectures. Interestingly, students who did not attend lectures or use the CAL package scored just as well as students in either the CAL or Lecture group. The students had lecture notes and textbooks available and the extent of independent study by these, and other students, is an unknown variable within the study.

Comparing the time to undertake the quiz revealed no significant difference between the four groups. This result suggests that CAL did not improve participants pace of recalling information. This finding contradicts previous conclusion by Fletcher (1990). He claimed, by reviewing 47 studies, that using CAL reduced 31% of the time required from students to perform the training compared to the traditional method [23]. The majority of students (40 out of 45) in Lecture + CAL and CAL only groups were satisfied with the overall quality of the CAL and found the information it provided useful to assist their learning and understanding. Student satisfaction in this study can be attributed, in part, to the fact that the CAL's design was informed by a sound pedagogy. By adherence to these teaching theories/principles during development, students' attention was focused on the major points by the linked narration and visual depiction of mechanism of GIT drug action.[34] Despite the CAL being an innovative teaching format, to which students were unaccustomed, there was a definite trend towards student satisfaction with the tool. Distinct themes emerged from the open-ended feedback question. From a student perspective, iSpring Pro 4.3.0 generates a tool which is clearly easy to use. Many requested that these CALs be included into their course to assist them in their preparation for final assessment. Numerous students reported that the narration progressed too quickly. This was despite the narration being purposely linked to specific events. This would suggest that the learner should be given more control of the pace at which CALs progress. Students commented that they thought the CAL required additional text to be included. This was an interesting finding that should be evaluated in future studies on CALs. This finding is in contrast to numerous of the teaching theories (Table 1) that were used as a guide for the development of this CAL. The major limitation of this current study was that the concept of long-term knowledge retention following the use of CAL was not assessed. Other limitations included small sample size and potential for non-respondent bias. A study is currently underway to evaluate this potential benefit of self-developed CALs in a larger cohort of students.

5   CONCLUSION

The results of this pilot study suggest that it is feasible for pharmacology and pharmacy educators to develop their own CALs using commercially available software packages. These self-developed CALs supplement lectures and have the potential to improve students' performance and improve knowledge transfer. The majority of participants found the CAL useful and easy to use.

Competing interest: None

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