Development and Evaluation of e-Learning Tools Used as a Supplement to Standard Curricula in Pharmacology Education

Abdullah Karaksha
Bachelor of Pharmacy and Pharmaceutical Science
Master of Medical Research (Clinical Pharmacy)
Graduate Certificate in Higher Education

School of Pharmacy
Group Health
Griffith University

Submitted in fulfilment of the requirements of the degree of Doctor of Philosophy
August/2013
Statement of Originality

This work has not previously been submitted for a degree or diploma in any university. To the best of my knowledge and belief, the thesis contains no material previously published or written by another person except where due reference is made in the thesis itself.

(Signed)_____________________________

Abdullah Karaksha
ALL PAPERS INCLUDED ARE CO-AUTHORED

Acknowledgement of Papers included in this Thesis

Section 9.1 of the Griffith University Code for the Responsible Conduct of Research (“Criteria for Authorship”), in accordance with Section 5 of the Australian Code for the Responsible Conduct of Research, states:

To be named as an author, a researcher must have made a substantial scholarly contribution to the creative or scholarly work that constitutes the research output, and be able to take public responsibility for at least that part of the work they contributed. Attribution of authorship depends to some extent on the discipline and publisher policies, but in all cases, authorship must be based on substantial contributions in a combination of one or more of:

- conception and design of the research project
- analysis and interpretation of research data
- drafting or making significant parts of the creative or scholarly work or critically revising it so as to contribute significantly to the final output.

Section 9.3 of the Griffith University Code (“Responsibilities of Researchers”), in accordance with Section 5 of the Australian Code, states:

Researchers are expected to:

- Offer authorship to all people, including research trainees, who meet the criteria for authorship listed above, but only those people.
- Accept or decline offers of authorship promptly in writing.
- Include in the list of authors only those who have accepted authorship.
- Appoint one author to be the executive author to record authorship and manage correspondence about the work with the publisher and other interested parties.
- Acknowledge all those who have contributed to the research, facilities or materials but who do not qualify as authors, such as research assistants, technical staff, and advisors on cultural or community knowledge. Obtain written consent to name individuals.

Included in this thesis are papers as Chapters 2, 3, 4 and 5 which are co-authored with other researchers. My contribution to each co-authored paper is outlined at the front of the relevant chapter. The bibliographic details (if published or accepted for publication)/status (if prepared or submitted for publication) for these papers including all authors, are:

(Where a paper(s) has been published or accepted for publication, you must also include a statement regarding the copyright status of the paper(s)).
Chapter 2: Pilot study one “Development and Evaluation of Computer-Assisted Learning (CAL) Teaching Tools Compared to the Conventional Didactic Lecture in Pharmacology Education”

This paper was published as a peer-reviewed full conference paper at the International Conference on Education and New Learning Technologies (EDULEARN11), Barcelona (Spain). July 2011

Chapter 3: Pilot study two “Educational Benefit of an Embedded Animation Used as Supplement to Didactic Lectures in Nursing Pharmacology Courses”

This paper was published as a peer-reviewed full conference paper at the 7th International Technology, Education and Development Conference (INTED2013), Valencia (Spain). March 2013.

Chapter 4: Student engagement study “Student Engagement in Pharmacology Courses Using Online Learning Tools”

This paper was submitted on January 2, 2013; accepted February 17, 2013; scheduled for publication August 8, 2013.

Chapter 6: Griffith University versus Bond University study “The Evaluation of Educational Benefits of Online Learning Tools on Student Performance in a Major Assessment Item Across Two Higher Education Institutions in Australia”

This paper was submitted to the Focus on Health Professional Education. A Multi-Disciplinary Journal on the 18/03/2013. The paper received the associate editor approval and progressed to the peer reviewers on 23/05/2013.

Appendix D (Chapter 5): Student performance study “A Comparative Study to Evaluate the Educational Impact of e-Learning Tools on Griffith University Pharmacy Students’ Level of Understanding Using Bloom’s and SOLO Taxonomies”

This paper was submitted to the Higher Education Journal on 11/06/2013 for publication.

Appropriate acknowledgements of those who contributed to the research but did not qualify as authors are included in each paper.

(Signed) _________________________________ (Date) 26th July 2013
Abdullah Karaksha

(Countersigned) ___________________________ (Date) 26th July 2013
Supervisor: Dr. Shailendra Anoopkumar-Dukie
Dedication

This dissertation is dedicated to those people who have provided the love, support and encouragement necessary to continue this work through to completion; my family:

To my lovely wife Nisreen who supported me all the way from start to finish, who always eased my pain and encouraged me in the times of doubt. I am enormously indebted to her for motivating me to keep this dream alive. Without Nisreen’s support, encouragement, and sacrifice, I could not have achieved this goal. Nisreen is the love of my life.

To my precious gift from Allah, my daughter Leanne, who added a great joy to my life, who made me laugh and forget the difficult moments, who gave me the motivation to carry on to finish this work.

To my brothers and their families, and to my parents-in-law for their constant love, support and encouragement.

To the brave people of Syria, where I belong, who stood up against oppression and offered their lives as a price for freedom. Their sacrifices inspired me and kept me moving to finish this project.

And most of all, for my parents Ammar Karaksha and Malak Nasser who raised me to be high-achieving person, who cheered for every milestone I passed from childhood to this time, who planted the honesty and hardworking concept in me, who encouraged me to travel all the way to Australia to improve my education and obtain higher degrees. I can never repay my parents what they deserve, but I ask Allah to send his mercy upon them for all their great efforts.
Acknowledgments

While a dissertation may demonstrate the student’s ability to carry out independent research, no project of this significant could be completed without the support, guidance, encouragement, and plain hard-work by many individuals. Without them, this project would not have been possible. I would like to express my sincere gratitude and appreciation to my supervisors.

Thanks must go to Dr. Gary Grant and Dr. Shailendra Anoopkumar-Dukie, who mentored me since the start of this work, provided a solid foundation and gave me direction and encouragement when necessary. They were definitely a great support and help during my thesis from start to finish.

I have been blessed to work with the mentors Professor Andrew K. Davey and Dr. S. Niru Nirthanan who offered their experience and time to co-supervise this project to completion. They provided me with much needed advice, feedback, support and encouragement to complete this project.

I am also deeply indebted to my colleague Rebecca Grealy who helped me a lot during the difficult times and provided me with support and encouragement when I most needed them. Rebecca is a great giving person who offers her help without expecting anything in return.

Lastly, my heartfelt thanks are extended to my entire family who have listened when I needed a kind ear and have helped me stay focused. Thanks to all of you for your love, support and patience.
# Table of Content

Abstract ........................................................................................................................................ ix

Chapter 1 ....................................................................................................................................... 1
Introduction ................................................................................................................................... 1
  The Scholarship of Learning and Teaching in the Dynamic Discipline of Pharmacology ...... 2
  e-Learning Tools – What’s in a Name? .............................................................. 3
  Evaluating the Benefits of e-Learning Tools on Student Learning ...................... 4
  Significance and Rationale. ............................................................................. 6
  Hypotheses ................................................................................................. 12
  Aims and Objectives of the Project ......................................................... 13
  Reference............................................................................................... 15

Chapter 2 ..................................................................................................................................... 19
Pilot Study One ........................................................................................................................... 19
  Abstract .................................................................................................. 20
  1. INTRODUCTION............................................................................... 20
  2. METHOD.......................................................................................... 23
  3. RESULTS: ......................................................................................... 24
  4. DISCUSSION .................................................................................... 26
  5. CONCLUSION ................................................................................ 27

Chapter 3 ..................................................................................................................................... 30
Pilot Study Two ........................................................................................................................... 30
  Abstract .................................................................................................. 31
  1 INTRODUCTION............................................................................... 32
  2 METHOD.......................................................................................... 33
  3 RESULTS .......................................................................................... 34
  4 DISCUSSION .................................................................................... 37
  5 CONCLUSION ................................................................................ 39

Chapter 4 ..................................................................................................................................... 41
Student Engagement Study ......................................................................................................... 41
  INTRODUCTION............................................................................... 42
  DESIGN ............................................................................................ 43
  EVALUATION AND ASSESSMENT.................................................. 43
  DISCUSSION .................................................................................... 46
  CONCLUSION ................................................................................ 49
  REFERENCES .................................................................................. 50

Chapter 5 ..................................................................................................................................... 52
Abstract

Background: Pharmacology education entails rich and complex content involving a plethora of drugs and their mechanisms of action, numerous detailed facts about drug classes and individual compounds, and the therapeutic indications for these drugs. Over the years, the discipline has undergone rapid expansion and advancement which has increased pressure on pharmacology educators to continuously update their curricula. At the same time, education has been undergoing a paradigm shift, moving away from teaching-as-instruction towards student-centred learning approaches. This is set against a backdrop of increasing student numbers and static resources, universal challenges facing higher education in Australia. Moreover, generation Y students who have novel learning styles and have technology engrained as an integral part of their lives, perceive pharmacology as a more “difficult” learning area than other subjects in the undergraduate pharmacy curriculum. In this context, delivering the pharmacology curricula is a challenge and learning and teaching strategies have to keep pace with the student expectations, curricular requirements and practical realities that ultimately determine learning and teaching approaches. The implementation of technology, in the form of online learning tools (e-learning tools) has been proposed to provide students with self-directed and flexible learning opportunities and to keep the students engaged and up-to-date with the content.

Hypotheses: the hypotheses of this research were:

1. Alternative hypothesis one: a well-designed study can truly elucidate the benefits of e-learning tools in improving student level of understanding and perception;
2. Alternative hypothesis two: well developed e-learning tools will add significant educational benefit to an existing curriculum by improving student level of understanding and perception.
**Aims:** The overall aim of the research was to design and develop e-learning tools underpinned by widely accepted educational principles and theories and examine the impact of these e-learning tools on improving student learning experiences and outcomes.

The specific objectives were to: 1. compile a comprehensive review of literature pertaining to the pedagogy of e-learning tools in general, and in the discipline of pharmacology specifically; 2. develop a series of preliminary e-learning tools for pilot studies, define the pedagogy of these e-learning tools, and then quantitatively and qualitatively evaluate the effectiveness of these e-learning tools on student learning experience; 3. redefine the pedagogy underpinning the e-learning tools based on the results of the pilot studies; 4. develop and deliver a comprehensive series of e-learning tools that cover drug mechanisms of action within the context of our School’s pharmacology curriculum for third year pharmacy students; 5. develop a well-constructed methodology and evaluate student engagement with and uptake of the e-learning tools; and finally, 6. compare student level of understanding and perception between two cohorts of students who either received a traditional didactic pharmacology curriculum or a curriculum that additionally incorporated e-learning tools as a blended learning approach.

**Methods:** A comprehensive review of the literature was conducted to define the appropriate pedagogy that could be used as the cornerstone for the design of the e-learning tools. A series of two consecutive pilot studies were conducted in preparation for the main study in this investigation. The first pilot study was used to improve the design of the e-learning tools, and pilot test the survey which examined student preference and engagement with the e-learning tools. In addition to the above, the second pilot study was undertaken to pilot test the efficacy of the Structure of the Observed Learning Outcome
taxonomy as means of assessing the educational benefit of the e-learning tools on student level of understanding.

For the purposes of the first pilot study, an e-learning tool describing two gastrointestinal drug mechanisms of action was developed and delivered via a CD to participants. The study group comprised third year pharmacy students at Griffith University enrolled in pharmacology course in 2010. Seventy five participants were randomly allocated into four groups, students who received the lecture and viewed the e-learning tool (n = 23), students who utilised the e-learning tool only (n = 22), students who received the lecture only (n = 13) and students who received no formal instruction (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. Participant satisfaction with the tool was measured using a 5-point Likert scale (strongly agree, agree, neutral, disagree and strongly disagree).

The second pilot study was conducted by designing an e-learning tool, embedded as an animation in the lecture on the pharmacological mechanisms of action of gastrointestinal drugs for second year nursing students enrolled in a core pharmacology and pathophysiology course in 2011. Forty-five nursing students voluntarily participated in the study and were divided into two groups: the intervention group, which attended a face-to-face lecture with embedded animation (n=25), and the control group, which accessed the didactic lecture online without the embedded animation (n=20). Student performance in short-term retention was assessed using two case-based quizzes. The first quiz comprised multiple choice and short answer questions on the pharmacology of gastrointestinal drugs (including the content reinforced by the embedded animation). The second quiz was on immunology and included multiple choice questions. A short survey
was used to discriminate between the two groups, obtain students’ demographic data and evaluate their preference towards online e-learning tools.

The e-learning tool design was refined and improved after each pilot study, leading to the design of a series of 148 third generation e-learning tools describing the drug mechanisms of action for third year undergraduate pharmacology curriculum for pharmacy students at Griffith University, Australia. The e-learning tools were delivered as supplementary material to the Human Pharmacology I (3024PHM) and II (3028PHM) courses in 2012 and were uploaded to the courses’ website (Blackboard™) for ease of access by students and for monitoring usage statistics. Two important outcomes with regard to the e-learning tools were evaluated at the end of the courses - student preference and engagement with the e-learning tools; and student performance in the final summative examinations.

Student engagement and uptake of the e-learning tools during semester one and two of 2012 was assessed using a survey and usage statistics for the material which were delivered via the Blackboard™. Forty three students voluntarily participated in the survey, representing 54% of the total cohort. Of those, 23 students accessed the e-learning tools (group one) and the remaining did not use the e-learning tools (group two) during semester one.

Student performance in the final exams was assessed by conducting a qualitative and quantitative study. The study aimed to evaluate and compare the student level of understanding in the final examinations between the student cohort in 2012 (intervention group, n = 25), who studied the Human Pharmacology curriculum delivered via traditional face-to-face lectures which were supplemented with the e-learning tools, and the student cohort in 2011 (control group, n = 53) where the Human Pharmacology
curriculum was delivered without the e-learning tools. To control for the differences in the level of difficulty of the content in exam questions between 2011 and 2012, the short and long answer questions were classified according to Bloom’s revised taxonomy. Consequently, student answers were qualitatively evaluated using the Structure of the Observed Learning Outcomes taxonomy. The key demographic variables (age, gender, and GPA) were also collected and compared between the two groups to control for the inherent ability of the participants.

The final component of this PhD study was conducted to compare the educational benefit of adding e-learning tools as supplements to the pharmacology curriculum on student performance between Bond University, another higher education institution on the Gold Coast, Australia and Griffith University. Student demographic data and attitudes towards the e-learning tools were assessed using a survey; student uptake of the e-learning tools was evaluated by analysing data from the Blackboard™. Finally, student performance in a major assessment item was analysed before e-learning tools were implemented (2011) and after deployment of the e-learning tools (2012), to evaluate the improvement in learning at each university.

Ethical approval was granted by the Griffith University Human Ethics Committee for all studies (protocol PHM/05/10/HREC). Student participation was voluntary and anonymous in all studies. Data were statistically analysed by t-test, ANOVA, Pearson correlation, Chi square and Backward linear regression using GraphPad InStat and IBM SPSS softwares. Probability (p) values of less than 0.05 were considered statistically significant.

Results: Performance, as measured by mean test scores, was significantly greater (p<0.05) in the pharmacy student group that received the pharmacology content via the
lecture and viewed the e-learning tool as compared with those who received the lecture only, or had neither. The majority of participants were satisfied with the e-learning tool and found it easy to use.

The second pilot study found no significant difference ($p>0.05$) in academic performance between the two nursing student cohorts who either attended the face-to-face lecture with the embedded animation or those who accessed the didactic lecture online without the embedded animation. The results also showed that students’ performance correlated positively with their grade point average ($p<0.05$, $r = 0.63$) and that there was a strong association between attendance at lectures and performance in the quizzes ($p<0.05$). Another finding of this study was the significant relationship between non-attendance at lectures and preference for using online learning materials ($p<0.05$).

Analysing student engagement with the e-learning tools revealed low usage during semester one in 2012. This was attributed to the majority of students (75%) either being unaware of, or forgetting about the embedded e-learning tools, while a few (20%) stated a lack of interest in accessing additional learning materials. E-learning tools usage significantly increased in semester two after using frequent email reminders and announcements ($p=0.0001$). Student qualitative comments indicated their positive preference towards the e-learning tools.

The key demographic variables between the control group (standard curricula in 2011) and intervention group (standard curricula + e-learning tools in 2012) were comparable in the component of the PhD study that evaluated the impact of e-learning tools on student level of understanding. Backward linear regression analysis was performed to model the level of student understanding while controlling for possible confounding variables during each semester (semester 1 and 2 in each academic year)
separately. For semester one, four models were generated, with the most significant model containing the variables *intervention group* (control vs intervention) and *grade point average*, with the variables *domestic/international, age, gender* removed from the model. This model showed *grade point average* as the most significant predictor of level of understanding (p<0.05) and *intervention group* approaching significance as a predictor of level of understanding (p=0.09). Student background, age, and gender were not shown to be significant predictors (p>0.05). For semester two, again the model containing the variables *intervention group* and *grade point average* was the most significant of the four models generated. This model demonstrated *grade point average* as the most significant predictor of level of understanding (p<0.05); however, *intervention group* was also shown to be a highly significant predictor for semester two (p<0.05). These results were supported by correlation analysis of student level of understanding in the intervention group and e-learning tools usage. In both semesters a strong positive correlation was observed; however in semester one the correlation was 77% compared to 88% in semester two.

Finally, the study that was conducted at both Bond and Griffith universities demonstrated that, overall, students preferred the addition of e-learning tools to supplement their standard curriculum. The uptake of the e-learning tools was significantly higher at Bond compared to Griffith University (p<0.05). However, students from Griffith performed significantly better in the 2012 exam when compared to 2011 (p<0.05), while no significant difference in performance was observed at Bond across the two academic years studied (p>0.05).

**Conclusion:** This PhD investigation identified the required educational theories and principles to design effective self-designed e-learning tools and the software needed to produce those tools. The results of the pilot studies were used to refine the design of
the e-learning tools to be more effective in their content, delivery and appeal, leading to the development of a comprehensive suite of e-learning tools which were utilised to supplement the Human Pharmacology curriculum in the undergraduate pharmacy program. Across the two pilot and main studies, different student cohorts (Nursing, Pharmacy and Health Science students at Griffith and Bond universities) showed positive preference and attitude towards the implementation of technology as a supplement to the traditional teaching methods. E-learning tools appeared to significantly improve student level of understanding as scored by the Structure of the Observed Learning Outcomes taxonomy when there was substantial engagement of students with the tools. The study demonstrated that a holistic approach underpinned by educational pedagogy could be employed to objectively evaluate the impact of technology on student learning, effectively comparing different student cohorts using Bloom’s revised taxonomy to classify exam questions into common learning dimensions, and using the Structure of the Observed Learning Outcomes taxonomy scoring to evaluate student level of understanding. This approach is superior to a simplistic comparison of summative exam grades as has been utilised in previous studies. The study has answered the two hypotheses by showing that a well-designed study was able to truly elucidate the educational benefits of the e-learning tools, and that well developed e-learning tools indeed added significant educational benefit to existing pharmacology curricula by improving student level of understanding and perception.
Chapter 1
Introduction
The Scholarship of Learning and Teaching in the Dynamic Discipline of Pharmacology

The scholarship of learning and teaching (SoLT) involves research into practices of teaching, learning and curriculum. SoLT’s main principle is that effective teachers in higher education should engage in scholarly teaching practices as a matter of course, by staying in touch with the latest research developments in their discipline, integrating these developments into their curriculum, and routinely gathering and using student feedback to guide curriculum review and improvement. SoLT research focuses on understanding student learning in order to improve the teaching and learning experience for participants (Boyer 1991, Grauerholz and Zipp 2008, Buckridge, Krause et al. 2010). One area in which SoLT principles are particularly important is pharmacology education, because it entails rich content involving a plethora of drugs and their mechanisms of action, numerous detailed facts about drug classes and individual compounds, and the therapeutic indications for these drugs (Michel, Bischoff et al. 2002). Over the years, the discipline of pharmacology has undergone rapid expansion and advancement - the number of United States Food and Drug Administration-approved drugs has increased exponentially, patients have become more educated and demanding, and our knowledge of the mechanisms underlying many adverse drug events and interactions have evolved (Zgheib, Simaan et al. 2011). This expansion in our knowledge of the discipline has placed more pressure on pharmacology educators to continuously incorporate new facts and principles and update their curricula (Hughes 2003). Moreover, students perceive pharmacology as a more “difficult” learning area than other subjects in the undergraduate pharmacy curriculum (Badyal, Bala et al. 2010, Wang, Hu et al. 2012). Consequently, teaching pharmacology curricula to students has been a challenge (Badyal, Bala et al. 2010, Halliday, Devonshire et al. 2010) and up-to-date teaching methods, such as e-learning
tools, have been proposed to keep the students engaged and up-to-date with the content (Michel, Bischoff et al. 2002, McGil 2011, Beetham and Sharpe 2013).

**e-Learning Tools – What’s in a Name?**

The term ‘e-Learning tool’ encompasses electronic devices that are focused on implementing technology-based solutions for improving student performance and learning experience. It can refer to instruction delivered on a computer by way of CD-ROM (offline content), the internet, or intranet for the use of technology in education and training, and can contain content such as videos, slides, photographs, and animations (Lewis, Davies et al. 2005, Yelland, Tsembas et al. 2008). There are a plethora of terms describing *e-learning* in the educational literature, placing it in the sub-category of ‘educational technology’ which describes the general processes and tools involved in addressing the educational needs of the student (Roblyer and Doering 2010)—as well as ‘multimedia learning’—which refers to the use of media tools, delivered online or offline (Shavinina and Loarer 1999), aiming to generate or enhance learning. Multimedia tools integrate at least three of the following seven types of presentation: text, data, graphics, audio, photographic images, animation or moving pictures (Shavinina and Loarer 1999). ‘Online-learning’ encompasses a range of technologies such as the worldwide-web, email, chat, newsgroups, text, audio and video conferencing delivered over computer networks (Yelland, Tsembas et al. 2008), while ‘blended-learning’ is used to describe the blend of conventional didactic lectures and online tools (Krause 2009). Additionally, e-learning tools themselves can be described by the terms Computer-Assisted Instruction (CAI), Computer-Assisted Learning (CAL), Computer-Based Instruction (CBI) and Computer-Based Learning (CBL), which were initially used when personal computers were first available as a resource for the delivery of learning material (Trigwell and Prosser 1996, Grigg and Stephens 1998, Hughes 2002, Lewis, Davies et al. 2005).
2005, Carbonaro, King et al. 2008). Moreover, some of these terms are still used to describe e-learning tools, to reflect the main function or mode of delivery; for example, e-learning tools delivered through the internet can be termed Web-Based Instruction (WBI) or Web-Based Learning (WBL) (Erickson, Chang et al. 2003, Lahaie 2007), while e-learning tools used for delivery, marking and analysis of student assignments or examinations can be termed Computer-Assisted Assessment (CAA) (Adams 2004, Lahaie 2007). As there are many methods to deliver the teaching instruction using technology, e-learning tools are most commonly used as a more comprehensive term (Yelland, Tsembas et al. 2008). Thus, for the purpose of this dissertation, the term e-learning tool will be used to refer to this technology henceforth.

**Evaluating the Benefits of e-Learning Tools on Student Learning**

Reviewing the literature regarding e-learning tools revealed a large number of studies, investigations, projects and articles that have investigated aspects of this new teaching method, but these studies do not concur in their conclusions. For instance, some researchers proposed that e-learning tools support academics and educators to meet the growing needs and expectations for improving the quality of tertiary education (Walley, Bligh et al. 1994, Candler, Ihnat et al. 2007, O'Shaughnessy, Haq et al. 2010) and provide a number of advantages to students that help educators promote learning and improve education quality (Maxwell 2012). Other authors have discounted such benefits and claim that the use of e-learning tools remains limited (Berman, Fall et al. 2008, Masters and Ellaway 2008, Yelland, Tsembas et al. 2008, MacLean, Scott et al. 2011). This discrepancy can be attributed to two major reasons: lack of underlying pedagogical principles, and a focus on differing e-learning tool aspects.
The first reason for the observed conflicting reports is that the majority of e-learning tools are designed with no specific focus on pedagogy. Pedagogical knowledge includes cognitive, social, and developmental theories of learning and how they apply to students in the classroom (Harris, Mishra et al. 2009). These concepts are important to understand how students construct knowledge and learn. Consequently, e-learning tool designers should put as much emphasis on the educational theories that help students learn better as they do when designing the tools (Harris, Mishra et al. 2009). Failing to do so may result in producing e-learning tools that are attractive to academics and students but in reality do not carry any true educational benefit on student learning (Yelland, Tsembas et al. 2008).

The second reason for the observed conflicting reports is the fact that these studies focus on widely different aspects of e-learning tools. Some studies have only assessed student preferences and their attitudes to the use of e-learning tools (Chen, Lambert et al. 2010, Euzent, Martin et al. 2011, MacLean, Scott et al. 2011, Taplin, Low et al. 2011), while others have examined student motivations for using online learning approaches, such as perceptions of flexibility or convenience (Horspool and Lange 2010). While these studies have found that student attitudes towards e-learning tools are generally positive, student preferences for or against e-learning tools (and for that matter, the course in which the e-learning tools are applied) does not accurately reflect the impact of e-learning tools on student learning (Sun, Tsai et al. 2008). Other studies which chose to investigate the impact of the tools on learning by assessing student performance, however, took into account only the students’ final grades in the course as their marker of performance and learning (Nieder, Borges et al. 2011, Sari 2012, Williams, Birch et al. 2012). While exam grades determine whether a student passes or fails the course, students may pass a course
and strategically perform well in the exams without deep understanding of the course content (Chan, Tsui et al. 2002).

A more comprehensive and objective approach to evaluate the impact of e-learning tools on student learning would be to assess students’ levels of understanding of the learned content using an expansive analyses of performance at assessment tasks including the taxonomic classification of examination answers. To the best of our knowledge, no study to date has employed this approach to evaluate the impact of e-learning tools in higher education. Therefore, it would appear that no study focused on higher education has followed a holistic approach to evaluate the impact of technology on student learning, which might have contributed to the overly cautious implementation of e-learning tools in higher education settings (Berman, Fall et al. 2008). Hence, there is a pressing need for further scholarly research to address this critical gap in our knowledge and elucidate the true educational benefits of the e-learning tools on student learning experiences and level of understanding and harness the full potential of e-learning tools in tertiary education.

**Significance and Rationale**

The American Commission to Implement Change in Pharmaceutical Education (AACP) was initiated in 1989, with the task of developing a series of recommendations to guide pharmacy education as it evolved to meet the changing demands of the profession, the healthcare system, and society (AACP 2011). The Commission concluded that there was an increased need for pharmacy schools to examine not only what they teach, but more importantly, how they teach and how students learn (AACP 1993). It is therefore crucial for pharmacy educators to consult and reflect on known teaching theories in order to promote and develop new practices in the learning process. Moreover,
the Higher Education Funding Council for England (HEFCE) poses the question: “How can higher education institutions become more flexible at a time of change while maximising the talent and commitment of the students?” (HEFCE 2010). Both, the AACP recommendation and the HEFCE question, come in line with the findings of research into student engagement which suggest that student engagement with traditional didactic lectures, and attendance in traditional learning activities, has significantly declined (Barnett and Coate 2005). Students are now entering higher education with a diverse range of backgrounds and skill sets which are very different from the ‘traditional’ university entrance criteria (Franklin and Van Harmelen 2007). Moreover, increasing student numbers and ballooning financial costs of higher education have raised concerns about the quality of student learning and experience (Haggis 2006, Kukulska-Hulme 2012). At the same time, education has been undergoing a paradigm shift, moving away from teaching-as-instruction (what lecturers teach) towards student-centred learning approaches (what students do to learn) (Ramsden 2003). Teaching is not seen as a method to transit information from teachers to students anymore. It is the time where teachers are playing the role of facilitators and students are taking more responsibility for their learning (Horgan 2003). As a consequence, curricula have been redesigned around learning outcomes rather than content (Biggs 2003). Moreover, the rapid expansion and innovation in technology, and the fact that students expect technology to be integrated into their learning experiences, (Berman, Fall et al. 2008, Yelland, Tsembas et al. 2008) have encouraged higher education institutions to incorporate technology-based teaching into their curriculum to increase student engagement (Cole 2009, Rennie and Morrison 2012).

The Commission placed great emphasis on the importance of developing and implementing educational plans and strategies to evolve students from dependent to
independent learners (AACP 1993). For dependent learners, teachers are the directors of learning and the student role is to respond to the direction brought by the teacher. In other words, teachers tell the student what, how and when the content is or has to be learnt (Moore 1973, Martin, Prosser et al. 2000). Independent learners, on the other hand, are self-directing their learning activities; they can plan their study effectively without the need for teacher directions. For independent learners, the teachers’ role is limited to providing information and advice when needed (Moore 1973, Martin, Prosser et al. 2000).

The Commission also encourages academics to apply the concept of student-focused learning which places student as the focus of activities (Trigwell, Prosser et al. 1999). Students in this approach have to construct their own knowledge, and re-construct their previous knowledge to produce a new knowledge framework or conception with the teacher’s role limited to encouraging and facilitating students to lead their self-directed learning (Trigwell, Prosser et al. 1999). This approach to learning is usually associated with students developing a deeper approach to learning (attempting to make sense of content), rather than a surface approach (attempting to remember factual content) (Gibbs and Coffey 2004, Biggs and Tang 2007). A deeper approach to learning is linked with students achieving superior learning outcomes, particularly in terms of understanding and developing new and more sophisticated conceptions of the subject (Trigwell and Prosser 1996, Gibbs and Coffey 2004). This is strongly supported by a large body of research (Ramsden 1992, Gibbs and Coffey 2004, Biggs and Tang 2007). For instance, one study showed that 90% of the participants who passed all their examinations in both experiment and normal studies, were classified as deep learners (Ramsden 1992). Moreover, university students, from different disciplines, were more likely to outperform other students when they used a deep learning approach (Ramsden 1992).
The recommendations of the Commission are particularly important in pharmacology education due to the rapid expansion of the pharmacology knowledge-base, an increased understanding of the mechanisms of drug action, discovery of novel drugs and therapeutic targets, and an increase in therapeutic classes and drugs available for the treatment of disease (Francis, Mauriello et al. 2000). It is essential to keep adding this new knowledge into existing pharmacology curricula (Pahinis, Stokes et al. 2007), a task for which no additional time is usually allocated (Pahinis, Stokes et al. 2007). Furthermore, academic staff are curtailed of some teaching time due to the emphasis on excellence in research that is imperative to achieve career progression (Hughes 2003). Another challenge posed by rapidly increasing student numbers is the greater differences of academic ability and maturity at university entry and a more diverse range of student expectations, aspirations and outcomes (Hughes 2003). Often, many students find that they are unable to participate in face-to-face teaching for geographic, financial, family or logistical reasons and consequently lose opportunities for study; while other preferentially choose to be self-learners and do not attend lectures (Barajas and Owen 2000). The diversity of the international student cohort with the majority of these students being from a non-English speaking background poses further challenges (Hughes 2003). Digital native students (students ingrained in the advances in new technologies) who have novel learning styles that are non-linear and fluent in simulation-based virtual settings, consequently need more than the traditional teaching approaches to engage in the learning process (Prensky 2009). It is likely that these abovementioned factors, at least in part, hinder student learning, prevent true comprehension and understanding, and restrict integration of new knowledge into a student’s existing knowledge-base or conceptual frame-work (Pahinis, Stokes et al. 2007). As a result, teaching styles have changed and pharmacology educators have evolved and adopted a number of teaching strategies to
address these challenges including: small group discussions, problem-based learning, peer teaching, recitation, simulations, and use of technology resources (AACP 1993).

The focus of this thesis is about the implementation of e-learning tools as an innovative, interactive and flexible teaching method to be an important supplement of the existing pharmacology curriculum in the School of Pharmacy at Griffith University. However, it is important to note that the use of e-learning tools in learning and teaching requires an intricate combination of content, pedagogy, and technological knowledge (Harris, Mishra et al. 2009, Roblyer and Doering 2010). Educators, therefore, must be fluent in more than just the content to be taught and the technology to be used to deliver it but also in the learning and teaching pedagogy that underpins the strategy (Harris, Mishra et al. 2009, Roblyer and Doering 2010). These three critical elements need to converge and coalesce in order to design and deliver instruction effectively and optimally with technology (Harris, Mishra et al. 2009, Roblyer and Doering 2010). This approach is proposed for the development and use of e-learning tools by pharmacology educators to enhance the impact and learning experience for their students (Hughes 2002, Hughes 2003, Candler, Ihnat et al. 2007). Additionally, e-learning tools have the potential to increase student knowledge and understanding of a particular subject, allow flexibility in learning, offer distance learning and enable them to direct their own learning (Lewis, Davies et al. 2005); thereby conforming to an optimal model for student-focused learning (Hughes 2002, Hughes 2003).

Many e-learning tools have been implemented and evaluated in dental, health science, nursing curricula and continuing professional education (Francis, Mauriello et al. 2000, Lahaie 2007, Carbonaro, King et al. 2008). In addition, the use of e-learning tool resources is becoming widespread to support pharmacology teaching with some increase in resources in the last decade (Dewhurst and Norris 2003, Hughes 2003). In the same
context, implementing e-learning tools is perceived to be one solution for educational institutions constrained by limited budgets and sub-optimal staff-student ratios. Schools and colleges are becoming more conscious of cost-benefit balances and are trying to reduce the number of cost- and labour-intensive teaching methods such as small-group tutorials (Hughes 2003). The development of e-learning tools is primarily a one-off investment in time and financial commitment for a method of instruction that may be used repeatedly (Bachman, Lua et al. 1998). Real costs are associated with faculty and programmer effort and time (opportunity costs), in addition to software and hardware requirements (Ried and Byers 2009). At a time of financial constraints and fiscal responsibilities, the use of technological systems that do not require the presence of staff has obvious attractions (Clark, Weekrakone et al. 1997). Computer-based or web-based delivery of learning and teaching is likely to be substantially more cost-effective than budgetary allocations for teaching and sessional staff to do the same work (Allum 2002). Therefore, this method of instruction may be more cost-effective in the long-term than traditional classroom methods that depend primarily on the annual cost of the instructor (Bachman, Lua et al. 1998).

However, a significant limitation of commercially purchased e-learning tools is that the content will potentially be out of date after a relatively short period of time due to the rapid advancement in new knowledge in many scientific disciplines, particularly pharmacology (Barajas and Owen 2000). The content of the e-learning tools should be aligned with the educational objectives and aims of the specific course that chooses to employ them, or they will fail to benefit student learning (Charsky and Ressler 2011). In this regard, commercially available e-learning tools are typically generic and prescriptive to the discipline, profession, publisher or country of origin. Consequently, this research
focused on defining the pedagogy\(^1\) to create e-learning tools, designed and developed in-house that conform to our program’s educational needs as well as our curricular requirements to align with the objectives of the courses to form a system which operates well for the benefit of students. They were also designed to be easily updatable without extra cost or the need for complex programming skills.

Therefore, the significance of our study is underpinned by the anticipated ability of e-learning tools to provide solutions for the following four issues facing higher education - (1) conform to the recommended educational change towards a student-focus approach and facilitate students to progress into independent life-long learners; (2) provide opportunities to academics to effectively compensate for any loss of face-to-face teaching time; (3) satisfy diverse student needs and requirements and cater to their differing learning styles and academic abilities by providing them with flexible learning opportunities; and (4) assist educational institutions cope with budgetary restraints and sliding staff-student ratios by providing a cost-effective learning and teaching strategy.

**Hypotheses**

With the growing need to fully harness the power of technology for learning and teaching; it is imperative that these new technology-driven strategies are backed by sound educational theories that focus on promoting deep and self-directed learning rather than appease the logistical constraints in a given moment. Given the current lack of well-designed studies and appropriately designed e-learning tools it seemed feasible that this investigation evaluated the development and application of e-learning tools based on well-defined educational pedagogy and evaluated its impact as accurately and objectively as feasible in a well-designed study. In this context, the hypotheses of this research were:

\(^1\) Pedagogy in this context refers to the teaching theories and principles that apply in designing e-learning tools.
1. Alternative hypothesis one: a well-designed study can truly *elucidate the benefits of e-learning tools in improving student level of understanding and perception*;

2. Alternative hypothesis two: well developed *e-learning tools will add significant educational benefit to an existing curriculum by improving student level of understanding and perception*.

**Aims and Objectives of the Project**

The overall aim of the research was to design and develop e-learning tools incorporating well-recognized educational principles and theories and examine the impact of these e-learning tools on improving student learning experiences and outcomes.

The specific objectives were to:

1. Compile a comprehensive review of literature pertaining to the pedagogy of e-learning tools in general, and in the discipline of pharmacology specifically;

2. Develop a series of preliminary e-learning tools for pilot studies, define the pedagogy of these e-learning tools, and then quantitatively and qualitatively evaluate the effectiveness of these e-learning tools on student learning experience;

3. Redefine the pedagogy underpinning the e-learning tools based on the results of the pilot studies;

4. Develop and deliver a comprehensive series of e-learning tools that cover drug mechanisms of action within the context of our School’s pharmacology curriculum for third year pharmacy students;

5. Develop a well-constructed methodology and evaluate student engagement with and uptake of the e-learning tools;

6. Finally, compare student level of understanding and perception between two cohorts of students who either received a traditional didactic pharmacology
curriculum or a curriculum that additionally incorporated e-learning tools as a blended learning approach.
Reference


Franklin, T. and M. Van Harmelen (2007). Web 2.0 for content for learning and teaching in higher education, Bristol: JISC.


Chapter 2
Pilot Study One

Development and Evaluation of Computer-Assisted Learning (CAL) Teaching Tools Compared to the Conventional Didactic Lecture in Pharmacology Education

STATEMENT OF CONTRIBUTION TO CO-AUTHORED PUBLISHED PAPER

This chapter includes a co-authored paper. This paper was published as a peer-reviewed full conference paper at the International Conference on Education and New Learning Technologies (EDULEARN11), Barcelona (Spain). July 2011. The authors of the paper are: Abdullah Karaksha, Gary Grant, Andrew K. Davey, Shailendra Anoopkumar-Dukie.

My contribution to the paper involved: designing and conducting the study, collecting the data, analysing and categorizing the data and providing direction on the scope and structure of the analysis. I also wrote the first draft, made revisions responding to supervisor comments and feedback, prepared the final document, and submitted the article. I also responded to and addressed the reviewer comments when we received them, made appropriate revisions, and re-submitted the revised article after including reviewer-requested modifications.

(Signed) _________________________________ (Date) 26th July 2013
Abdullah Karaksha

(Countersigned) ___________________________ (Date) 26th July 2013
Corresponding author of paper: Abdullah Karaksha

(Signed) _________________________________ (Date) 26th July 2013
Supervisor: Dr. Shailendra Anoopkumar-Dukie
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

<table>
<thead>
<tr>
<th>Teaching Principles</th>
<th>Description and Evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Multimedia Principle:</strong> Students learn better from words and pictures than from words alone. [17]</td>
<td>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]</td>
</tr>
<tr>
<td><strong>Spatial Contiguity Principle:</strong> Students learn better when multiple source of information are integrated rather than separated. [27]</td>
<td>The designed CAL eliminates the need to collate information from different disciplines. Mayer and Moreno (1998) stated that students performed significantly (p&lt;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]</td>
</tr>
<tr>
<td><strong>Temporal Contiguity Principle:</strong> Students learn better when corresponding words and pictures are presented simultaneously rather than successively. [27]</td>
<td>Moreno and Mayer (1999) demonstrated in their study that students who watched the animation concurrently with the narration, performed significantly better (p&lt;0.05) in retention and problem solving tests from those who had them separately. [28]</td>
</tr>
<tr>
<td><strong>Coherence Principle:</strong> Students learn better when extraneous words, pictures, and sounds are excluded rather than included. [17]</td>
<td>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]</td>
</tr>
<tr>
<td><strong>Modality Principle:</strong> Students learn better from animation and narration than from animation and onscreen text. [17]</td>
<td>Moreno and Mayer (1999) confirmed in their study that students who watched the animation and listened to the narration performed significantly better (p&lt;0.05) in retention, matching and problem solving tests than those who watched the animation and read the on-screen text. [28]</td>
</tr>
<tr>
<td><strong>Individual Differences Principles:</strong> Design effects are stronger for low-knowledge learners than for high knowledge learners. [17]</td>
<td>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]</td>
</tr>
<tr>
<td><strong>Interactivity:</strong> Students learn better when they interact with learning materials rather than by receiving direct instruction. [17]</td>
<td>Moreno (2005) explained that students learn better when allowed to interact with CAL. [30]</td>
</tr>
</tbody>
</table>

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).

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.
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)

<table>
<thead>
<tr>
<th>(n)</th>
<th>Mean</th>
<th>SD</th>
<th>Minimum %</th>
<th>Maximum %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lecture+CAL (23)</td>
<td>66.96</td>
<td>23.82</td>
<td>20</td>
<td>100</td>
</tr>
<tr>
<td>CAL (22)</td>
<td>54.55</td>
<td>26.32</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>Lecture (13)</td>
<td>41.54</td>
<td>22.30</td>
<td>0</td>
<td>80</td>
</tr>
<tr>
<td>No intervention (17)</td>
<td>45.88</td>
<td>18.39</td>
<td>20</td>
<td>80</td>
</tr>
</tbody>
</table>

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.

<table>
<thead>
<tr>
<th>Students’ satisfaction</th>
<th>Positive (N)</th>
<th>Neutral (N)</th>
<th>Negative (N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lecture + CAL Group (N =23)</td>
<td>22</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>CAL Group (N =22)</td>
<td>18</td>
<td>4</td>
<td>0</td>
</tr>
</tbody>
</table>

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 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.

Acknowledgment: The authors would like to thank the faculty of Griffith Health at Griffith University for providing the blended learning grant.

Competing interest: None

REFERENCES


Chapter 3
Pilot Study Two
Educational Benefit of an Embedded Animation Used as Supplement to Didactic Lectures in Nursing Pharmacology Courses

STATEMENT OF CONTRIBUTION TO CO-AUTHORED PUBLISHED PAPER
This chapter includes a co-authored paper. This paper was published as a peer-reviewed full conference paper at the 7th International Technology, Education and Development Conference (INTED2013), Valencia (Spain). March 2013. The authors of the papers are: Abdullah Karaksha, Gary Grant, Andrew K. Davey, Shailendra Anoopkumar-Dukie, S. Niru Nirthanan

My contribution to the paper involved: designing and conducting the study, collecting the data, analysing and categorizing the data and providing direction on the scope and structure of the analysis. I also wrote the first draft, made revisions responding to supervisor comments and feedback, prepared the final document, and submitted the article. I also responded to and addressed the reviewer comments when we received them, made appropriate revisions, and re-submitted the revised article after including reviewer-requested modifications.

(Signed) _________________________________ (Date) 26th July 2013
Abdullah Karaksha

(Countersigned) ___________________________ (Date) 26th July 2013
Corresponding author of paper: Dr. S. Niru Nirthanan

(Countersigned) ___________________________ (Date) 26th July 2013
Supervisor: Dr. Shailendra Anoopkumar-Dukie
EDUCATIONAL BENEFIT OF AN EMBEDDED ANIMATION USED AS SUPPLEMENT TO DIDACTIC LECTURES IN NURSING PHARMACOLOGY COURSES

Abdullah Karaksha¹, Gary Grant¹, Andrew K. Davey¹, Shailendra Anoopkumar-Dukie¹, S. Niru Nirthanan²,³

¹ School of Pharmacy, Griffith University, Queensland (AUSTRALIA)
² School of Medical Science, Griffith University, Queensland (AUSTRALIA)
³ School of Medicine, Griffith University, Queensland (AUSTRALIA)
n.nirthanan@griffith.edu.au

Abstract

Background: Student expectations for technology to be integral in their learning experience has encouraged higher education institutions to incorporate new technology driven resources into their curriculum, often without valid evidence of effectiveness.

Aims: The aims of this study were to develop and evaluate the educational benefits of an embedded-animation as a supplement to the traditional didactic lecture for nursing students and to evaluate student attitudes towards the application of online e-learing tools in their learning and teaching.

Method: An embedded animation of the pharmacological mechanisms of action of gastrointestinal (GI) drugs was designed for second year nursing students enrolled in a core pharmacology and pathophysiology course in 2011. Ethical approval for this project was granted by Griffith University Human Ethics Committee. Forty five nursing students voluntarily participated in the study and were divided into two groups: group which attended a face-to-face lecture with embedded animation (n=25) and group which accessed the didactic lecture online without the embedded animation (n=20). Student performance in short term retention was assessed using two case-study based quizzes. The first case comprised of multiple choice and short answer questions on the pharmacology of GI drugs (including the content reinforced by the embedded animation). The second case was on immunology and included five multiple choice questions. A short survey was used to discriminate between the two groups, obtain students' demographic data and evaluate their preference towards online e-learning tools. Data were statistically analysed by t-test, ANOVA, Pearson correlation and Chi square using IBM SPSS software (ver 20). Probability (p) values of less than 0.05 were considered statistically significant.

Results: Forty five students participated in the study. Of those, only two students were males (4.5%). The results demonstrated no significant difference in academic performance between the two groups (t = 0.8, p > 0.05). However, the embedded animation had a positive impact on student learning, in particular on students who had a low Grade Point Average (GPA) and struggled with the theory content in courses. The results also showed that students' performance correlated with their GPA (p < 0.05, r = 0.63). The quiz results were divided into three categories: Fail (less than 50%), Pass (50-75%), and Distinction (more than 75%) and this classification of results was compared with the frequency of those attending lectures (never or rarely and frequently and always). The results demonstrated strong association between attendance at lectures and performance with pass and distinction in the quizzes (χ² = 9.15, p < 0.05). Another finding of this study was the significant relationship between non-attendance at lectures and preference for using online learning materials (χ² = 12.0, p < 0.05).

Conclusion: Albeit the small sample size, the results of this preliminary study suggest that the addition of embedded animation, as supplement to the didactic traditional lectures, did not have a significant effect on improving students' performance in assessments. Attendance at lectures and students' GPA showed positive correlation with performance at the quiz suggesting that these may be indicators of student outcomes at examinations. Students who did not routinely attend lectures were more likely to prefer the addition of online e-learning tools into the curriculum.

Keywords: Nursing education, pharmacology, embedded animation.
1 INTRODUCTION

The rapid expansion in the discipline of pharmacology, has placed more pressure on academics to consistently incorporate new facts and update their curricula [1]. While it is essential to add this new content into existing pharmacology curricula because of its relevance to contemporary clinical practice; in most instances no additional teaching time is allocated for its inclusion [2]. This disproportionate increase in content within the limitations of existing contact teaching hours may hinder student learning, limit comprehension and understanding, and restrict the integration of new information into students’ existing knowledge-base [3]. Therefore, it has been proposed that technological advancement may assist academic educators overcome these challenges and meet the growing needs and expectations for improving the quality of education, whilst encouraging student-focused learning and developing independent life-long learners [3]. Consequently, the use of technology in higher education has started to grow rapidly in both quantity and quality [2].

Although students generally perceive technology resources to be valuable for their learning, published studies reveal that the currently available tools provide little educational benefit in nursing education [4], with many tools never achieving a significant level of usage or being no longer in use [5]. One suggested theory is that the rush by institutions to embrace technology has often been made without the input of key educators and stake holders [6]. Moreover, the development of these tools has been more focused on the use of state-of-the-art technology rather than consultation with educationalists who value learning and pedagogy [6]. Further, the technology tools’ perceived lack of educational benefit may be attributed to their design not being governed by any relevant pedagogy or teaching theories. Therefore, the need for well-designed studies to identify the relevant pedagogy for the development of technology tools, and to better understand the relationship between the defined pedagogy, the educational objectives and specific elements of technology tools in improving student learning is a pressing need in the current educational context.

We have previously designed a series of online learning tools to complement the delivery of pharmacology content within the framework of a defined pedagogy and successfully evaluated its efficacy among pharmacy students, whose curriculum includes a significant component of advanced pharmacology [7]. Within the present study, we adapted one of our online tools to be an embedded animation within a didactic lecture for a different student cohort comprising of nursing students, who are often challenged by science-intensive courses amid perceived disconnect between nursing practice and basic science [8, 9].

The embedded animation that was developed covered the content relating to the mechanisms of action of two gastrointestinal (GI) drug classes, namely histamine 2 (H2) receptor antagonists and proton pump inhibitors (PPIs). The embedded-animation was designed to meet the following learning objectives: (1) to describe the normal physiological processes regulating the release of hydrochloric acid (HCl) from the stomach’s parietal cells; and, (2) to describe the pharmacological mechanisms by which H2 receptor antagonists and PPIs reduce the secretion of HCl from the parietal cells.

An assessment task was developed to evaluate the educational benefit of the embedded animation. The assessment consisted of a combination of well-constructed multiple choice questions (MCQs) and short answer questions (SAQs) delivered as two case-study based quizzes. Questions were carefully developed to assess the stated learning objectives and attempted to evaluate the four levels of the knowledge dimension, namely: factual, conceptual, procedural, and metacognitive knowledge, as defined by Bloom’s taxonomy and Bloom’s revised taxonomy [10, 11]. The Structure of the Observed Learning Outcome (SOLO) taxonomy was used as the rubric for the qualitative analysis of student answers for the SAQs. SOLO is a model for qualitative evaluation of teaching and assessing [12]. This taxonomy consists of five levels of increasing structural complexity: pre-structural, uni-structural, multi-structural, relational and extended abstract [12]. A similar method has already been used successfully by other researchers to qualitatively analyse student responses in a biology course [13, 14].

Therefore, the aim of this study was to design a GI pharmacology embedded animation based on previously established online learning tools and to evaluate its educational benefit. Moreover, the investigation aimed to evaluate student attitude towards the application of online e-learning tools in their learning and teaching.
2 METHOD

This investigation was conducted at the School of Medical Science, Griffith University, Gold Coast Campus, Australia. Ethical approval was granted by the Griffith University Human Ethics Committee (protocol PHM/05/10/HREC).

Second year nursing students enrolled in the course “Pathophysiology & Pharmacology 2” (n = 247) convened by the School of Medical Science at Griffith University, Australia in the academic year 2011 constituted the study sample. Prior to the scheduled lecture on the topic of gastrointestinal pathophysiology and pharmacology, the study design, participation guidelines, ethical considerations and expected outcomes were described to the students. Additionally, to inform students who did not attend the lecture, an announcement was made through the course website regarding the proposed study. All students were given equal opportunity to accept or decline participation at any point of the study. Importantly, it was emphasised that no extra credit towards the course grade would be given for participation in the study and no penalty imposed for non-participation. Forty-five students voluntarily participated in the study and were allocated into two groups: students who attended the face-to-face lecture and viewed the embedded-animation (n = 25) and those who only viewed the lecture online without the embedded-animation (n = 20) (Figure 1). All students enrolled in this course could access the course Blackboard using their university student number and password to undertake the quizzes.

![Study design showing participant numbers. The study compared quiz performance between two groups: lecture + embedded-animation (n = 25) and online lecture (n = 20).](image)

Custom animations were sequenced in Microsoft PowerPoint 2010 and narration was added using iSpring Pro 4.3.0 to produce the embedded animation. The embedded animation was incorporated into a didactic face-to-face lecture but removed when the lecture was edited prior to posting online for student access via the course website. Hence, students who attended the lecture in person were able to view the animation but those who accessed the lecture online were not.

A mix of well-constructed MCQs and SAQs were used in the assessment tool of this study, delivered as two case-study based quizzes. The first case was composed of three MCQs and three SAQs on the pharmacology of drugs acting on the gastrointestinal system including the material covered by the embedded animation. Of the three SAQs, the first tested only factual knowledge, the second designed to test factual, conceptual, and metacognitive knowledge and the last designed to examine procedural and metacognitive levels [10, 11]. SOLO taxonomy was used to qualitatively evaluate the student responses for these two questions. Finally, the second case, for comparison, was on immunology and included five MCQs only. The quizzes were made available via the course website in Griffith University’s Blackboard interface for students to access them online.
Additionally, a short survey was also designed to obtain students’ demographic data and included after the case study questions. The purpose was to find if there were any associations between the demographic data and performance in the quizzes. The survey was also used to evaluate student attitude towards the embedded-animation by way of a 5-point Likert scale (strongly agree, agree, no comment, disagree and strongly disagree). Two questions were included in the survey to elucidate whether students had attended the face-to-face lecture and viewed the embedded animation or had only viewed the lecture online. Prior to accessing the survey, participants were reminded that their participation was voluntary and their responses would be de-identified by the course lecturer.

The data were statistically analysed using IBM SPSS software (v 20). Probability (p) values of less than 0.05 were considered statistically significant. Both quantitative and qualitative analyses were undertaken on the survey results. For the quantitative analyses, firstly, demographic data were compared to find the commonalities and differences in variables such as gender, age, first language, etc. between the two groups. Descriptive statistics, t-tests, and chi-square tests were used for this purpose. Secondly, student performance across the two groups was evaluated using the following statistical tests: (1) t-tests to compare student total performance in both quizzes between the lecture + embedded-animation and online lecture groups; (2) ANOVA tests to assess student performance in the individual questions between the two groups; and (3) an ANOVA test to evaluate student performance between the two case-study quizzes within the same group. Thirdly, a linear regression analysis was performed to determine whether there was a significant correlation between demographic data and student performance. Finally, student preference for the embedded-animation and online e-learning tools was also statistically analysed using descriptive statistics and Chi-square test. The survey evaluated participant attitudes towards the online e-learning tool by way of a 5-point Likert scale (strongly agree, agree, no comment, disagree and strongly disagree). To improve sample size per group, these categories were collapsed into three types of response: “positive”, “neutral” and “negative” responses.

For the qualitative analyses, the SAQs from the GI case study quiz were analysed, using SOLO taxonomy, for conformation to intended knowledge levels. A validation process was followed in this analysis to ensure consistency in evaluating student responses. Student answers were checked against the SOLO taxonomy criteria by the main investigator and two senior pharmacology lecturers with an educational degree background. A meeting was set up to reach a consensus for student answers that were given inconsistent SOLO levels between the markers.

3 RESULTS

The embedded animation illustrated and described the mechanisms of action of two GI drug classes: H2 receptor antagonists and PPIs. A representative screen capture of the embedded-animation is presented in Figure 2.

![Figure 2. Example screen capture of developed embedded-animation describing mechanism of action of H2 receptor antagonist.](image-url)
Two case-based summative quizzes were successfully uploaded into the course website Blackboard. The first case study was on the pharmacology of drugs acting on the gastrointestinal system including the content reinforced by the embedded animation. The second case study was on the immunology content.

A total of 67 students originally participated in the study. However, 12 students did not undertake the survey and were consequently excluded from the study. Therefore, the remaining 45 students were considered as participants in the study. Of those, only two students were males (4.5%). The demographic data was compared between the two groups (Table 1). The majority of students from both groups were between 31-40 years old. There was no significant difference in age group frequency between the lecture + embedded-animation group and the online lecture one ($\chi^2 = 4.1$, $p > 0.05$). The Grade Point Average (GPA) was also collected from participants through the survey. All recorded values were valid and within the normal GPA range (1.0 – 7.0). Students from the online lecture group had a significantly higher mean score for GPA than the other group (respectively, mean ± SD= 5.6 ± 0.84, 5.0 ± 1.01, $t = 2.1$, $p < 0.05$). There was no significant difference between the two groups in the numbers of students whose first language was not English ($\chi^2 = 0.01$, $p > 0.05$). Students were also surveyed on whether they had studied pharmacology course in their previous degree (if applicable). Only four students from each group had studied pharmacology before, indicating no significant difference in pharmacology prior knowledge between the two groups. Students were also asked to indicate whether they read through the lecture notes before attending lectures. No significant difference was seen in this variable between the groups ($\chi^2 = 0.1$, $p > 0.05$). Finally, participants were requested to rate the level of difficulty they had in understanding course content that involved drug mechanisms of action. All students selected either neutral or difficult as their response; however, more students from the lecture + embedded animation group (84%) found these topics difficult than students from the other group (45%) and the difference was found to be statistically significant ($\chi^2 = 7.6$, $p < 0.05$). Sample descriptive data for student performance in both case study quizzes are also presented in Table 1. The highest percentage of correct answers was achieved by the lecture + embedded-animation group with a mean of 55% (± 23.3), with a minimum of 0% and a maximum of 85%. The overall students’ performance as measured by mean test scores was not significantly different between the two groups ($t = 0.8$, $p > 0.05$). Additionally, there was no significant difference in student performance between the two groups for any of the individual questions ($F = 5.1$, $p > 0.05$). Moreover, there was no statistical difference in student performance between the two case study quizzes within the same group ($F = 3.4$, $p > 0.05$).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Online lecture (n=20)</th>
<th>Lecture +embedded-animation (n=25)</th>
<th>Statistic, p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age groups</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>21-30 (n = 26)</td>
<td>9 (45%)</td>
<td>17 (68%)</td>
<td>$\chi^2 = 4.1$, $p &gt; 0.05$</td>
</tr>
<tr>
<td>31-40 (n = 8)</td>
<td>6 (30%)</td>
<td>2 (8%)</td>
<td></td>
</tr>
<tr>
<td>41-50 (n = 11)</td>
<td>5 (25%)</td>
<td>6 (24%)</td>
<td></td>
</tr>
<tr>
<td><strong>GPA (Mean, SD)</strong></td>
<td>5.6 ± 0.84</td>
<td>5.0 ± 1.01</td>
<td>$t = 2.1$, $p &lt; 0.05$</td>
</tr>
<tr>
<td><strong>English as first language</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes (n = 34)</td>
<td>15 (75%)</td>
<td>19 (76%)</td>
<td>$\chi^2 = 0.01$, $p &gt; 0.05$</td>
</tr>
<tr>
<td>No (n = 11)</td>
<td>5 (25%)</td>
<td>6 (24%)</td>
<td></td>
</tr>
<tr>
<td><strong>Previous pharmacology knowledge</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes (n = 8)</td>
<td>4 (20%)</td>
<td>4 (16%)</td>
<td>$\chi^2 = 1.7$, $p &gt; 0.05$</td>
</tr>
<tr>
<td>No (n = 37)</td>
<td>16 (80%)</td>
<td>21 (84%)</td>
<td></td>
</tr>
<tr>
<td><strong>Prior lecture study</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes (n = 28)</td>
<td>13 (65%)</td>
<td>15 (60)</td>
<td>$\chi^2 = 0.1$, $p &gt; 0.05$</td>
</tr>
<tr>
<td>No (n = 17)</td>
<td>7 (35%)</td>
<td>10 (40%)</td>
<td></td>
</tr>
<tr>
<td><strong>Difficulty to follow topics that cover drug MOA</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neutral (n=15)</td>
<td>11 (55%)</td>
<td>4 (16%)</td>
<td>$\chi^2 = 7.6$, $p &lt; 0.05$</td>
</tr>
<tr>
<td>Difficult (n=30)</td>
<td>9 (45%)</td>
<td>21 (84%)</td>
<td></td>
</tr>
<tr>
<td><strong>Student performance in case study quizzes (case1+2)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Mean, SD)</td>
<td>50 ± 28.3</td>
<td>55 ± 23.3</td>
<td>$t = 0.8$, $p &gt; 0.05$</td>
</tr>
<tr>
<td>Minimum %</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Maximum %</td>
<td>100</td>
<td>85</td>
<td></td>
</tr>
</tbody>
</table>
This table includes statistical comparisons of demographic data and student performance in the case study quizzes. A mechanism of action.

The demographic variables above were analysed to determine their impact on student performance, and a significant association was found between student performance and GPA. Linear regression analysis showed that participants’ GPA was significantly correlated with performance in the case study quizzes ($r = 0.63$, $R^2 = 0.39$, $p < 0.05$); see Figure 3.

![Figure 3. Scatterplot of overall student performance in the assessment quizzes and their GPA, showing a strong positive correlation.](image)

Student attitudes toward the online e-learning tools were analysed using a short survey, which demonstrated, in general, a preference for the e-learning tools regardless of whether students viewed the embedded-animation or not (see Table 2; $p > 0.05$ for all comparisons).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Online lecture (n=20)</th>
<th>Lecture +embedded-animation (n=25)</th>
<th>Statistic, p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Participants prefer online e-learning tools</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Positive (n = 29)</td>
<td>16 (80%)</td>
<td>13 (52%)</td>
<td>$\chi^2 = 4.1$, $p&gt;0.05$</td>
</tr>
<tr>
<td>Neutral (n = 6)</td>
<td>2 (10%)</td>
<td>4 (16%)</td>
<td></td>
</tr>
<tr>
<td>Negative (n = 10)</td>
<td>2 (10%)</td>
<td>8 (32%)</td>
<td></td>
</tr>
<tr>
<td><strong>Participants think online e-learning tools are useful for their learning in pharmacology course</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Positive (n = 40)</td>
<td>19 (95%)</td>
<td>21 (84%)</td>
<td>$\chi^2 = 1.3$, $p&gt;0.05$</td>
</tr>
<tr>
<td>Neutral (n = 5)</td>
<td>1 (5%)</td>
<td>4 (16%)</td>
<td></td>
</tr>
<tr>
<td>Negative (n = 0)</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td><strong>Participants think online e-learning tools can assist in understanding drug MOA</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Positive (n = 36)</td>
<td>16 (85%)</td>
<td>20 (80%)</td>
<td>$\chi^2 = 2.7$, $p&gt;0.05$</td>
</tr>
<tr>
<td>Neutral (n = 5)</td>
<td>1 (5%)</td>
<td>4 (16%)</td>
<td></td>
</tr>
<tr>
<td>Negative (n = 4)</td>
<td>3 (15%)</td>
<td>1 (4%)</td>
<td></td>
</tr>
<tr>
<td><strong>Participants think online e-learning tools can change the way to recall information</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Positive (n = 33)</td>
<td>14 (70%)</td>
<td>19 (76%)</td>
<td>$\chi^2 = 3.3$, $p&gt;0.05$</td>
</tr>
<tr>
<td>Neutral (n = 7)</td>
<td>2 (10%)</td>
<td>5 (20%)</td>
<td></td>
</tr>
<tr>
<td>Negative (n = 5)</td>
<td>4 (20%)</td>
<td>1 (4%)</td>
<td></td>
</tr>
</tbody>
</table>
This table includes statistical comparisons of student preference towards online-learning tools between two groups; no statistical significant difference was observed in any comparison. A mechanism of action.

Student attitude toward the application of online e-learning tools was also analysed in relation to the demographic variables above; only lecture attendance was significantly associated with preference for using those tools ($\chi^2 = 12.0, p<0.05$). Students who rarely attended lectures stated a preference for face-to-face teaching to be substituted with online e-learning tools; see Table 3.

### Table 3: student preference for replacing lectures with online e-learning.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Never or rarely (n=8)</th>
<th>Frequently or always (n=37)</th>
<th>Statistic, p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Replace didactic lectures with online e-learning tools</td>
<td></td>
<td></td>
<td>$\chi^2 = 12, p&lt;0.05$</td>
</tr>
<tr>
<td>Positive (n = 12)</td>
<td>6 (75%)</td>
<td>6 (16%)</td>
<td></td>
</tr>
<tr>
<td>Neutral (n = 7)</td>
<td>1 (12.5%)</td>
<td>6 (16%)</td>
<td></td>
</tr>
<tr>
<td>Negative (n = 26)</td>
<td>1 (12.5%)</td>
<td>25 (68%)</td>
<td></td>
</tr>
</tbody>
</table>

This table includes statistical comparisons of student preference for replacing lectures online e-learning tools between students who never or rarely attend lectures (n = 8) and those who frequently or always attend (n = 37). Students who rarely or never attend lecture were more positive towards this question. The difference was statistically significant.

Qualitative analysis was performed to assess the quality and depth of student answers in the two SAQs (Question 3 and Question 6) of the GI case study. The analysis was done according to the SOLO taxonomy. None of the students were able to reach the highest level of SOLO taxonomy (extended abstract) in their answers. The results showed no significant difference in SOLO taxonomy scoring for student answers on either Question 3 or Question 6 between the groups (respectively, $\chi^2 = 4.9, p > 0.05$; $\chi^2 = 0.6, p > 0.05$); see Table 4.

### Table 4: qualitative analysis of short answers according to SOLO taxonomy.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Online lecture (n=20)</th>
<th>Lecture +embedded animation (n=25)</th>
<th>Statistic, p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q3 (Factual, conceptual and metacognitive knowledge)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-structural (n = 18)</td>
<td>5 (25%)</td>
<td>13 (52%)</td>
<td>$\chi^2 = 4.9, p &gt; 0.05$</td>
</tr>
<tr>
<td>Uni-structural (n = 22)</td>
<td>11 (55%)</td>
<td>11 (44%)</td>
<td></td>
</tr>
<tr>
<td>Multi-structural &amp; relational (n=5)</td>
<td>4 (20%)</td>
<td>1 (4%)</td>
<td></td>
</tr>
<tr>
<td>Q6 (Procedural and metacognitive knowledge)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-structural (n = 36)</td>
<td>17 (85%)</td>
<td>19 (76%)</td>
<td>$\chi^2 = 0.6, p &gt; 0.05$</td>
</tr>
<tr>
<td>Uni-structural (n = 9)</td>
<td>3 (15%)</td>
<td>6 (24%)</td>
<td></td>
</tr>
</tbody>
</table>

This table includes statistical comparisons of student performance in the two SAQs according to SOLO taxonomy. No statistical difference was found between the two groups.

### 4 DISCUSSION

Our team was able to successfully develop embedded animations designed to meet the curriculum’s learning objectives and underpinned by relevant teaching theories, using commercially available software packages such as iSpring Pro and PowerPoint. The advantage of these embedded-animations custom designed and developed in-house is that educators can easily update content to match evolved course learning objectives or changed practices, unlike commercially available tools developed by trained programmers using complex software packages.

Demographic data was collected to ensure that there were no systematic differences in the characteristics of students in the two study groups to control for confounding factors. These included participants’ gender, age group, GPA and English as their first language. The analyses revealed that participants from the online lecture group had a significantly higher mean GPA than students from the other group, suggesting that students performing well academically were confident in learning online whereas students challenged by the course content preferred to attend lectures. Other variables were similar across the groups; see Table 1.
Another significant difference between the two groups was rating the difficulty to follow topics that cover drug mechanisms of action. The majority of students from the lecture + embedded-animation group rated those topics as difficult to follow. It is suggested that the complexity of pharmacology as a discipline may hinder student learning [1]. Therefore, the answer might be found in using embedded animation tools as novel approaches to facilitate student learning, and placing emphasis on transforming students as independent learners [1, 15]. However, the impact of those tools on student performance and preference should be examined carefully before conclusions are drawn in this regard.

While students who attended the face-to-face lecture and viewed the embedded-animation slightly outperformed the other group in the case study quizzes, this difference was not significant. This would imply that the benefit of adding embedded-animation tools as supplements to pharmacology lectures, for this cohort at least, is still under question. However, the limitations of the study including the small sample size, an ad hoc rather than continuous supplementation of lectures with embedded-animations and evaluation that tested short-term recall must also be considered. Although the ultimate goal of our work would be to develop a suite of embedded-animation tools that complement the lectures in pharmacology and make these tools available and freely accessible online, for purposes of this study, the embedded-animation was shown once only at the lecture and not included as a resource online. Nonetheless, our finding contradicts the results of another study, which showed that adding web-based interactive instructional techniques, which supplemented traditional lectures, significantly improved student performance [16]. However, other researchers argued that the use of e-learning tools should be continuous to provide advantage to students [17].

No significant difference was found in assessing student performance in the individual questions between the two groups; the purpose of this comparison was to discover any effect of the embedded-animation on improving a particular knowledge dimension as described by Bloom’s revised taxonomy. A previous finding from our team was that embedded-animation tools might have the potential to improve student factual knowledge [7]. However, this was not evident in this study. Other ANOVA tests were also used to evaluate student performance between the two case-study quizzes (one on content which employed an embedded-animation as supplement; and the other which did not) within the same group. The purpose of this assessment was to determine the effect of the embedded-animation on improving the performance for the same student. No significant difference was noted indicating that the embedded-animation in this study did not have any impact on improving student performance.

Participants were given two weeks period between the application of the embedded-animation during the lecture and implementing the quizzes. Students from both groups had the chance to review their lecture notes and textbooks before undertaking the quizzes. The study asked participants to indicate the extent of independent study they usually undertake, before attending lectures. No significant difference was found between the two groups suggesting that participant motivation for self-study was similar across the groups. Therefore, the difference in performance might be related to other factors than the self-study.

One important finding in this study was the strong positive correlation between the grade point average (GPA), for students in both groups, and performance in the quizzes as demonstrated by the results. It can be seen that participants, who had a high GPA performed better in the quizzes regardless of their assigned group. It is widely accepted that GPA is a strong indicator of academic performance, and a similar conclusion was found by other studies that support our findings [18, 19].

The demographic data showed that the lecture + embedded-animation group had significantly lower GPA and they rated the course content as significantly more difficult to follow and understand compared to the online lecture group. Surprisingly, the participants from the lecture + embedded-animation group slightly outperformed, but not in a significant way, the students from the online lecture group who had higher GPA and found the course content easier to understand. It is, therefore, possible to construe that the embedded animation had a positive impact on improving student performance, especially for those who struggled in courses which were heavy in theoretical concepts, such as pharmacology. However, this conclusion warrants further exploration in a bigger student cohort.

Students from both groups indicated positive responses towards the application of technology into their curricula with a preponderance of students from the online lecture group being more positive towards the technology driven learning. This corroborates other study evidence that student expect and embrace technology as part of their learning experience [20].
Another finding of this study was the significant association between non-attendance at lectures and preference for using online e-learning tools. Students who rarely attended lectures stated a preference for face-to-face teaching (lectures) to be substituted with online e-learning tools \( (\chi^2 = 12.0, P<0.05) \). This can be explained by the benefits of online e-learning tools to allow students to direct their own learning by providing flexible learning opportunities [4, 6]. Online e-learning tools allow students to learn when, how (learning style, collaborative or independent learning), what (content) and where (place) they want [21].

Finally, qualitative analysis of student performance in the SAQs showed no difference between the groups in the level of understanding of the content. This suggested that the embedded-animation was not successful in helping students to develop higher levels of thinking and understanding in this pilot study. We acknowledge that there were limitations in this study. The concept of long-term knowledge retention following the use of embedded-animation was not assessed. The quiz was implemented online, and student could access it from their computers. No control measures were taken for the online quizzes or the survey and students could have easily compared or discussed responses to the questions, or have accessed their learning materials while taking the quizzes. Self-reporting bias is also a possibility. One solution to ensure honesty in responses was to conduct the quizzes in an examination room under the observations by invigilators [22]. Other limitations included small sample size and potential for non-respondent bias.

5 CONCLUSION
Albeit the small sample size, the results of this preliminary study suggest that the addition of embedded-animations, as supplement to the didactic traditional lectures, might have a positive impact on student learning, in particular for students who have low GPA and are challenged by courses that are heavy on theoretical concepts. Students’ GPA showed positive correlation with performance at assessments and students who did not routinely attend lectures were more likely to prefer the addition of online e-learning tools into the curriculum.

ACKNOWLEDGMENT
The authors would like to thank the faculty of Griffith Health at Griffith University for providing the blended learning grant.

Competing interest: None

REFERENCES


CHAPTER 4

STUDENT ENGAGEMENT STUDY

Student Engagement in Pharmacology Courses Using Online Learning Tools

STATEMENT OF CONTRIBUTION TO CO-AUTHORED PUBLISHED PAPER

This chapter includes a co-authored paper. This paper was accepted for publication at the American Journal for Pharmaceutical Education on 18/02/2013. The paper is scheduled for publication in August (issue 6) 2013. The authors of the paper are: Abdullah Karaksha, Gary Grant, Shailendra Anoopkumar-Dukie, S. Niru Nirthanan, Andrew K. Davey.

My contribution to the paper involved: designing and conducting the study, collecting the data, analysing and categorizing the data and providing direction on the scope and structure of the analysis. I also wrote the first draft, made revisions responding to supervisor comments and feedback, prepared the final document, and forwarded it to the corresponding author for submission. I also responded to and addressed the reviewer comments from the journal when we received them, made appropriate revisions, and re-submitted the revised article after including reviewer-requested modifications.

(Signed) _________________________________ (Date) 26th July 2013
Abdullah Karaksha

(Countersigned) ___________________________ (Date) 26th July 2013
Corresponding author of paper: Professor Andrew K. Davey

(Countersigned) ___________________________ (Date) 26th July 2013
Supervisor: Dr. Shailendra Anoopkumar-Dukie

In order to comply with copyright this article has been removed.
Chapter 5
Student Performance Study
A Comparative Study to Evaluate the Educational Impact of e-Learning Tools on Griffith University Pharmacy Students’ Level of Understanding Using Bloom’s and SOLO Taxonomies

The referencing style of this chapter was prepared according to the Higher Education Journal guidelines. However, an edited version of this chapter was submitted to the journal on 11/06/2013 for publication to comply with the word limit. The submitted version for publication is attached in the appendix D along with the statement of contribution to co-authored paper.
Abstract

**Background:** Generation Y students have novel learning styles that are non-linear, personalised to individual needs, and fluent in 'simulation-based virtual settings'. These students need more than the traditional teaching approaches to engage in the learning process. Online learning tools (e-learning tools) provide many advantages to student learning such as, self-directed and flexible learning opportunities.

**Aim:** The objective of this study was to evaluate the educational benefits of in-house designed e-learning tools that were embedded as supplements to the standard pharmacology curricula during semesters one and two of 2012.

**Methods:** A series of 148 customised animation and narration tools (e-learning tools) describing the drug mechanisms of action was designed for 3rd year undergraduate pharmacy students, enrolled in pharmacology courses at Griffith University, Gold Coast, Australia. E-learning tools were uploaded to the courses’ website (Blackboard™) for ease of access by students and use monitoring. Ethical approval was granted by the Griffith University Human Ethics Committee. Student participation was voluntary and anonymous.

To determine the educational benefit of the e-learning tools on student learning, we evaluated their level of understanding in the final exams between the control group (standard curricula) in 2011 (n=53) and the intervention group (standard curricula + e-learning tools) in 2012 (n=25). To control for the different content in exam questions between 2011 and 2012, the short and long answer questions were classified according to Bloom’s revised taxonomy. Consequently, student answers were qualitatively evaluated using the Structure of the Observed Learning Outcome (SOLO) taxonomy. The key
demographic variables (age, gender, and GPA) were also collected and compared between the two groups to control for the inherent ability of the participants.

**Results:** There were no significant differences on the key demographic variables between the groups. Backward linear regression analysis was performed to model the level of student understanding while controlling for possible confounding variables during each semester separately. For semester one, four models were generated with the most significant model containing the variables *intervention group* (control vs intervention) and *GPA*, with the variables *domestic/international, age, gender* removed from the model. This model showed *GPA* as the most significant predictor of level of understanding and *intervention group* approaching significance as a predictor of level of understanding (*p* = 0.09). Student background, age, and gender were not shown to be significant predictors. For semester two, again the model containing the variables *intervention group* and *GPA* was the most significant of the four models generated. This model demonstrated *GPA* as the most significant predictor of level of understanding; however, *intervention group* was also shown to be a highly significant predictor for semester two. These results were supported by correlation analysis of student level of understanding in the intervention group and e-learning tools usage. In both semesters a strong positive correlation was observed; however in semester one the correlation was 77% compared to 88% in semester two.

**Conclusion:** This study has revealed a number of significant benefits of e-learning tools on student learning. E-learning tools appeared to significantly improve student level of understanding as scored by the SOLO taxonomy when students engaged highly with the tools. It was also found that introducing e-learning tools into the pharmacology curricula significantly reduced the decrease in level of understanding observed when students progress into more complex courses. The study also
demonstrated that a holistic approach can easily be employed to evaluate the impact of technology on student learning, effectively comparing different student cohorts using Bloom’s revised taxonomy to classify exam questions into common learning dimensions, and using SOLO taxonomy scoring to evaluate student level of understanding instead of simply exam grades.
Introduction

The scholarship of learning and teaching (SoLT) involves research into practices of teaching, learning and curriculum. SoLT’s main principle is that effective teachers in higher education should engage in scholarly teaching practices as a matter of course, by staying in touch with the latest research developments in their discipline, integrating these developments into their curriculum, and routinely gathering and using student feedback to guide curriculum review and improvement. SoLT research focuses on understanding student learning in order to improve the teaching and learning experience for participants (Buckridge et al. 2010; Boyer 1991; Grauerholz and Zipp 2008). One area in which SoLT principles are particularly important is pharmacology education, because it entails rich content involving many drugs and drug mechanisms of action, numerous detailed facts about drug classes and individual compounds, and even the diseases for which the various drugs are used (Michel et al. 2002). Moreover, students perceive pharmacology as a more “difficult” learning area than other subjects in the undergraduate pharmacy curriculum (Wang et al. 2012). Consequently, teaching pharmacology curricula to students has been a challenge (Badyal et al. 2010; Halliday et al. 2010) and up-to-date teaching methods, such as e-learning tools, have been proposed to keep the students engaged in the content (Michel et al. 2002). E-learning tools have been shown to assist academics and educators to meet the growing needs and expectations for improving the quality of pharmacology education (Candler et al. 2007; Walley et al. 1994; O'Shaughnessy et al. 2010). They have a number of advantages to students that help educators promote learning and improve education quality. Students can access e-learning tools at their preferred times, which help them have active learning experiences and engage them in the learning process (Maxwell 2012). Moreover, some studies have found that e-learning tools help students undertake a deep learning approach and progress into independent life-long learners (Buckridge et al. 2010; Pahinis et al. 2007; Hughes 2002; Hughes 2003). Further, a large body of
research suggest that this progression is essential for successful teaching (Martin et al. 2002; Ramsden 2003; Biggs and Tang 2007b).

Yet, while e-learning tools offer a number of inherent features such as flexibility in place and time for learning, adaptability to diverse learning styles and paces of the students, or scalability to rising student numbers, their use remains limited (MacLean et al. 2011). This may be due to miscommunication between e-learning tool developers and the educators who make decisions about their use, economic factors such as high costs and time requirements for the development of e-learning tool content, the paucity of knowledge regarding how to effectively integrate e-learning tools into higher education curricula and, perhaps most importantly, a lack of consensus in the scholarly literature on e-learning tool effectiveness (Berman et al. 2008; Masters and Ellaway 2008; Yelland et al. 2008). Assessment of student level of understanding is possible using taxonomic classification of exam answers; however, to the best of our knowledge, no study has employed this approach to evaluate the effect of e-learning tools within higher education sector thus far. Therefore, it would appear that no higher education study has followed a holistic approach to evaluate the impact of technology on student learning, which might have contributed to the overly cautious implementation of e-learning tools in higher education settings (Berman et al. 2008). Hence, there is a need for further scholarly research to overcome these challenges and maximise the potential of e-learning tools.

Our team has aimed to address some of these issues by designing a series of e-learning tools to complement the delivery of pharmacology content within the framework of a defined pedagogy and to evaluate the impact of our e-learning tools on student level of understanding through taxonomic classification of student final exam answers. We chose to analyse student level of understanding in a summative assessment that contributed significantly to the course grade. The Human Pharmacology I and II final
exams contained multiple choice questions (MCQs), short answer questions (SAQs) and long answer questions (LAQs); however, because the examination questions were not identical in each course, Bloom’s revised taxonomy was used to classify the SAQs and LAQs according to appropriate knowledge and cognitive dimensions and to ensure that the assessments were of comparable standard. Bloom’s revised taxonomy has been used by educators to provide similarity to the purpose of the activities and assessments that reveal whether the objectives of the course have been achieved by students (Chyung and Stepich 2003; Halawi et al. 2009).

Further, we aimed to assess student level of understanding in each question, instead of quantifying their performance by exam scores. The Structure of the Observed Learning Outcome (SOLO) taxonomy was therefore chosen as an evaluation rubric to qualitatively analyse student level of understanding for the short and long answer exam questions. SOLO provides a consistent framework through which to evaluate student responses and has been widely used in educational research as a means of determining the complexity and depth of student learning outcomes (Chan et al. 2002). SOLO is a hierarchical model that is suitable for measuring learning outcomes of different kinds of subjects, among different levels of students and for all lengths of questions (Chan et al. 2002). Several researchers who have applied SOLO into their studies value both the comprehensiveness and the objectivity of the criteria provided for measuring students’ cognitive attainment and the degree of deep learning that has occurred throughout a course (Taylor et al. 2007; Taylor and Cope 2007; Holmes 2005).

This study also intended to evaluate the educational benefits of in-house designed e-learning tools that were embedded as supplements to the standard pharmacology curricula. The e-learning tools were implemented during semesters one and two of 2012 and student performance in terms of level of understanding (scored using SOLO
taxonomy) was compared to the previous academic year (2011) where students received their pharmacology content solely through the standard curriculum. Our overarching goal of this research is to apply SoLT principles to improve the pharmacology courses we teach, and the study has the potential to achieve this by providing a framework for standardising the evaluation of student performance, determining student level of understanding, and improving students’ learning experiences.
Methodology

This study was conducted at the School of Pharmacy, Griffith University, Gold Coast campus, Australia. A suite of 83 e-learning tools (first set) was designed for the third year Human Pharmacology I course in semester one - 2012 and 65 e-learning tools (second set) for the Human Pharmacology II course in semester two - 2012. These are both 13 week courses normally delivered by means of three hours of didactic teaching per week and weekly tutorials and laboratories totalling 2 to 4 hours. The e-learning tools covered the mechanisms of action for the majority of drug classes in the 3rd year pharmacology curriculum and supplemented the usual delivery of this content.

To evaluate the educational benefits of the e-learning tools, our team conducted a comparative study that consisted of two academic cohorts as well as two phases. The two academic cohorts were as follows: third year pharmacy students who studied the standard Human Pharmacology I and II curricula in 2011 (control group) and those who studied the standard curricula + e-learning tools in 2012 (intervention group). The first phase of the study was to invite students, from both groups, to participate in a survey while the second phase was to evaluate and compare student level of understanding (based on SOLO taxonomy) during the final exams between the two groups. Ethical approval was granted by the Griffith University Human Ethics Committee (protocol PHM/05/10/HREC).

Survey design and pilot testing:

To evaluate student baseline attributes in semester one, a paper-based survey was designed according to previous studies that examined student preference towards technology (Taplin et al. 2011; MacLean et al. 2011; Euzent et al. 2011; Chen et al. 2010) and obtained demographic data including gender, the Grade Point Average (GPA),
frequency of attending lectures, and difficulty of following topics that cover drug mechanisms of action.

As students from the control group in 2011 did not use the customised e-learning tools designed and implemented specifically for the purpose of this study, the survey examined student preference for technology, using a general term namely: online-learning tools, by way of a five-point Likert scale (strongly agree, agree, no comment, disagree and strongly disagree). Student learning style was assessed by asking students whether they remember text and/or images (animations) in responding to questions related to drug mechanisms of action. A number of measures were considered to increase the response rate in the survey. The most considerable criticism of surveys is that long surveys tend to discourage potential participants (students) from responding (McLaren and Shelley 2000); thus the study survey was designed to be completed in approximately 5 - 10 minutes. Moreover, the chief investigator explained the study aims and objectives for potential participants before the distribution of the survey. This is another approach to increase the response rate as suggested by previous research (Osborn M 1996).

The survey was validated to confirm that it accurately measures the required variables (Maughan 2009; Lee 2004) and pre-tested by two independent lecturers to examine the clarity and adequacy of the instrument to meet the stated aims and to improve the internal validity of the survey. Moreover, it was important to determine the time required to complete the survey and whether the target timeframe was reasonable (5 - 10 minutes). This method has already been used to validate surveys (Monaghan et al. 2011). The survey was also independently pilot tested on a group of nursing students as an additional measure for validity (Karaksha et al. 2013b). The comments from lecturers and feedback from the pilot study confirmed that the survey questions provided the required
information and allowed identification of unnecessary, difficult, or ambiguous questions, which were removed or rephrased to improve the survey.

**E-learning tool design and implementation:**

Custom animations were sequenced in Microsoft PowerPoint 2010 and narration was added using iSpring Pro 6.1.0 to both produce the embedded animation and to convert the animations into a Flash format for ease of delivery through Blackboard (Karaksha et al. 2011). Participants could easily control the speed of the final e-learning tools, skip content, and move forward and backward as needed to revisit specific concepts. Each e-learning tool contained accompanying multiple choice questions as built-in formative assessment, generated by the software Question Writer-3 (Professional) and accessed through Blackboard. Question Writer-3 sent the results anonymously to the researcher’s designated email for evaluation. Questions were carefully developed to assess stated learning objectives. The first and second sets of e-learning tools were made available to students who enrolled in the Human Pharmacology I and II courses in 2012 via the course websites in Griffith University’s Blackboard interface. We made the e-learning tools available to students before the first major assessment item (mid-semester exam).

**Student recruitment:**

The control group (2011).

The course convenor approached students who enrolled in the Human Pharmacology I course (semester one – 2011) to explain the study aims and objectives. The students were then invited to participate in the first phase of the study and undertake the survey. Students who expressed interest to continue in the second phase of the study were instructed to tick a designated box that appeared on their exam paper. This box indicated their consent for the research team to evaluate their exam answer booklets for both Human Pharmacology courses I and II in 2011. The exam booklets were de-
identified and coded to keep student participation anonymous. In each phase, students were advised that their participation was completely voluntary and would not affect their academic standing or course grades.

The intervention group (2012).

The course convenor approached students who enrolled in the Human Pharmacology I course (semester one – 2012) in the introductory lecture to explain the study aims and objectives. The students were also informed about the e-learning tools and the method to access them through the Blackboard. Student engagement with the e-learning tools during semester one and two was reported previously (Karaksha et al. 2013a); the study demonstrated significant difference in student usage of e-learning tools between both semesters. The students accessed the e-learning tools more often in semester two after receiving multiple reminders through emails and announcements.

The students were then invited to participate in the first phase of the study and undertake the survey to obtain their demographic data and attitude towards online-learning tools. As in the control group, students who expressed interest to continue in the second phase of the study were instructed to tick the designated box that appeared on their exam paper, which indicated their consent for the research team to evaluate their exam answer booklets for both Human Pharmacology courses I and II in 2012. The exam booklets were de-identified and coded to keep student participation anonymous. As in the control group, students were reminded in each phase that their participation was completely voluntary and would not affect their academic standings.
Demographic data:

Demographic data were obtained from participants through two resources. Students who participated in phase one of the study self-reported their demographic information via the survey. Demographic data were also consensually obtained from university records for the students who chose to participate in the second phase of the study.

Exam questions classification and scoring procedure:

To evaluate the educational benefit of the e-learning tools, student level of understanding in the final exams was evaluated using the SOLO taxonomy and compared between the control and the intervention groups. As the e-learning tools were designed to explain drug mechanisms of action, we only evaluated the questions that concerned drug mechanisms of action. A reference question which covered drug mechanisms of action but for which no e-learning tool was designed was also evaluated as a negative control. To compare the short and long answer questions between the two groups in the semester one and semester two final exams, our team used Bloom’s revised taxonomy to classify the questions according the appropriate knowledge and cognitive dimensions (Anderson et al. 2001; Bloom 1969). Then we grouped the questions that examined for the same level of knowledge and cognitive dimensions to ensure valid comparisons between different exam questions. Bloom’s revised taxonomy can be used to classify the questions in categories according to what they examine. This can be the knowledge dimension (four levels): factual, conceptual, procedural, and metacognitive knowledge; and the cognitive dimension (six levels): remember, understand, apply, analyse, evaluate and create (Anderson et al. 2001; Bloom 1969). However, the highest levels of the taxonomy namely: metacognitive knowledge, evaluate, and create are not usually examined within the undergraduate level (Amer 2006).
To evaluate student level of understanding in the short and long answer questions, SOLO taxonomy was used to classify each student’s exam responses. This taxonomy consists of five levels of increasing structural complexity: pre-structural, uni-structural, multi-structural, relational and extended abstract (Biggs and Tang 2007a). SOLO taxonomy has been used successfully by other researchers to measure cognitive learning outcomes and qualitatively evaluate student performance in different courses among different levels of students (Bhattacharyya et al. 2012; Shea et al. 2011; Taylor et al. 2007; Biggs and Tang 2007a). Description of the scoring system is available in Table 1.

This process was pilot tested by our team (Karaksha et al. 2013b) and a validation process was followed to ensure consistency in evaluating student responses. Student answers were checked against the SOLO taxonomy criteria by the main investigator and two senior pharmacology lecturers with post-graduate educational qualifications. A meeting was set up to reach a consensus for student answers that were given inconsistent SOLO levels between the markers.

**Long term retention assessment**:

A follow-up quiz was introduced to students from both groups to examine their performance in long term knowledge retention. The quiz consisted of one multiple choice question (MCQ) to test for factual knowledge and one short answer question to test for factual + procedural knowledge. The follow-up quiz was introduced to students approximately six months after finishing the course. An additional question was included to ask the students how they recalled the information (text and/or images) when answering the questions.
Data analysis:

To evaluate the survey results, a number of quantitative analyses were undertaken. Demographic data including gender, GPA, and English as first language, as well as student preference for technology and learning style, were compared between the students from the control and intervention groups using t-tests and chi-squared tests. Student performance in the long-term retention questions across the two groups was evaluated using t-tests and the method used to recall information when answering these questions was analysed using a chi-squared test. Participant attitudes towards the technology were assessed by way of a 5-point Likert scale (strongly agree, agree, no comment, disagree, and strongly disagree); however to improve sample size per group, these categories were collapsed into three types of response: “positive,” “neutral,” and “negative” responses. Student level of understanding in short and long answer questions was scored according to SOLO taxonomy and SOLO scores were compared between the two groups using t-tests. Backward linear regression analysis was performed to model student level of understanding, using the demographic data variables (age, gender GPA, and domestic/international) and control/intervention group. The effect of e-learning tools usage on student level of understanding for the intervention group was assessed by correlation analysis. Power analysis using Russ Lenth’ power applet showed that we had at least 80% power to detect one standard deviation difference in the means for all t-test analyses. However, we had only 76% power to detect a difference of 15% in proportions between groups for the chi-squared analyses for student preference (Lenth 2006). All statistical analyses were performed using IBM SPSS software (v 20). Probability (p) values of less than 0.05 were considered statistically significant.
<table>
<thead>
<tr>
<th>SOLO score</th>
<th>SOLO level descriptor</th>
</tr>
</thead>
<tbody>
<tr>
<td>0. No answer</td>
<td>No answer, or there are written words, but not relevant to the question.</td>
</tr>
<tr>
<td>1. Pre-structural</td>
<td>Here students do not have any kind of understanding but use irrelevant information and/or miss the point altogether. Scattered pieces of information may have been acquired, but they are unorganized, unstructured, and essentially void of actual content or relation to a topic or problem</td>
</tr>
<tr>
<td>2. Uni-structural</td>
<td>Students can deal with one single aspect and make obvious connections. Students can use terminology, recite (remember things), identify names, etc.</td>
</tr>
<tr>
<td>3. Multi-structural</td>
<td>At this level students can deal with several aspects but these are considered independently and not in connection. Metaphorically speaking, the students see the many trees, but not the forest. They are able to enumerate, describe, classify, combine, apply methods, structure, execute procedures, etc.</td>
</tr>
<tr>
<td>4. Relational</td>
<td>At level four, students may understand relations between several aspects and how they might fit together to form a whole. The understanding forms a structure. They may thus have the competence to compare, relate, analyze, apply theory, explain in terms of cause and effect, etc.</td>
</tr>
<tr>
<td>5. Extended abstract</td>
<td>At this level, which is the highest, students may generalize structure beyond what was given, may perceive structure from many different perspectives, and transfer ideas to new areas. They may have the competence to generalize, hypothesize, criticize, theorize, etc.</td>
</tr>
</tbody>
</table>

SOLO: Structure of the observed learning outcomes.
Results

A total of 118 students were enrolled in Human Pharmacology I course in the year 2011 compared to 82 in 2012. Fifty five (47%) students participated in the survey from the year 2011 compared to 43 (53%) from the 2012 cohort. There was no significant difference between the two groups in the demographic data (Table 2; p > 0.05). Students were also asked to indicate their studying habits for the Human Pharmacology courses (Table 2). No significant difference was seen in the number of students who read through the lecture notes before attending lectures ($\chi^2 = 1.2, p > 0.05$). The level of difficulty in understanding course content responses were divided between easy, neutral or difficult, with no significant difference between the groups. Finally, participants were asked to indicate their attendance behaviour at Human Pharmacology lectures. There was no significant difference between groups; only a small percentage (12%) of students rarely attended lectures with the majority (88%) either frequently or always attending.

Table 2: Student demographic data and behaviour in the Human Pharmacology courses.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Control n = 55 (%)</th>
<th>Intervention n = 43 (%)</th>
<th>Statistic, p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female (n = 62)</td>
<td>37 (67)</td>
<td>25 (58)</td>
<td>$\chi^2 = 0.9, p = 0.35$</td>
</tr>
<tr>
<td>Male (n = 36)</td>
<td>18 (33)</td>
<td>18 (42)</td>
<td></td>
</tr>
<tr>
<td>GPA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Mean, SD)</td>
<td>5.4 ± 0.58</td>
<td>5.3 ± 0.62</td>
<td>$t = 0.8, p = 0.41$</td>
</tr>
<tr>
<td>English as first language</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes (n = 70)</td>
<td>39 (71)</td>
<td>31 (72)</td>
<td>$\chi^2 = 0.01, p = 0.9$</td>
</tr>
<tr>
<td>No (n = 28)</td>
<td>16 (29)</td>
<td>12 (28)</td>
<td></td>
</tr>
<tr>
<td>Prior lecture study</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes (n = 14)</td>
<td>6 (13)</td>
<td>8 (18)</td>
<td>$\chi^2 = 1.1, p = 0.3$</td>
</tr>
<tr>
<td>No (n = 83)</td>
<td>48 (87)</td>
<td>35 (82)</td>
<td></td>
</tr>
</tbody>
</table>

$\chi^2$ = Chi-squared
Easy (n = 32)  17 (31)  15 (35)  \( \chi^2 = 0.2, p = 0.9 \)
Neutral (n = 36)  21 (39)  15 (35)
Difficult (n = 29)  16 (30)  13 (30)

Attend Pharmacology lectures
Rarely (n = 12)  9 (17)  3 (7)  \( \chi^2 = 3.1, p = 0.21 \)
Frequently (n = 32)  20 (36)  13 (30)
Always (n = 53)  26 (47)  27 (63)

This table includes statistical comparisons of demographic data and student behaviour towards Human Pharmacology courses. No statistical significant difference was observed in any comparison. #: mechanism of action.

Student attitude towards online-learning tools was also analysed and compared between the groups (Table 3). The results demonstrated, in general, positive preference for the online-learning tools. Significantly more students from the intervention group were positive towards the benefit of the online learning tools for understanding the mechanism of action concepts and for changing their learning style, compared to the control group (p < 0.05). However, the majority (79%) of students from both groups were either negative or neutral regarding the substitution of traditional didactic lectures with online-learning tools.

Table 3: Student attitude towards online-learning tools.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Control n = 55 (%)</th>
<th>Intervention n = 43 (%)</th>
<th>Statistic, p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preference towards online-learning tools application in L&amp;T #</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Positive (n = 62)</td>
<td>31 (57)</td>
<td>31 (72)</td>
<td>( \chi^2 = 2.8, p = 0.25 )</td>
</tr>
<tr>
<td>Neutral (n = 25)</td>
<td>16 (29)</td>
<td>9 (21)</td>
<td></td>
</tr>
<tr>
<td>Negative (n = 11)</td>
<td>8 (14)</td>
<td>3 (7)</td>
<td></td>
</tr>
<tr>
<td>Online-learning tools are useful for learning MOA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Positive (n = 81)</td>
<td>46 (84)</td>
<td>35 (82)</td>
<td>( \chi^2 = 0.1, p = 0.95 )</td>
</tr>
<tr>
<td>Neutral (n = 15)</td>
<td>8 (14)</td>
<td>7 (16)</td>
<td></td>
</tr>
<tr>
<td>Negative (n= 2)</td>
<td>1 (2)</td>
<td>1 (2)</td>
<td></td>
</tr>
</tbody>
</table>

Online-learning tools assist in understanding MOA
This table includes statistical comparisons of preference towards online-learning tools between two groups: students who studied the standard pharmacology curricula (control) and those who studied the standard curricula + e-learning tools (intervention). #L&T: learning and teaching.

A total of 78 students consented to participate in the second phase of the study, with 53 (45%) students from the control cohort (2011) and 25 (31%) from the intervention cohort (2012). The demographic data of those participants were obtained from the university records to ensure accuracy (Table 4). Statistical analysis for demographic data showed no significant difference between the two groups in any of the comparisons. However, the difference in the gender variable approached significance (p = 0.07), as more females participated in the control group.
Table 4: Demographic data of the participants from the second phase.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Control n = 53</th>
<th>Intervention n = 25</th>
<th>Statistic, p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (Mean, SD)</td>
<td>24.2 ± 4.36</td>
<td>23.3 ± 6.24</td>
<td>t = 0.73, p = 0.43</td>
</tr>
<tr>
<td>GPA (Mean, SD)</td>
<td>5.2 ± 0.83</td>
<td>5.1 ± 0.80</td>
<td>t = 0.64, p = 0.52</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female (n = 48)</td>
<td>36 (68)</td>
<td>12 (48)</td>
<td>$\chi^2 = 3.2$, p = 0.07</td>
</tr>
<tr>
<td>Male (n = 29)</td>
<td>16 (32)</td>
<td>13 (52)</td>
<td></td>
</tr>
<tr>
<td>Background</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Domestic (n = 69)</td>
<td>47 (89)</td>
<td>22 (88)</td>
<td>$\chi^2 = 0.1$, p = 0.75</td>
</tr>
<tr>
<td>International (n = 8)</td>
<td>5 (11)</td>
<td>3 (12)</td>
<td></td>
</tr>
</tbody>
</table>

This table includes statistical comparisons of demographic data between the two groups for the second phase participants.

Student level of understanding for the semester one exam (Human Pharmacology I) was scored according to SOLO taxonomy and compared between the e-learning tool and control groups. Table 5 shows SOLO scoring for both overall performance and for individual questions classified by Bloom’s revised taxonomy. Students from the intervention group significantly outperformed their peers from the control group in question one, which examined the factual and procedural knowledge domain in addition to remembering and understanding from the cognitive domain. One question was repeated in both years’ exams (digoxin) and students from the intervention group outperformed the students from the control group, with the difference approaching significance (p = 0.059). On the other hand, there was no significant difference between the control group and intervention group when answering the reference exam question (no e-learning tool was designed to cover this question).
Table 5: Student level of understanding in semester one exams.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Control n = 53</th>
<th>Intervention n = 25</th>
<th>Statistic, p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Factual + procedural knowledge and remember + understand</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q1 (2011) vs (2012)</td>
<td>2.6 ± 0.63</td>
<td>3.0 ± 0.64</td>
<td>t = -2.1, p = 0.03</td>
</tr>
<tr>
<td><strong>Factual knowledge and understand + analyse</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q3 (2011) vs Q8 (2012)</td>
<td>3.2 ± 0.85</td>
<td>3.0 ± 0.79</td>
<td>t = 1.1, p = 0.26</td>
</tr>
<tr>
<td><strong>Factual + conceptual knowledge and understand</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q4 (2011) vs Q7 (2012)</td>
<td>1.9 ± 1.13</td>
<td>2.1 ± 0.83</td>
<td>t = -0.9, p = 0.36</td>
</tr>
<tr>
<td><strong>Factual + conceptual knowledge and understand + analyse (Reference question - no e-tool)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q5 (2011) vs Q10 (2012)</td>
<td>3.2 ± 0.67</td>
<td>2.9 ± 0.64</td>
<td>t = 1.9, p = 0.06</td>
</tr>
<tr>
<td><strong>Factual + procedural knowledge and understand + analyse</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Digoxin 2011 vs 2012</td>
<td>3.5 ± 0.61</td>
<td>3.8 ± 0.72</td>
<td>t = 1.9, p = 0.059</td>
</tr>
<tr>
<td>Q12 (2011) vs Q5 (2012)</td>
<td>2.4 ± 1.15</td>
<td>2.8 ± 1.05</td>
<td>t = -1.3, p = 0.21</td>
</tr>
<tr>
<td>LAQ(^#) (2011) vs (2012)</td>
<td>3.9 ± 1.11</td>
<td>4.0 ± 0.88</td>
<td>t = -0.07, p = 0.95</td>
</tr>
<tr>
<td><strong>Total performance</strong></td>
<td>2.9 ± 0.52</td>
<td>3.0 ± 0.5</td>
<td>t = -1.0, p = 0.32</td>
</tr>
</tbody>
</table>

This table includes statistical comparisons of student level of understanding in Human Pharmacology I course between the control and intervention groups as measured by SOLO taxonomy. Scoring ranges between 2 (uni-structural level) and 4 (relational level). #LAQ: long answer questions.

One student from the control group and two students from the intervention group failed in the Human Pharmacology I course and were not able to proceed to study the Human Pharmacology II course in second semester. Table 6 shows SOLO scoring of student level of understanding for the semester two exam (Human Pharmacology II), again for both overall performance and for individual questions classified by Bloom’s revised taxonomy. Students from the intervention group performed better than the control group when comparing the overall level of understanding, with the difference approaching significance (p = 0.08). Moreover, four questions on specific drugs were repeated in both years’ exams; participants from the intervention cohort outperformed the control group, with a significant difference (p = 0.02 and p = 0.04) for two out of the four
questions. Finally, students from the control group performed significantly better (p = 0.002) in the reference exam question for which there was no e-learning tool (question 8), which examined the factual and procedural knowledge domain in addition to understand and analyse from the cognitive domain.

Table 6: Student level of understanding in semester two exams.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Control</th>
<th>Intervention</th>
<th>Statistic, p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Factual + procedural knowledge and remember + understand</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cytarabine 2011 vs 2012</td>
<td>2.2 ± 1.1</td>
<td>3.0 ± 1.4</td>
<td>t = - 2.32, p = 0.02</td>
</tr>
<tr>
<td>Mitomycin C 2011 vs 2012</td>
<td>2.0 ± 1.1</td>
<td>2.4 ± 1.5</td>
<td>t = - 0.98, p = 0.33</td>
</tr>
<tr>
<td>Trastuzumab 2011 vs 2012</td>
<td>2.1 ± 1.0</td>
<td>2.7 ± 1.3</td>
<td>t = - 2.1, p = 0.04</td>
</tr>
<tr>
<td>Nitromidazole 2011 vs 2012</td>
<td>1.9 ± 1.1</td>
<td>2.3 ± 1.0</td>
<td>t = - 1.2, p = 0.23</td>
</tr>
<tr>
<td><strong>Factual knowledge and understand + analyse</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q4 (2011) vs Q2 (2012)</td>
<td>2.3 ± 0.7</td>
<td>2.4 ± 0.8</td>
<td>t = - 0.5, p = 0.62</td>
</tr>
<tr>
<td><strong>Factual + procedural knowledge and understand + analyse (Reference question - no e-tool)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q8 (2011) vs (2012)</td>
<td>3.3 ± 1.2</td>
<td>2.5 ± 0.6</td>
<td>t = 3.3, p = 0.002</td>
</tr>
<tr>
<td><strong>Factual + procedural knowledge and understand + analyse</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q7 (2011) vs Q6 (2012)</td>
<td>2.3 ± 0.7</td>
<td>2.7 ± 1.1</td>
<td>t = - 1.7, p = 0.08</td>
</tr>
<tr>
<td>LAQ⁼ (2011) vs (2012)</td>
<td>3.7 ± 1.3</td>
<td>3.7 ± 1.1</td>
<td>t = - 0.05, p = 0.96</td>
</tr>
<tr>
<td><strong>Total performance</strong></td>
<td>2.4 ± 0.6</td>
<td>2.7 ± 0.7</td>
<td>t = - 1.8, p = 0.08</td>
</tr>
</tbody>
</table>

This table includes statistical comparisons of student level of understanding in Human Pharmacology II course between the control and intervention groups as measured by SOLO taxonomy. Scoring ranges between 2 (uni-structural level) and 4 (relational level). #LAQ: long answer questions.

There was no significant decrease in level of understanding in the intervention group while there was a significant decrease in the control group (Table 7). Figure 1 demonstrates that the decrease in the level of understanding for the intervention group was significantly less than the control cohort.
Table 7: Student level of understanding (Total performance) between semesters.

<table>
<thead>
<tr>
<th>Group</th>
<th>Semester one</th>
<th>Semester two</th>
<th>Statistic, p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control (2011; n = 53 vs 52)</td>
<td>2.9 ± 0.52</td>
<td>2.4 ± 0.6</td>
<td>t = 4.6, p = 0.001</td>
</tr>
<tr>
<td>Intervention (2012; n = 25 vs 23)</td>
<td>3.0 ± 0.5</td>
<td>2.7 ± 0.7</td>
<td>t = 1.7, p = 0.09</td>
</tr>
</tbody>
</table>

This table includes statistical comparisons of the decrease in student level of understanding.

Figure 1: Decrease in student level of understanding between the semester one course (3024PHM) and semester two course (3028PHM). Error bars represent the standard error of mean.

To model the level of student understanding while controlling for possible confounding variables, we performed backward linear regression analysis for each semester separately. For semester one, four models were generated with the most significant model (p = 1.67 x 10^-8) containing the variables intervention group (control vs intervention) and GPA, with the variables domestic/international, age, gender removed from the model. This model explained approximately 38.4% of the variance in
semester one level of understanding ($R^2 = 0.384$), with $GPA$ as the most significant predictor of level of understanding ($\beta = 0.39; p = 3.79 \times 10^{-9}$) and intervention group approaching significance as a predictor of level of understanding ($\beta = 0.17; p = 0.09$). Student status (domestic or international), age, and gender were not shown to be significant predictors ($p > 0.2$). For semester two, again the model containing the variables intervention group and $GPA$ was the most significant of the four models generated ($p = 1.52 \times 10^{-6}$). This model explained approximately $31.1\%$ of the variance in semester two level of understanding ($R^2 = 0.311$). Again, $GPA$ was the most significant predictor of level of understanding ($\beta = 0.39; p = 1.18 \times 10^{-6}$); however, intervention group was also shown to be a highly significant predictor for semester two ($\beta = 0.344; p = 0.009$). Students who used the e-learning tools had an increase of about $0.35$ in their total level of understanding SOLO score. This may be because student uptake of the e-learning tools was significantly higher in semester two than semester one, showing the significant effect of the e-learning tools on student level of understanding in semester two. This is supported by correlation analysis of student level of understanding in the intervention group and e-learning tools usage (Figure 2). In both semesters a strong positive correlation was observed; however in semester one the correlation was $77\%$ compared to $88\%$ in semester two.
Figure 2: Scatterplots showing the number of hits on e-learning tools and student level of understanding in the related questions. (A) for the course 3024PHM (semester one – 2012). (B) for the course 3028PHM (semester two – 2012). Student level of understanding is categorised according to SOLO taxonomy into five levels: 1. pre-structural, 2. uni-structural, 3. multi-structural, 4. relational, 5. extended abstract.

Student performance in the long term retention was also assessed, using two questions in the survey (Table 8). Students from the intervention group significantly outperformed their peers from the control group. Students were also requested to report the method they used to answer the questions. The majority of students from the control group answered the questions using text, while on the other hand, the majority of the
intervention group used both images and text. Additionally, significantly more of the students from the intervention group answered the questions remembering both images and text (48% vs 27%; p = 0.04).

Table 8: student performance in the long term retention and method to recall information.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Control n = 55 (%)</th>
<th>Intervention n = 43 (%)</th>
<th>Statistic, p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1-MCQ</td>
<td>0.3 ± 0.45</td>
<td>0.53 ± 0.51</td>
<td>t = - 2.5, p = 0.02</td>
</tr>
<tr>
<td>Factual knowledge and remember</td>
<td>Q2-short answer</td>
<td>2.5 ± 0.79</td>
<td>2.8 ± 0.67</td>
</tr>
<tr>
<td>Recall method to the 2 questions.</td>
<td>Images/animation (n = 14)</td>
<td>8 (15)</td>
<td>6 (14)</td>
</tr>
<tr>
<td></td>
<td>Text (n = 36)</td>
<td>26 (48)</td>
<td>10 (24)</td>
</tr>
<tr>
<td></td>
<td>Both (n = 36)</td>
<td>15 (27)</td>
<td>21 (49)</td>
</tr>
</tbody>
</table>

This table includes statistical comparison of student performance in the long term retention. There is a statistical significant difference in the method to recall information between the groups.
Discussion

Our team was able to successfully develop and embed 148 e-learning tools designed to meet our pharmacology curriculum’s learning objectives and underpinned by relevant teaching theories, using commercially available software packages such as iSpring Pro and PowerPoint. The advantage of these e-learning tools designed and developed in-house is that, in addition to the explicit alignment in their content and context with our curriculum, educators can easily update content to match evolving course learning objectives or changed practices, unlike commercially available tools developed by trained programmers using complex software packages.

Student preference towards the application of technology into their learning and teaching experience were uniformly positive among the majority of students from both groups (67%). Although students from the control group did not have the opportunity to use our e-learning tools, the majority were positive that technology would be useful for learning and understanding the difficult concept of drug mechanisms of action based on the limited experiences in accessing material available on the internet. A similar trend was found from a pilot e-learning tools study that examined nursing students preference within Griffith University (Karaksha et al. 2013b). These findings corroborate evidence that university students have positive preference towards technology and high expectations for technology to be part of their learning experiences (Berman et al. 2008; Yelland et al. 2008; Prensky 2009). However, while our students had positive preference for technology, the majority (79%) were either neutral or not in favour of the substitution of didactic lectures entirely with online-learning tools. Thirunarayanan et al (2011) confirmed this finding in their report by stating that 70% of participants in their study preferred to attend traditional face-to-face lectures (Thirunarayanan et al. 2011). Others have found that students still consider face-to-face discussions with lecturers and peer
interaction in the classroom as critical to their learning success (Lohnes and Kinzer 2007; Garcia and Qin 2007). Thus, e-learning tools may be most successful when implemented as supplement to face-to-face teaching.

To analyse the benefit of e-learning tools, we used Bloom’s revised taxonomy to classify the questions according the knowledge and cognitive dimensions they examine for and then scored student level of understanding using SOLO taxonomy when attempting the questions. Overall, it appeared that the e-learning tools had a significant effect improving the SOLO level of understanding for exam questions that addressed concepts and content that were reinforced by the e-learning tools. For instance, in a question that examined factual and procedural knowledge domains in addition to remembering and understanding from the cognitive dimension, students from the intervention group significantly outperformed their peers from the control group. On the other hand, students from the control group outperformed their colleagues in the reference question for which no e-learning tool was designed to cover the concept. To examine overall results, we averaged the total level of understanding on all questions (except the reference question), and found that the students from the intervention group outperformed their peers, with the difference approaching significance level. Similar results were found by a study on secondary school children to evaluate the impact of e-learning tools on student level of understanding using SOLO taxonomy (Bhattacharyya et al. 2012). Another study for secondary school students found that e-learning tools helped students to proceed into higher level of understanding when compared with the traditional teaching method (Padiotis and Mikropoulos 2010). It is important to note that our study is the first to use both Bloom’s revised and SOLO taxonomies to analyse student level of understanding and evaluate the effect of e-learning tools within medical sciences in higher
education. This has been a successful approach in our study and showed that e-learning tools have a significant effect on student understanding.

Demographic variables such as gender, GPA, age and background have been shown to influence exam performance/level of understanding. Previous research suggested that males usually have positive experience with technology while females do not like to learn from computers and prefer person-to-person learning (Ausburn et al. 2009; Johnson 2011). Other research has suggested that age could impact student performance and interaction with technology (Willey et al. 2008). Thus, we analysed demographic variables in our participants to ensure that there were similar characteristics of students in all groups and found that there were no significant differences in the distribution of the key demographic variables between groups. We also modelled the level of student understanding while controlling for these possible confounding variables by performing backward linear regression analysis for each semester. This analysis demonstrated that age, gender, and background did not have a significant effect on level of understanding. However, the analysis confirmed that GPA did significantly affect student level of understanding, conforming to the widely accepted conclusion that GPA is a strong indicator of academic performance (Willey et al. 2008; Sonnert and Fox 2012). However, in our study, GPA alone did not account for the improvement in students’ level of understanding, as the e-learning tools were also found to be a significant predictor for student level of understanding. Thus, the benefit of e-learning tools still remained even when student GPA was taken into account.

E-learning tools also appeared to mitigate the effect of a decrease in understanding as students move on from a less complex course (Human Pharmacology I, semester one) to a more complex subject (Human Pharmacology II, semester two). It is commonly acknowledged that academics should not challenge students with difficult concepts at the
start of their courses (Norton 2009); and instead, the focus should be to introduce them to the environment of the course and then include the difficult content in the final stages of the course (Norton 2009). Therefore, the Human Pharmacology curriculum has been structured to start from simple modules in Human Pharmacology I, in order to build student knowledge, and then proceed to more complicated and complex modules involving processes and mechanisms in Human Pharmacology II. A typical example of a more complex module is the mechanism of cancer drugs in the semester two Human Pharmacology II course, where students usually struggle to digest the mechanism of action. Thus, we expected to observe an overall drop in the student level of understanding of content from semester one as compared to content from semester two, given that semester two was a more complex course. Although, in general, a decrease in understanding was observed for both groups only the decrease in level of understanding among the control cohort was found to be statistically significant. Further, students from the control group achieved only a uni-structural level of understanding when answering questions related to cancer drugs in semester two, while students from the intervention group scored a higher level of understanding. This further supports the benefit of e-learning tools on student level of understanding when students move from introductory courses to more complex courses in the same field.

However, the significant impact of the e-learning tools was only observed when student engagement with the tools was at high levels. For instance, in semester one the total level of understanding was not significantly different between the groups; however, analysis of student engagement with the e-learning tools revealed low level of usage and engagement. This was because students either forgot or did not have time to access the tools (Karaksha et al. 2013a). This was addressed in semester two by constantly reminding the students about the e-tools throughout the semester, which led to a significantly higher
engagement with the e-learning tools in semester two (Karaksha et al. 2013a). The increase in student engagement with the e-learning tools was reflected in their level of understanding; students from the intervention group outperformed their peers from the control group in every short answer question reinforced by e-learning tools. This was also confirmed by further analysis which showed strong positive correlation between e-learning tool usage and student level of understanding in the exam. A previous study reported a similar conclusion by showing a strong relationship between study materials usage and exam performance (Nieder et al. 2011).

In addition to the benefits of e-learning tools observed in the final exam results, we also found a benefit for the tools in improving student performance in long-term knowledge retention. The retention of knowledge has been always a concern for academics from different science degrees. The general belief is that a substantial portion of the information is lost after short period of time only (Custers 2010; Larsen et al. 2009). However, long-term knowledge retention is especially important for students in Human Pharmacology courses, as they will need to use the acquired knowledge in the subsequent years of their study. Previous studies have showed that using online education tools can improve participant long-term retention after several months (Kerfoot et al. 2010; Savoy et al. 2009). Similarly, our study showed that approximately six months after course completion, students from the intervention group had a significantly higher level of knowledge retention than their peers in the control group. Thus, the significant enhancement of long-term knowledge retention is another benefit of e-learning tools for student learning.

Lastly, the final benefit we found of e-learning tools for student learning was the fact that it provided flexible learning opportunities catering for different learning styles. It is acknowledged that students have various distinctive learning styles, and these affect
how they engage with traditional and new teaching methods (Hunt et al. 2004). The flexibility of the e-learning tools as supplement to standard curricula (in using both text and animations to convey concepts) may thus maximise students’ knowledge retention, whether they are aware of their own learning styles or not. We can conclude this because although the majority of students from both groups reported that they prefer to learn both text and images (animations) when studying drug mechanisms of action, the majority of students from the control group stated they remembered only text when answering the questions in the long term retention. Conversely, approximately 50% of the respondents from the intervention group remembered both animation and text. Mogey (1999) supports this finding, commenting that one of the advantages of e-learning tools is to present information to students in different ways, and thereby catering to individual learning styles (Mogey 1999).

To conclude, this study evaluated the effects of a set of in-house designed e-learning tools, embedded as supplements to standard pharmacology curricula in semester one and two, and found a number of significant benefits for student learning. E-learning tools appeared to significantly improve student level of understanding as scored by the SOLO taxonomy when there was substantial engagement of students with the tools. We also found that e-learning tools appeared to mitigate the decrease in student understanding observed when students progress into more complex courses and significantly increase long-term knowledge retention. E-learning tools also showed the capacity to cater for different learning styles and to improve retention. The study also demonstrated that a holistic approach underpinned by educational pedagogy could be employed to objectively evaluate the impact of technology on student learning, effectively comparing different student cohorts using Bloom’s revised taxonomy to classify exam questions into common learning dimensions, and using SOLO taxonomy scoring to evaluate student level of
understanding instead of simply exam grades. Our approach and findings contribute to the scholarship of learning and teaching (SoLT) in relation to e-learning tools, and may potentially enhance both pharmacology and other courses by providing framework on standardising the evaluation of the impact of online learning strategies on student performance and learning experiences.
Reference


Chapter 6

Griffith University versus Bond University Study

The Evaluation of Educational Benefits of Online Learning Tools on Student Performance in a Major Assessment Item Across Two Higher Education Institutions in Australia.

STATEMENT OF CONTRIBUTION TO CO-AUTHORED PUBLISHED PAPER

This chapter includes a co-authored paper. This paper was submitted to the Focus on Health Professional Education A Multi-Disciplinary Journal on the 18/03/2013. The paper received the associate editor approval and progressed to the peer reviewers on 23/05/2013. The authors of the paper are: Karaksha, Abdullah., Chess-Williams, Russ., Holani, Candice., Davey, Andrew K., Anoopkumar-Dukie, Shailendra., Grant, Gary., Perkins, Anthony V., Nirthanan, S. Niru., McDermott, Catherine.

My contribution to the paper involved: designing and conducting the study at the School of Pharmacy – Griffith University, collecting the data from the School of Pharmacy, analysing and categorizing the data (from both Griffith and Bond universities) and providing direction on the scope and structure of the analysis. I also wrote the first draft, made revisions responding to supervisor/co-author comments and feedback, prepared the final document, and submitted the article.

(Signed) _________________________________ (Date) 25th July 2013
Abdullah Karaksha

(Countersigned) ___________________________ (Date) 25th July 2013
Corresponding author of paper: Dr. Catherine McDermott

(Countersigned) ___________________________ (Date) 26th July 2013
Supervisor: Dr. Shailendra Anoopkumar-Dukie
The evaluation of educational benefits of online learning tools on student performance in a major assessment item across two higher education institutions in Australia.

Karaksha, Abdullah¹, Chess-Williams, Russ³, Holani, Candice¹, Davey, Andrew K¹, Anoopkumar-Dukie, Shailendra¹, Grant, Gary¹, Perkins, Anthony V², Nirthanan, S. Niru², McDermott, Catherine³.

1. School of Pharmacy, Griffith University, Queensland, AUSTRALIA
2. School of Medical Science, Griffith University, Queensland, AUSTRALIA
3. School of Health Science, Bond University, Queensland, AUSTRALIA

Abdullah Karaksha: BPharm, MMedRes (Clinical Pharmacy), PhD candidate.
Russ Chess-Williams: BSc(Hons), PhD, FBPharmacolS
Candice Holani: BSocSc
Andrew K. Davey: BPharm (Hons), PhD, PGCertTertT.
Shailendra Anoopkumar-Dukie: BSc (Hons), MSc, PhD, Grad Cert Higher Education.
Gary Grant: BPharm, PhD, Grad Cert Higher Education.
Anthony V Perkins: BSc, MPhil, PhD
S. Niru Nirthanan: MBBS, PhD
Catherine McDermott: BSc (Hons), PhD

Corresponding author: Dr. Catherine McDermott
School of Health Science, Bond University, Queensland, Australia.
Office number: +61
Fax number: +61
Email address: camcderm@bond.edu.au

Keywords: E-tools, Pharmacology education, constructive alignment.
Abstract

**Background:** Online learning tools (e-tools) offer a number of inherent features such as independence of time of learning. However, despite several decades of research in the use of computers in education, recent studies show that e-tools implementation has not been as extensive as expected.

**Purpose:** The purposes of this study were to: evaluate the educational benefit of e-tools, designed and produced in-house, on student performance in a major assessment item for pharmacology curriculums in two universities, and evaluate the importance of aligning the objectives of the course with the e-tool content.

**Methods:** A qualitative and quantitative study was conducted to evaluate the impact of adding e-tools, as supplements to the pharmacology curriculums in 2012, on student learning across two Australian universities; Griffith and Bond. Student attitudes towards the e-tools were assessed using a survey. Student uptake of the e-tools was evaluated by the Blackboard data. Finally, student performance in the first major assessment exams, after the deployment of the e-tools, was analysed in two academic years (2011 versus 2012) to evaluate the improvement in learning at each university.

**Results:** Overall, students preferred the addition of e-tools to supplement their standard curriculum. The uptake of the e-tools was significantly higher at Bond compared to Griffith. However, students from Griffith performed significantly better in the 2012 exam when compared to 2011. No significant difference in performance was observed at Bond across the two academic years.

**Conclusions:** Students have a positive attitude towards the implementation of e-tools as supplements to the standard curriculum. However, e-tools should be aligned with the course aims and objectives to be effective in student learning.
Introduction

Pharmacology is considered a core course for almost every health school in the world (Candler, Ihnat, & Huang, 2007). Over the years, pharmacology has undergone rapid expansion and discoveries, the number of United States Food and Drug Administration-approved drugs has increased, patients have become more educated and demanding, and more adverse drug events and interactions have been reported (Zgheib, Simaan, & Sabra, 2011). This information is debated as necessary for all health-related students, and the United Kingdom General Medical Council has called for the development of a new pharmacology curriculum that encompasses the core knowledge and skills (Walley, Bligh, Orme, & Breckenridge, 1994). The expansion in our knowledge of the discipline has placed more pressure on pharmacology educators to continuously incorporate new facts and update their curriculum (Hughes, 2003). But, while it is essential to add this new content into existing pharmacology curricula because of its relevance to contemporary clinical practice, in most instances, no additional teaching time is allocated for its inclusion (Francis, Mauriello, Phillips, Englebardt, & Grayden, 2000). This disproportionate increase in content within the limitations of existing contact hours may hinder student learning, limit comprehension and understanding, and restrict the integration of new information into students’ existing knowledge-base (Pahinis, Stokes, Walsh, & Cannavina, 2007). To effectively address this issue, clinical pharmacologists and educators have identified the use of technological advancement (e-tools) as self-directed learning programs (O'Shaughnessy, Haq, Maxwell, & Llewelyn, 2010; Walley et al., 1994). E-tools have been implemented in different undergraduate curriculums as they assist academics and educators to meet the growing needs and expectations for improving the quality of pharmacology education (Candler et al., 2007; O'Shaughnessy et al., 2010; Walley et al., 1994). This new teaching method encourages the movement from a teacher-focused approach to student-focused one (AACP, 1993; Grigg &
Stephens, 1998), because e-tools are constantly accessible by students at their preferred times, help them have active learning experiences, and engage them in the learning process (Maxwell, 2012). Moreover, some studies have found that e-tools help students undertake a deep learning approach and progress into independent life-long learners (Buckridge, Krause, & Alexander, 2010; Hughes, 2003; Hughes, 2002; Pahinis et al., 2007). Further, a large body of research suggest that this progression is essential for successful teaching (Biggs & Tang, 2007; Martin, Prosser, Trigwell, Ramsden, & Benjamin, 2002; Ramsden, 2003).

Yet, while e-tools offer a number of inherent features such as independence of place and time, adaptability to diverse learning styles and paces of the students or scalability to rising student numbers, their use remains limited. Despite several decades of research and development in and around the use of computers in education, recent studies show that e-tools implementation has not been as extensive as expected (Berman, Fall, Maloney, & Levine, 2008; MacLean, Scott, Marshall, & Asperen, 2011; Zollner et al., 2013). This may be due to misinterpretation of the literature for e-tools effectiveness, miscommunication between e-tool developers and the educators who make decisions about their use, the paucity of knowledge regarding how to integrate e-tools effectively into higher education, and economic factors such as high costs and time requirements for the generation of e-tool content (Berman et al., 2008; Masters & Ellaway, 2008). Thus, there is a need for research to overcome these challenges and maximise the potential of e-tools to assist in the teaching of students. Our team has aimed to address some of these issues by designing a series of e-tools to complement the delivery of pharmacology content within the framework of a defined pedagogy. The e-tools content encompassed the basic mechanisms of action for different drug classes and was aligned with the objectives of the Human pharmacology course (3028PHM) at Griffith University. This alignment aimed to form a system which operates well for the benefit of students (Biggs & Tang, 2007). These e-tools were used as supplement
to traditional face-to-face lectures in pharmacology courses at two higher education
institutions namely: Griffith University and Bond University, Gold Coast, Australia.
The aims of this project were to: a) evaluate the educational benefit of the e-tools on student
performance in a major assessment item for pharmacology curriculums in two different
higher education institutions, and b) evaluate the importance of aligning the objectives of the
course with the e-tool content.
Methodology

This investigation was conducted at the School of Pharmacy, Griffith University and School of Health Science, Bond University, both located on the Gold Coast, Queensland, Australia. A suite of e-tools was designed for the pharmacology curriculums in these institutions in semester two of 2012. The e-tools were used as supplement to the standard curriculum (Figure 1). Ethical approval was granted by Griffith University Human Ethics Committee (protocol PHM/05/10/HREC) and Bond University Human Ethics committee (protocol RO1544).

E-tool design

Custom animations were sequenced in Microsoft PowerPoint 2010 and narration was added using iSpring Pro 6.1.0 to produce the embedded animation and then convert the animations into a Flash format for ease of delivery and access through Blackboard (Karaksha, Grant, Davey, & Anoopkumar-Dukie, 2011). Participants could easily control the speed of the final e-tools, skip content, and move forward and backward as needed to revisit specific concepts. The full information about the design process for our in-house e-tools within the framework of a defined pedagogy and relevant teaching theories has previously been published (Karaksha et al., 2011).

Implementing the e-tools

The e-tools were made available to students via the pharmacology courses websites using the Blackboard interface - 2012. Students were informed about the e-tools by the chief investigator during the course introductory lecture and were reminded on different occasions at lectures and tutorials. Full details of the study were made available to students via the course Blackboard site. Finally, announcements and emails were also sent to remind the students about the study and encourage them to use the e-tools. This procedure was followed at both, Griffith and Bond Universities.
Survey to assess student attitude towards the e-tools

A survey was designed to obtain student demographic data and evaluate their preference for the e-tools at both universities.

At the School of Pharmacy, Griffith University: A paper-based approach was followed when distributing the survey. Students were approached in person to participate in the survey during one of the Human pharmacology workshops. The timing of the survey gave the students the chance to access the e-tools and ensured that all students would have the opportunity to participate in the survey. Student participation in the survey was voluntary and anonymous. More details about the survey and student responses can be found in a recent study that was published by our group (Karaksha, Grant, Anoopkumar-Dukie, Nirthanan, & Davey, 2013).

At the School of Health Science, Bond University: An online-based approach was used to make the survey available to students. The survey was uploaded on the Blackboard course website and student participation was invited by emails and announcements. The online survey was made available for the students during the semester. Student participation in the survey was voluntary and anonymous.

The survey was designed according to previous studies that examined student preference towards technology (Chen, Lambert, & Guidry, 2010; Euzent, Martin, Moskal, & Moskal, 2011; MacLean et al., 2011; Taplin, Low, & Brown, 2011) and obtained demographic data including gender, frequency of attending lectures, and difficulty of following topics that cover drug mechanisms of action. Additionally, students were given the opportunity to provide their perception, feedback, and additional comments in an open-end question.

Student preference for technology, in general, was examined by way of a five-point Likert scale (strongly agree, agree, no comment, disagree and strongly disagree). Student learning
styles were assessed by asking students whether they remember words and/or pictures in responding to questions related to drug mechanisms of action.

Assessment

The pharmacology curriculums had different foci in each school. Thus, to evaluate the educational benefits of the e-tools on student learning, our team analysed student performance in the first main assessment item following the deployment of the e-tools, across two academic years, namely 2011 versus 2012. Students in 2011 studied the pharmacology standard curriculum which consisted of lectures, tutorials and workshops. In 2012 the e-tools were added as a supplement to the same standard pharmacology curriculum.

The assessment exams at both institutions consisted of a mix of well-constructed multiple choice, short answer and essay questions. Questions were carefully developed to assess the courses’ stated learning objectives and attempted to evaluate the four levels of the knowledge dimension, namely: factual, conceptual, procedural, and metacognitive knowledge, as defined by Bloom’s taxonomy and Bloom’s revised taxonomy (Anderson, Krathwohl, & Bloom, 2001; Bloom, 1969). Therefore, the comparative performance at the 2011 and 2012 exams was considered as a measure of the impact of e-tools on student learning.

Data analysis

For the survey results, a number of quantitative analyses were undertaken. Demographic data including gender and English as first language, as well as student preference for technology and learning style, were compared between the students, who used the e-tools, from Bond and Griffith Universities. T-tests and Chi-square tests were used to determine whether the two groups significantly differed in these baseline variables. The survey evaluated participant attitudes towards the technology by way of a 5-point Likert scale (strongly agree, agree, no comment, disagree, and strongly disagree). To improve sample size per group, these
categories were collapsed into three types of response: “positive,” “neutral,” and “negative” responses.

To evaluate student uptake of the e-tools, data from the online courses website (Blackboard) were obtained, including the number of hits for each e-tool along with the time and date for accessing them. The data were de-identified by the course convenors before being analysed using t-test to compare the total e-tool usage (in terms of number of hits) between the two academic institutions.

Student grades in the assessment exams were evaluated and t-tests were used to determine the improvement in performance in each school by comparing students’ grades in 2011 versus 2012.

The data were statistically analysed using IBM SPSS software (v 20). Probability (p) values of less than 0.05 were considered statistically significant.
Results

A total of 69 Pharmacy students enrolled in the Human pharmacology course in semester 2-2012 at Griffith University were compared to a cohort of 61 students from the School of Health Sciences at Bond University.

Twenty two students from the School of Pharmacy, Griffith University voluntarily participated in the paper-based survey, representing 32% of the total cohort. In contrast, only 11 students from the School of Health Sciences, Bond University completed the online survey, representing 18% of the total cohort.

The demographic data were compared between the two schools (Table 1). Statistical analysis for demographic data showed no significant difference between the two groups in any of the comparisons.

The results found no significant difference between the two groups in the numbers of students for whom the first language was English (p > 0.05). Student responses were split between easy, neutral or difficult with no significant differences noted (p > 0.05) when asked to rate the level of difficulty they had in understanding the course content that involved drug mechanisms of action. Student attitude towards online-learning tools was also analysed and compared between the groups. Overall, the results demonstrated positive preference for the inclusion of online-learning tools into the standard curriculum. However, the majority of students, from both groups, were either negative or neutral regarding the substitution of traditional didactic lectures with online-learning tools. Student preferred methods toward learning were also compared between the groups. The majority of students from the two groups preferred using both text and animations to study drug mechanisms of action. The difference between the two groups was not statistically significant (p > 0.05; Table 1).

Students also included comments and feedback regarding the e-tools’ perceived usefulness. From Griffith University, two students found the e-tools not useful because they found the
information to be either too basic or took too long to view. The remaining comments were positive and can be classified into three major themes. In the first theme, students appreciated that the e-tools were a visual explanation of drug mechanisms of action (7 comments). In the second theme, the e-tools were seen as helpful for further understanding the drug mechanisms of action (4 comments). Finally, students considered it valuable because e-tools provided additional reinforcement of the lecture materials and reviewing them was more interesting than reading the lecture notes repeatedly (9 comments).

All students from the Bond University gave positive feedback (4 comments) that conforms to the previous themes. However, one student highlighted the fact that the e-tools went into greater details than what they were required to know. The same student added that other e-tools explained the relevant mechanisms in greater depth than what they covered in the lectures.

Data from Blackboard provided more in-depth analyses regarding student uptake of the e-tools across the two institutions. Comparing the total number of hits on e-tools between the two schools showed a significant difference in student uptake. Students from Griffith University made 1054 hits compared to 4058 hits from Bond students (Table 2). The preferred time of day for visiting the e-tools was spread across the 24 hour period. A similar trend was found in both Schools.

Student performance in the assessment exams was compared in each school across two academic years. One hundred and twelve students enrolled in the Human pharmacology course at the school of Pharmacy, Griffith University in 2011 compared to 69 students in 2012. Students in 2012 significantly performed better than their peers in 2011 ($t= -3.3$, $p < 0.001$). At the School of Health Science, Bond University, 55 students enrolled in the pharmacology course in 2011 compared to 61 in 2012. There was no significant difference in student performance across those years (Table 3).
Discussion

The aims of the study were to assess the educational benefit of the e-tools on student performance across two higher education institutions in Australia, and evaluate the importance of aligning the objectives of the course with the e-tool content. The data indicated that participants in the School of Pharmacy, Griffith University and School of Health Sciences, Bond University were not significantly different on key demographic variables.

Students who used the e-tools and participated in the survey had similar attitudes towards the application of technology into their learning and teaching. In general, students from both groups (67%) were positive towards the addition of online-learning tools to the pharmacology curriculum. This is an expected outcome from present day students who anticipate technology to be integrated into their learning experiences (Berman et al., 2008; Yelland, Tsembas, & Hall, 2008).

Students have various learning styles, and these affect how they engage with traditional and new teaching methods (Hunt, Eagle, & Kitchen, 2004). Therefore, student preference towards studying using text, animation or both was assessed in the survey. The results showed that the majority of students (88%) preferred to study either animations or both text and animation. This finding can be linked to the qualitative comments from students who stated that they found the e-tools as a valuable visual explanation for drug mechanisms of action. It is documented in the literature that students with a visual learning style learn more easily with diagrams and using audio-visual materials over textual information (Hunt et al., 2004; Lindquist & Long, 2011). This serves as a good example to show the benefit of using e-tools for improving the quality of pharmacology education (Candler et al., 2007; O'Shaughnessy et al., 2010; Walley et al., 1994).

Nonetheless, the survey results showed that only 21% of the students were positive regarding the replacement of traditional lectures with online-learning tools. Thirunarayanan et al (2011)
support this finding. The authors surveyed 359 undergraduate students, and the minority (30%) favoured using online teaching methods over attending the traditional face-to-face lectures (Thirunarayanan, Lezcano, McKee, & Roque, 2011). It is an obvious trend that students still consider traditional didactic lecturers and peer interaction in the classroom as critical to their learning success (Garcia & Qin, 2007; Lohnes & Kinzer, 2007).

Students from Bond University appeared to have used the e-tools significantly more than their peers from Griffith (Table 2). Email remainders and announcements were sent to students regularly to increase their engagement with the e-tools and the frequency of this process was similar at both institutions. A previous study demonstrated that students appreciate receiving announcements and emails about information related to their courses (McCabe & Meuter, 2011). However, a further study is necessary to determine conclusively why the uptake was greater among Bond students than Griffith students; especially since the same procedure to encourage student engagement was followed in both universities and there were no significant differences in the demographic data between the groups.

Although their uptake of the e-tools was significant, on evaluating student grades in the assessment exams showed that Bond students had no significant improvement in their performance between 2011 versus 2012, before and after the supplementation of e-tools respectively. Interestingly, there was a significant improvement in student grades at Griffith University. One explanation is that the e-tool content, which was originally developed at Griffith University for Griffith’s curriculum, was more aligned with the objectives of their Human pharmacology course (3028PHM). This is supported by a Health Sciences student comment, which noted that some e-tools covered extra materials that were not required by their curriculum at Bond University. A recent study by Charsky and Ressler (2011) concluded that commercial e-tools failed to improve student learning when included as part of their teaching and learning experiences. However, the authors noted that the content of the
e-tools should be aligned with the educational objective of the course or they will not benefit student learning (Charsky & Ressler, 2011). Thus, the lack of alignment between our in-house built e-tools and the pharmacology curriculum at Bond University might be the reason for not benefiting student learning. According to the constructive alignment theory, the curriculum should form a system that has consistency between its three major components namely; teaching materials, learning outcomes, and assessment tasks (Biggs & Tang, 2007). This system operates well for the benefit of students (Biggs & Tang, 2007). Failing to undertake this step has been suggested to cause negative influence on students’ achievement (English & Steffy, 2001) like that observed in our study.

The purpose of this study was to examine the educational benefit of a set of e-tools across two academic institutions. What we discovered is that the same set of e-tools might/might not improve student learning when aligned/not aligned with the course aims and objectives. Therefore, a recommendation of this study is to ensure that a constructive alignment approach has been followed when designing the content of the e-tools before application. Limitations to this study include the omission of students’ grade point average (GPA) as a variable in our analyses, the small sample size, potential for non-respondent bias and self-reporting bias.

Conclusion

The results of this investigation suggest that students have positive attitude towards the implementation of e-tools as a supplement to the standard curriculum. However, e-tools should be aligned with the course aims and objectives to be effective on student learning and improve their performance at assessments.
Figure 1. Study design. A suite of e-tools was deployed across two higher education institutes (Bond & Griffith Universities) to supplement the standard pharmacology curriculum in 2012. The standard curriculum includes: lectures, workshops and/or tutorials. Student performance in a major assessment item was assessed across two academic years (2011 vs 2012) to evaluate the educational benefit of the e-tools on student learning. Student preference of the e-tools was assessed through a survey. 22 students from Griffith and 11 from Bond voluntary participated in the survey.
Table 1: Demographic data and preference towards online-learning tools.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Griffith students (2012) n = 23 (%)</th>
<th>Bond students (2012) n = 11 (%)</th>
<th>Statistic, p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gender:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female (n = 19)</td>
<td>14 (61)</td>
<td>5 (45)</td>
<td>$\chi^2 = 0.55, p = 0.46$</td>
</tr>
<tr>
<td>Male (n = 15)</td>
<td>9 (39)</td>
<td>6 (55)</td>
<td></td>
</tr>
<tr>
<td><strong>English as first language</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes (n = 25)</td>
<td>16 (70)</td>
<td>9 (82)</td>
<td>$\chi^2 = 0.69, p = 0.41$</td>
</tr>
<tr>
<td>No (n = 9)</td>
<td>7 (30)</td>
<td>2 (18)</td>
<td></td>
</tr>
<tr>
<td><strong>Difficulty of topics that cover drug MOA</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Easy (n = 9)</td>
<td>7 (30)</td>
<td>2 (18)</td>
<td></td>
</tr>
<tr>
<td>Neutral (n = 11)</td>
<td>8 (35)</td>
<td>3 (27)</td>
<td></td>
</tr>
<tr>
<td>Difficult (n = 12)</td>
<td>8 (35)</td>
<td>4 (36)</td>
<td></td>
</tr>
<tr>
<td><strong>Attend pharmacology lectures:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rarely (n = 4)</td>
<td>3 (13)</td>
<td>1 (10)</td>
<td></td>
</tr>
<tr>
<td>Frequently (n=12)</td>
<td>7 (30)</td>
<td>5 (45)</td>
<td></td>
</tr>
<tr>
<td>Always (n = 18)</td>
<td>13 (57)</td>
<td>5 (45)</td>
<td></td>
</tr>
<tr>
<td><strong>Preference towards online-learning tools application in L&amp;T</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Positive (n = 22)</td>
<td>17 (74)</td>
<td>5 (45)</td>
<td></td>
</tr>
<tr>
<td>Neutral (n = 8)</td>
<td>6 (26)</td>
<td>2 (18)</td>
<td></td>
</tr>
<tr>
<td>Negative (n= 1)</td>
<td>-</td>
<td>1 (10)</td>
<td></td>
</tr>
<tr>
<td><strong>Preference to replace traditional lectures with online-learning tools</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Positive (n = 7)</td>
<td>6 (26)</td>
<td>1 (10)</td>
<td></td>
</tr>
<tr>
<td>Neutral (n = 6)</td>
<td>5 (22)</td>
<td>1 (10)</td>
<td></td>
</tr>
<tr>
<td>Negative (n= 19)</td>
<td>12 (52)</td>
<td>7 (63)</td>
<td></td>
</tr>
<tr>
<td><strong>Online-learning tools are useful for learning MOA</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Positive (n = 27)</td>
<td>19 (83)</td>
<td>8 (72)</td>
<td></td>
</tr>
<tr>
<td>Neutral (n = 4)</td>
<td>3 (13)</td>
<td>1 (10)</td>
<td></td>
</tr>
<tr>
<td>Negative (n= 1)</td>
<td>1 (4)</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td><strong>Online-learning tools assist in understanding MOA</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Positive (n = 30)</td>
<td>21 (91)</td>
<td>9 (82)</td>
<td></td>
</tr>
<tr>
<td>Neutral (n = 0)</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Negative (n = 2)</td>
<td>2 (9)</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>
**Online-learning tools can change the learning style**

<table>
<thead>
<tr>
<th></th>
<th>Positive (n = 24)</th>
<th>Neutral (n = 8)</th>
<th>Negative (n = 0)</th>
<th>( \chi^2 )</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>18 (78)</td>
<td>5 (22)</td>
<td>-</td>
<td>0.83</td>
<td>0.36</td>
</tr>
<tr>
<td></td>
<td>6 (55)</td>
<td>3 (27)</td>
<td>-</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Preference towards studying MOA format**

<table>
<thead>
<tr>
<th></th>
<th>Animation (n = 8)</th>
<th>Text (n = 2)</th>
<th>Both (n = 22)</th>
<th>( \chi^2 )</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>7 (30)</td>
<td>1 (4)</td>
<td>15 (66)</td>
<td>3.3</td>
<td>0.19</td>
</tr>
<tr>
<td></td>
<td>1 (10)</td>
<td>1 (10)</td>
<td>7 (63)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

This table includes statistical comparisons of demographic data and preference towards online-learning tools between two groups; students who accessed the e-tools from the school of Pharmacy, Griffith University and those from the Health Sciences school, Bond University. All demographic data and student preference towards the online tools were not significantly different between the groups.

a mechanism of action.

b learning and teaching
Table 2: Comparisons of e-tools usages between the two academic institutions.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>SD</th>
<th>Statistic, p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>E-tools usage (total)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>School of Pharmacy (n = 1054)</td>
<td>16.4</td>
<td>± 13.3</td>
<td>t=13.2, p = 0.0001</td>
</tr>
<tr>
<td>School of Health Science (n = 4058)</td>
<td>190.3</td>
<td>± 40.2</td>
<td></td>
</tr>
</tbody>
</table>

This table includes statistical comparisons of mean number of hits per day on e-tools between the school of Health Sciences, Bond University and the school of Pharmacy, Griffith University. E-tools usage significantly increased in semester two when compared with semester one. The comparison showed that the first group usage was significantly lower than the second group.
Table 3: Comparisons of student performance in the assessment exams (2011 vs 2012).

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>School of Pharmacy (n = 112 vs 69)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exam grades (Mean, SD)</td>
<td>67.8 ± 5.2</td>
<td>74.0 ± 4.4</td>
<td>t = -3.3, p = 0.001</td>
</tr>
<tr>
<td><strong>School of Health Science (n = 55 vs 61)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exam grades (Mean, SD)</td>
<td>66.1 ± 2.2</td>
<td>66.4 ± 2.1</td>
<td>t = -0.75, p = 0.45</td>
</tr>
</tbody>
</table>

This table includes statistical comparisons of student performance in the assessment exams. Students from the school of Pharmacy in 2012 significantly outperformed their peers in 2011. However, no significant difference was observed in student performance from the school of Health Sciences in 2011 vs 2012.
Reference


Chapter 7
General Discussion
The overall aim of this PhD study was to design e-learning tools incorporating established educational theories and to examine the effect of these e-learning tools on improving student learning experiences and outcomes. The specific objectives were to compile a comprehensive review of the literature pertaining to the pedagogy of e-learning tools, develop a series of preliminary e-learning tools for sequential pilot studies, quantitatively and qualitatively evaluate the effectiveness of these tools on student learning, refine the design of the tools according to the data obtained from pilot studies, develop and deploy a comprehensive series of e-learning tools that cover drug mechanisms of action within the pharmacology curriculum for third year pharmacy students at Griffith University, evaluate student engagement with the e-learning tools and finally, assess the impact of the e-learning tools on improving student level of understanding and perception.

The first pilot study was undertaken at the School of Pharmacy in 2010, to assess the relevance of the teaching theories in which underpinned the development of the piloted e-learning tool. By using commercially available software packages such as iSpring Pro, PowerPoint and Question Writer (Professional), the first generation e-learning tool was successfully developed in-house. There are three main advantages of this custom designed e-learning tool. The first advantage of the e-learning tools is that they were designed and developed incorporating established educational theories, including that students learned better from a combination of words and pictures presented simultaneously, but only when extraneous words, pictures, and sounds are excluded, when multiple source of information are integrated, when animation and narration are combined, and when students can interact with learning materials; these principles are related to the cognitive load theory and Mayer’s dual channel assumption (Sweller 1994, Mayer 2001). The second advantage of the custom e-learning tool is that the content and
delivery is structured and moulded to the specific requirements of our pharmacology curriculum and learning and teaching needs. The third advantage of the custom e-learning tool is that educators can easily and economically update the content to encompass evolving course learning objectives, changed practices and new developments in drug discovery and applications. This overcomes a serious limitation of commercially available tools; the commercial tools developed by trained programmers using complex software packages are often too generic or prescriptive in our specific learning and teaching contexts. Results from the first pilot study revealed that student performance in the short-term knowledge retention quiz suggested that there was added educational value in supplementing the traditional pharmacology curricula with e-learning tools developed in-house. Moreover, the majority of students indicated satisfaction with the e-learning tool. Finally, student feedback and suggestions for improvement were taken on board to refine the design and delivery of the e-learning tools leading to the second pilot study.

The second pilot study was conducted at the School of Medical Science in 2011, to further improve the design and delivery of the e-learning tools as well as to pilot test both the assessment method to evaluate student level of understanding and the survey to evaluate student engagement with the tools. For the purpose of this study, a second generation e-learning tool was designed that incorporated both the previously defined educational principles and the required improvements identified by the first pilot study, and which was developed using the same commercial software packages (iSpring Pro and PowerPoint). The e-learning tool was not uploaded online for this study and consequently called an “embedded animation”. Like the first pilot study, the second also received positive feedback from students about the inclusion of e-learning tools into their curricula. However, adding the e-learning tool as an embedded animation in the relevant didactic lecture did not appear to improve student level of understanding in the assessment quizzes
in this pilot study, when analysed using the Structure of the Observed Learning Outcome (SOLO) taxonomy. In keeping with widely reported findings that grade point average (GPA) is a strong indicator of academic performance (Willey, Edwards et al. 2008, Sonnert and Fox 2012), a strong positive correlation between GPA and performance in the quizzes was noted for students in both groups, those who had or did not have the animation embedded into their lecture. This finding was important to confirm that SOLO taxonomy was a valid measurement tool to be used to assess the educational improvement in student learning in the main study to follow.

While the results of the two pilot studies on student performance revealed conflicting conclusions, there were several limitations that might have contributed to this inconsistency. The impact of e-learning tools on student learning in the pilot studies was likely to have been blunted since these tools were used as an ad hoc rather than continuous supplementation to all lectures. Further, the concept of long-term knowledge retention following the use of the e-learning tool was also not assessed in the pilot studies. The assessment items were either distributed on a CD (first pilot study) or implemented online (second pilot study) for the participants to access them from their computers. No control measures were taken for the assessment items and students could have compared or discussed responses to the questions, or have accessed their learning materials while taking the quizzes. Self-reporting bias is also a possibility. Therefore, to minimise these limitations, in planning the main study, it was decided to design a comprehensive series of e-learning tools that could be used to supplement all the lectures in the pharmacology course and to evaluate student performance in the final summative examinations in the course as a means of assessing their level of understanding to determine the educational benefit of the e-learning tools.
The data from the pilot studies were used to improve the design of the e-learning tools, leading to the development of the third generation of 148 e-learning tools which conformed to the learning objectives of the pharmacology curriculum for third year pharmacy students, reinforcing the content that was focused on drug mechanisms of action. The tools were underpinned by the educational principles previously outlined in the first pilot study and constructed using the iSpring Pro and PowerPoint. The e-learning tools were delivered as supplementary material to the Human Pharmacology I (3024PHM) and II (3028PHM) courses in semesters one and two in 2012. Two important outcomes with regard to the e-learning tools were evaluated at the end of the courses: student preference and engagement with the e-learning tools, and student performance at the end of semester summative examination.

Overall, student attitudes towards the addition of e-learning tools into their learning and teaching experience was positive. Positive feedback from students included: “I wouldn't pass without those e-learning tools. Great benefit, I passed the courses using them”. Moreover, student feedback also indicated that supplementing lectures with the e-learning tools gave them the flexibility to choose the learning method that best suited their needs. One student said in this regard; “the e-tools were useful because they were graphic representations of drugs' mechanism of action - I'm a visual learner and remember and understand easier by looking at animations”. However, while the students had positive preference for technology, the majority (79%) were either neutral or not in favour of the substitution of didactic lectures entirely with online-learning tools. Therefore, the technology-based teaching methods are recommended to be used as supplement to, and not a substitution for, face-to-face teaching. Another important finding in this study was that students do not purposefully engage with supplement teaching materials (like e-learning tools in this instance) unless they are consistently reminded and encouraged to
do so. During semester one of this study, student engagement with and uptake of e-learning tools was poor. Analysing students’ reasons for not accessing the e-learning tools during semester one showed that the majority either forgot or did not know about them, and only a few students indicated that they were not interested in accessing additional learning materials. This minority indicated that the lecture notes and textbook were enough support for their learning. “I found lecture text to be enough” and “I did not want to use too many resources as I already understood everything”. To improve student uptake and engagement with the e-learning tools, a student-focused approach was followed in the second semester by sending frequent emails and announcements through the course website to emphasise the benefits of the e-learning tools and to remind the students about the importance of using these resources. This approach significantly increased the e-learning tools usage in semester two when compared with semester one, suggesting more student engagement with the tools.

While student engagement with the e-learning tools is an important measure of success of implementing e-learning tools, their true educational benefit can be only determined by evaluating students’ level of understanding of the content as assessed by their performance in the final course examinations. In doing so, a comparison was undertaken between the performance of the student cohort in 2012 (intervention group), who studied the Human Pharmacology curriculum delivered via traditional face-to-face lectures which were supplemented with the e-learning tools, with student cohort performance from 2011 (control group) where the Human Pharmacology curriculum was delivered without the e-learning tools. As the comparison was conducted between two different academic cohorts, it was important to control for confounding factors such as the demographic variables and ensure that the assessment was comparable. There were no significant differences in the distribution of the key demographic variables between
the groups suggesting that participants had similar characteristics across the two academic years. The structure, quality and level of difficulty of the summative exam was consistent across both years.

To analyse the educational benefit of the e-learning tools, Bloom’s revised taxonomy was used to classify the questions according the knowledge and cognitive dimensions they examine for and then SOLO taxonomy was used to score student level of understanding when attempting the questions. Overall, it appeared that the e-learning tools had a significant effect in improving the SOLO level of understanding for exam questions that addressed concepts and content that were reinforced by the e-learning tools. Importantly, a significant impact of the e-learning tools was only observed when student engagement with the tools was at high levels. For instance, in semester one, the overall level of understanding was not significantly different between the student cohorts in 2011 and 2012, an observation that could be attributed to low level of usage and poor engagement with the e-learning tools. In comparison, the increase in student engagement with the e-learning tools during semester two was reflected as an increase in their level of understanding - students from the intervention group outperformed their peers from the control group in every short answer question which tested content that was reinforced by e-learning tools. This finding was confirmed by further analysis which showed strong positive correlation between e-learning tool usage and student level of understanding in the exam. In addition to the benefits of e-learning tools observed in the student outcomes in the final course exam, it was also found that the e-learning tools also improved long-term retention of content knowledge. The long-term knowledge retention is especially important for students in Human Pharmacology courses as students are required to build on their newly acquired knowledge in the subsequent years of their study as well as for safe prescribing in pharmacy practice. This study showed that approximately six months
after course completion, students from the intervention group had a significantly higher level of retention of content knowledge than their peers in the control group.

The final component of this PhD study aimed to compare the educational benefit of the e-learning tools on student performance at Bond University, another higher education institution on the Gold Coast, Australia. In contrast to Griffith University, where the e-learning tools were implemented for a pharmacology course run through the school of Pharmacy, these e-learning tools were used for a pharmacology course run through the school of Health Science at Bond. The results revealed that, interestingly, while students at Bond University engaged significantly more with the e-learning tools than students at Griffith University (where the tools were originally designed to be integrated with the pharmacology curriculum), the e-learning tools did not appear to improve student performance in their pharmacology examination in Bond University. This is most likely due to the fact that the e-learning tool content was not modified to be aligned with the course aims and objectives of Bond University’s pharmacology curriculum. The Constructive Theory states that learning materials which are not aligned with the specific course aims and objectives for which the materials are intended will have less of an educational benefit (Biggs and Tang 2007). Therefore, this study concludes that the content of the e-learning tools must align with the courses aims, objectives, and learning outcomes, and integrate with the structure of the course for maximal benefits to be derived. It must be noted that there was one major limitation in making a comparison of student performance at these two institutions, namely that the exam papers for students in 2011 at Bond University were not available for analyses. Consequently, SOLO taxonomy could not be applied for analysis of individual exam questions. Thus, in order to compare student performance between Bond and Griffith,
student grades in the exams (both 2011 and 2012, for both Bond and Griffith) were used as performance indicators for this study instead of student level of understanding.

**Limitations of this Thesis Project:**

As with any research, there were limitations should be addressed in future studies to improve the generalizability of the study results. This section presents some of theoretical, methodology and practical limitations of this thesis project.

**Theoretical limitations:**

Many of the studies in the literature are conducted to compare two different modes of teaching delivery, for example, didactic courses with online courses. Only a few studies have evaluated the use of online learning tools as supplement to traditional curricula which limited our ability to compare our results with published literature. Furthermore, to the best of our knowledge, our study is the first to utilise Bloom’s revised and SOLO taxonomies to evaluate student level of understanding within the higher education sector, making it difficult to compare our measures of student performance with measures from previously published literature (which mostly involved student final grade). However, we overcame this to some extent by examining student final grades in addition to student level of understanding during the Bond-Griffith comparison study. Additionally, if future studies make use of these taxonomies to evaluate student performance, our findings would become even more comparable with other research cohorts.
Methodology limitations:

Our methods aimed to control for potential confounding factors, obtain objective measures of student performance, and apply taxonomic classification in order to compare different cohorts/assessments. However, we faced some methodological limitations that should be improved upon in future studies. These include the following:

1. Our study aimed to assess the impact of e-learning tools on student cohorts, thus we evaluated the e-learning tools in three types of student cohorts: nursing students (pilot study two), pharmacy students (pilot study one and main study), and health science students (Griffith vs Bond study). These cohorts originated from two universities on the Gold Coast, Queensland: Bond University and Griffith University. Nevertheless, it was outside the scope of this study to evaluate a larger number of different cohorts at different universities. It would be interesting and necessary to address this larger research question by evaluating additional cohorts both in Australia and internationally.

2. Another limitation of the study focuses on the fact that students who participated in the study were not randomly selected. All students in 2012 were given the option to utilise the e-learning tools and were asked during the final assessment to ‘opt-in’ to the study. A more effective study design may have been to randomly assign students to intervention and control groups within a single cohort, and make the e-learning tools available only to the intervention group; however, this study design was not feasible in reality. This was due firstly to ethical concerns, as it would not be seen as fair to the students to withhold teaching materials from part of a cohort, and secondly it would be impossible to monitor compliance as students could share access to the e-learning tools. Thus, a non-random participant selection, while not ideal, was imperative for this study.
3. Another limitation of this study was that while the sample size resulted in adequate statistical power (~80%), it was necessary to collapse categories of the 1-5 Likert scale into positive, negative, and neutral categories for analysis. Additionally, it was impossible to stratify the groups (for instance, by gender) as the group sizes would have become too small. Thus, if future studies increase cohort sample size, more detailed stratified analyses may be carried out.

4. Lastly, surveys were administered to the students in order to determine their technology preferences and demographic details. Student administered questionnaires may potentially carry self-reporting bias (if students are not honest about their preferences or demographic data); however, this was the least intrusive way of determining student preferences (in comparison to interviews). Additionally, a subset of demographic data was confirmed through university records, indicating the reliability of the questionnaires.

**Practical limitations:**

1. E-learning tool usage was assessed according to the number of hits made by students in the Blackboard™, which controls for compliance. However, we were unable to determine the length of time and number of times that each individual student viewed the e-learning tools when they accessed them. While not essential, this information would have been interesting to include in the analysis to determine if a stronger improvement in performance correlated with increased individual time spent on the e-learning tool. We did observe that e-learning tools accessed by the cohort more frequently had a higher average performance in the final exam questions assessing that specific content; however, we may have observed an even stronger trend if individual data instead of cohort data were used. It may be possible in the future to utilise an alternate platform for e-learning
tool delivery that would allow individual student viewing times to be recorded for
analysis; however, it would need to be as easily accessible to the students as the
Blackboard system.

2. The e-learning tools were not compatible with smart phone devices and tablets,
which is expected to limit access by students. Students are increasingly using
smart phone devices and/or tablets as part of their studies; to take notes, view
lecture material, or record lectures/tutorials. Thus, making the tools available on
these devices may significantly improve student access, uptake, and preference
for e-learning tools.

3. Another limitation involved the potential for recruitment bias. As mentioned
previously, the nature of the study and the focus of analysis were explained to
students before they participated in the study, and students were given the option
to participate by “opting-in”. As in all studies, not all students in the cohorts
consented to participate, which may result in recruitment bias if students who
chose to participate in the study were high-achievers (who felt comfortable for
their exam papers to be analysed) or if they felt more experienced with technology
or were more interested in the course content. This may be difficult to control for,
though GPA (which presumably correlates with student achievement) was
observed to range from low to high, thus showing that both high- and low-
achievers participated in the study.

4. We controlled for some confounding factors (GPA, gender, age, English as first
language and frequency of attending lectures) by both ensuring that the
distribution of these variables was not significantly different in any of the
compared groups, and by adjusting for these variables in the regression analyses
conducted. However, we were not able to control all confounding factors due to
practicality; for instance, we could not determine whether students accessed extra
help, such as private tutors, study groups, or online YouTube videos. Any of these additional learning aids could potentially influence their exam performance and inflate the estimate of the e-learning tools effect. Additionally, students may have experienced personal or family problems that affected their performance and decrease the estimate of the e-learning tools effect. While some confounding factors were addressed in the initial survey, this was administered early in the semester and thus would not be able to determine study influences by the end of the semester; however, future studies may consider administering an additional short survey after the exam period which could determine this information.

The above-mentioned theoretical, methodological, and practical limitations of this study serve to encourage improvements to study designs that will bolster further research in this area. The recommendations for these improvements are outlined in the following section.

**Recommendations for Practice and Further Research**

**Recommendations for practice:**

A review of the literature revealed that many studies explored student preference for, attitude towards and satisfaction with different types of online learning tools. Only a few studies asked the question “does it work?” To the best of our knowledge, no study within the higher education setting used a holistic approach to evaluate the true educational benefit of technology on student learning. This study suggested positive gains in student level of understanding when using e-learning tools as supplement to the standard curriculum. Based on this finding, it is recommended that e-learning tools be included as supplement to the pharmacology curricula, as e-learning tools provide flexibility in time, place and pace for independent learners and greatly benefit visual learners. We also recommend that Bloom’s revised and SOLO taxonomies should be used
to determine the improvement in student level of understanding as an effective method of assessing the impact of on-line learning tools in learning and teaching, and which allows differing assessment questions to be compared across cohorts.

**Recommendations for further research:**

Further research should include larger student cohorts across different schools and universities. The use of a post-examination questionnaire would add valuable information in deriving at conclusions on the impact of technology-based learning, including determining student study behaviour (to know how much they studied for the course), their study load (how many courses they had in that particular semester) and whether they accessed any extra learning materials (such as commercial online tools and/or YouTube videos). Any further research should attempt to record the length of time that individual students accessed the e-learning tools so that individual (and not cohort) tool access can be correlated with performance and engagement. Additionally, future research should determine whether accessing the e-learning tools through smart phones and tablets could increase student engagement—this is now possible due to a recently issued update of the iSpring software, which makes it possible for the e-learning tools to be compatible with smart phone devices.

Furthermore, this study, as well as previous studies, has only examined the implementation of e-learning tools in relation to students: the student engagement, the student perceptions etc. However, future studies should also consider evaluating academics’ perception towards integrating technology into their teaching. There is lack of information regarding the current uptake of technology in learning and teaching and how it relates to academic perceptions and experiences with technology; therefore, further research is required to address this question.
In terms of the future directions of this research project, we are planning to take the project one step further and establish an immersive learning environment in the School of Pharmacy by developing a fully integrated pharmacology curriculum that can be a showcase for other schools and faculties. This environment will allow students to rapidly drill down to fundamental concepts associated with the treatment of various clinical conditions, and we plan to evaluate the impact of this immersion technology on student level of understanding using the same taxonomic classification of student final exam answers.

To conclude, this PhD investigation identified the required pedagogy to design effective in-house e-learning tools and the software needed to produce those tools; it is proposed that these processes can be easily replicated by other pharmacology and pharmacy educators. The results of the pilot studies were used to refine the design of the e-learning tools to be more effective. This resulted in a number of significant benefits for student learning that can be attributed to the e-learning tools. Different student cohorts showed positive preference and attitude towards the implementation of technology as a supplement to the traditional teaching methods. E-learning tools appeared to significantly improve student level of understanding as scored by the SOLO taxonomy when there was substantial engagement of students with the tools. The study demonstrated that a holistic approach underpinned by educational pedagogy could be employed to objectively evaluate the impact of technology on student learning, effectively comparing different student cohorts using Bloom’s revised taxonomy to classify exam questions into common learning dimensions, and using SOLO taxonomy scoring to evaluate student level of understanding instead of simply exam grades. The study has answered the two hypotheses by showing that a well-designed study was able to truly elucidate the educational benefits of the e-learning tools, and that well developed e-learning tools indeed added significant
educational benefit to existing pharmacology curricula by improving student level of understanding and perception. The approach and findings of this study contribute to the scholarship of learning and teaching (SoLT) in relation to e-learning tools, and may potentially enhance both pharmacology and other courses by providing framework on standardising the evaluation of the impact of online learning strategies on student performance and learning experiences.
Reference
Appendix A

Ethical Clearance Certificate
HUMAN RESEARCH ETHICS COMMITTEE

ETHICAL CLEARANCE CERTIFICATE

This certificate generated on 22-07-2013.

This certificate confirms that protocol 'NR: Development and Evaluation of E-Learning Tools Geared Towards Hospital Pharmacy Education.' (GU Protocol Number PHM/05/10/HREC) has ethical clearance from the Griffith University Human Research Ethics Committee (HREC) and has been issued with authorisation to be commenced.

The ethical clearance for this protocol runs from 26-08-2010 to 01-12-2013.

The named members of the research team for this protocol are:
Dr Gary Grant
Dr Niru Nirthanan
Dr Shailendra Dukie
Mr Abdullah Karaksha

The research team has been sent correspondence that lists the standard conditions of ethical clearance that apply to Griffith University protocols.

The HREC is established in accordance with the National Statement on Ethical Conduct on Research Involving Humans. The operation of this Committee is outlined in the HREC Standard Operating Procedure, which is available from www.gu.edu.au/hr/ethics.

Please do not hesitate to contact me if you have any further queries about this matter.

Rick Williams
Manager, Research Ethics
Office for Research
Bray Centre, N54 Room 0.15 Nathan Campus
Appendix B
Survey for Control Cohort (2011)
Are you:

☐ Male
☐ Female

Is English your first language?

☐ No
☐ Yes

What is your current GPA (grade point average)?
………………………………………………………………………………

How often did you usually attend Human Pharmacology lectures?

☐ Always
☐ Frequently
☐ Rarely
☐ Never

If you did not attend the lectures, what were the reasons?
…………………………………………………………………………………………
…………………………………………………………………………………………

Did you usually read through the lecture notes and/or textbook covering the same topic before attending lectures?

☐ No

If yes, for how long: ……………………………minutes.

How do you rate the difficulty to follow topics that cover drug mechanisms of action in a pharmacology lecture?

☐ Very Easy
☐ Easy
☐ Neutral
☐ Difficult
☐ Very Difficult

Did you go through any additional materials, which cover the same drug classes that you were taught in the Human Pharmacology I course, in the past 6 months?

☐ No

If yes, when this happened: …………………………………
To what extent do you agree or disagree with the following statements? Please tick where appropriate

<table>
<thead>
<tr>
<th>Strongly agree</th>
<th>Agree</th>
<th>Neutral</th>
<th>Disagree</th>
<th>Strongly disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>To what extent do you agree or disagree with this statement? -I prefer to use computer animation tools that give me flexibility in learning at your own time, location and pace?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>To what extent do you agree or disagree with this statement? -I prefer to replace the normal face-face pharmacology lectures that concern drug mechanisms of action by computer animation tools which cover the same topics?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>To what extent do you agree or disagree with this statement? -Using computer animations is a useful tool for learning the basic principles of a drug’s mechanism of action?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>To what extent do you agree or disagree with this statement? -Using computer animations will assist you more in understanding drug mechanisms of action?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>To what extent do you agree or disagree with this statement? -Using computer animations will change the way you recall information?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Please tick where appropriate:

<table>
<thead>
<tr>
<th>Computer animations</th>
<th>Conventional printed text</th>
<th>Both formats</th>
</tr>
</thead>
<tbody>
<tr>
<td>If you had to choose a format for learning the course content for pharmacology, you will choose:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Text (words)</td>
<td>Illustrations (pictures)</td>
<td>Both</td>
</tr>
<tr>
<td>When you study drugs’ mechanisms of action, do you study the text or illustrations (pictures)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
To help us in assessing the benefit of long-term retention recall, please answer the following two questions to the best you can:

Q1. Which one of the following statements regarding Levodopa is TRUE:
   a. Levodopa cannot cross the blood-brain barrier.
   b. Levodopa undergoes a decarboxylation process within the presynaptic terminals of dopaminergic neurons in the substantia nigra to produce dopamine.
   c. Levodopa undergoes a decarboxylation process within the intestinal mucosa and other peripheral sites to produce dopamine. The produced dopamine is important to treat Parkinson disease symptoms.
   d. Levodopa binds directly to the dopamine receptors in the substantia nigra, which produces its effect to treat Parkinson disease symptoms.
   e. All of the above are wrong.

Q2. Briefly explain Escitalopram’s mechanism of action.

When you answered the previous two questions, how did you attempt to recall the mechanisms of action?

Thanks for your help in this research project.
Appendix C

Survey for Intervention Cohort (2012)
TITLE OF PROJECT
Development and Evaluation of e-Learning Tools
Used as a Supplement to Standard Curricula in Pharmacology Education

Are you:

☐ Male
☐ Female

Is English your first language?

☐ No
☐ Yes

What is your current GPA (grade point average): ...........................................................

How often did you usually attend Human Pharmacology I lectures?

☐ Always
☐ Frequently
☐ Rarely
☐ Never

If you did not attend the lectures, what were the reasons?

........................................................................................................................................
........................................................................................................................................

Did you usually read through the lecture notes and/or textbook covering the same topic before attending lectures?

☐ No
☐ Yes, please indicate for how long:....................................................... minutes.

How do you rate the difficulty to follow topics that cover drug mechanisms of action in a pharmacology lecture?

☐ Very Easy
☐ Easy
☐ Neutral
☐ Difficult
☐ Very Difficult

Did you use the e-tools (computer animation) that were uploaded at L@G for the Human pharmacology I course?

☐ No, please explain the reason/s:.................................................................
☐ Yes, please proceed to respond to the following questions.
Did you access the complete set of the uploaded e-learning tools?

☐ Yes

☐ If no, please indicate the e-learning tools you accessed according to the drug classes……………………………………………………………………
………………………………………………………………………………
………………………………………………………………………………
…………..……………………………………………………………………

How often you accessed the e-learning tools:

☐ Daily

☐ Weekly

☐ Only before quizzes and exams

Did you use the feedback forms and/or the quizzes uploaded with the e-learning tools?

☐ No

☐ Yes, I used the feedback form

☐ Yes, I used the quizzes.

☐ Yes, I used both

Did you find the e-learning tools useful and helped in your study and preparation for the exams?

☐ No, please indicate the reason/s…………………………………………
………………………………………………………………………………
………………………………………………………………………………
…………..……………………………………………………………………

☐ Yes, please explain in what way you think the e-learning tools helped in your study…………………………………………………………………………
………………………………………………………………………………
………………………………………………………………………………
………………………………………………………………………………

Did you find the uploaded quizzes useful and helped in your study?

☐ No, please indicate the reason/s…………………………………………
………………………………………………………………………………
………………………………………………………………………………
………………………………………………………………………………

☐ Yes, please explain in what way:…………………………………………
………………………………………………………………………………
………………………………………………………………………………
To what extent do you agree or disagree with the following statements?
Please tick where appropriate

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly agree</th>
<th>Agree</th>
<th>Neutral</th>
<th>Disagree</th>
<th>Strongly disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>I prefer to use computer animation tools that give me flexibility in learning at your own time, location and pace?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Replace normal face-face pharmacology lectures that concern drug mechanisms of action by computer animation tools which cover the same topics?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Using computer animations is a useful tool for learning the basic principles of a drug’s mechanism of action?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Using computer animations will assist you more in understanding drug mechanisms of action?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Using computer animations will change the way you recall information?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Please tick where appropriate:

<table>
<thead>
<tr>
<th>Format for learning the course content for pharmacology, you will choose:</th>
<th>Computer animations</th>
<th>Conventional printed text</th>
<th>Both formats</th>
</tr>
</thead>
<tbody>
<tr>
<td>Text (words)</td>
<td></td>
<td>Illustrations (pictures)</td>
<td>Both</td>
</tr>
<tr>
<td>When you study drugs’ mechanisms of action, do you study the text or illustrations (pictures)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**To help us in assessing the benefit of long-term retention recall, please answer the following two questions to the best you can:**

Q1. Which one of the following statements regarding **Levodopa** is TRUE:

a. Levodopa cannot cross the blood-brain barrier.

b. Levodopa undergoes a decarboxylation process within the presynaptic terminals of dopaminergic neurons in the *substantia nigra* to produce dopamine.

c. Levodopa undergoes a decarboxylation process within the intestinal mucosa and other peripheral sites to produce dopamine. The produced dopamine is important to treat Parkinson disease symptoms.

d. Levodopa binds directly to the dopamine receptors in the *substantia nigra*, which produces its effect to treat Parkinson disease symptoms.

e. All of the above are wrong.

Q2. Briefly explain **Escitalopram’s** mechanism of action.

……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………

<table>
<thead>
<tr>
<th>When you answered the previous two questions, how did you attempt to recall the mechanisms of action?</th>
<th>Text (words)</th>
<th>Illustrations (pictures)</th>
<th>Both</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Thanks for your help in this research project.*
Appendix D

Student Performance Study

A Comparative Study to Evaluate the Educational Impact of e-Learning Tools on Griffith University Pharmacy Students’ Level of Understanding Using Bloom’s and SOLO Taxonomies.

STATEMENT OF CONTRIBUTION TO CO-AUTHORED PUBLISHED PAPER

This article was submitted to the Higher Education Journal on 11/06/2013 for publication. The authors of the paper are: Abdullah Karaksha, Gary Grant, S. Niru Nirthanan, Andrew K. Davey, Shailendra Anoopkumar-Dukie

My contribution to the paper involved: designing and conducting the study, collecting the data, analysing and categorizing the data and providing direction on the scope and structure of the analysis. I also wrote the first draft, made revisions responding to supervisor comments and feedback, prepared the final document, and forwarded it to the corresponding author for submission.

(Signed) _________________________________  (Date) 26th July 2013
Abdullah Karaksha

(Countersigned) ___________________________ (Date) 26th July 2013
Corresponding author of paper: Dr. Shailendra Anoopkumar-Dukie

(Countersigned) ___________________________ (Date) 26th July 2013
Supervisor: Dr. Gary Grant
A Comparative Study to Evaluate the Educational Impact of e-Learning Tools on Griffith University Pharmacy Students' Level of Understanding Using Bloom’s and SOLO Taxonomies.

Abdullah Karaksha¹, Gary Grant¹, S. Niru Nirthanan²,³, Andrew K. Davey¹, Shailendra Anoopkumar-Dukie¹.

1. School of Pharmacy, Griffith University, Queensland, AUSTRALIA
2. School of Medical Science, Griffith University, Queensland, AUSTRALIA
3. School of Medicine, Griffith University, Queensland, AUSTRALIA

Abdullah Karaksha: BPharm, MMed Research (Clinical Pharmacy), PhD candidate.
Gary Grant: BPharm, PhD, Grad Cert Higher Education.
S. Niru Nirthanan: MBBS, PhD
Andrew K. Davey: BPharm (Hons), PhD, PGCertTertT.
Shailendra Anoopkumar-Dukie: BSc (Hons), MSc, PhD, Grad Cert Higher Education.

Corresponding author: Dr. Shailendra Anoopkumar-Dukie
School of Pharmacy, Griffith University, Gold Coast Campus, Queensland, Australia.
Office number: +61 755 52 7725
Fax number: +61 755 52 8804
Email address: s.dukie@griffith.edu.au

Keywords: e-learning tools, pharmacology education, Bloom’s revised taxonomy, SOLO taxonomy.
Abstract

Aim: The aim of this study was to design a series of e-learning tools within the framework of a defined educational pedagogy to complement the conventional pharmacology curriculum at Griffith University and evaluate the impact of this strategy on student level of understanding through taxonomic classification of student final exam answers.

Methods: A series of 148 customised animation and narration e-learning tools was designed for 3rd year undergraduate pharmacy students and incorporated into their curriculum during semesters one and two of 2012. The educational benefits of the e-learning tools were evaluated by analyses of student level of understanding (by SOLO taxonomy) at the final exams between the control group (standard curricula) in 2011 and the intervention group (standard curricula + e-learning tools) in 2012.

Results: Backward linear regression analysis, performed to model the level of student understanding while controlling for possible confounding variables during each individual semester, demonstrated GPA to be the most significant predictor of level of understanding; while the intervention group was a highly significant predictor for greater level of understanding in semester two.

Conclusion: E-learning tools appeared to significantly improve student level of understanding as scored by the SOLO taxonomy when students engaged highly with the tools.
Introduction:
The scholarship of learning and teaching (SoLT) involves research into practices of teaching, learning and curriculum. SoLT’s main principle is that effective teachers in higher education should engage in scholarly teaching practices as a matter of course, by staying in touch with the latest research developments in their discipline, integrating these developments into their curriculum, and routinely gathering and using student feedback to guide curriculum review and improvement. SoLT research focuses on understanding student learning in order to improve the teaching and learning experience for participants (Buckridge et al. 2010; Boyer 1991; Grauerholz and Zipp 2008). One area in which SoLT principles are particularly important is pharmacology education, because it entails rich content involving many drugs and drug mechanisms of action, numerous detailed facts about drug classes and individual compounds, and even the diseases for which the various drugs are used (Michel et al. 2002). Moreover, students perceive pharmacology as a more “difficult” learning area than other subjects in the undergraduate curriculum (Wang et al. 2012). Consequently, teaching pharmacology curricula to students has been a challenge (Badyal et al. 2010; Halliday et al. 2010) and up-to-date teaching methods, such as e-learning tools, have been proposed to keep the students engaged in the content (Michel et al. 2002). E-learning tools have been shown to assist academics and educators to meet the growing needs and expectations for improving the quality of pharmacology education (Candler et al. 2007; Walley et al. 1994; O'Shaughnessy et al. 2010). They have a number of advantages to students that help educators promote learning and improve education quality. Students can access e-learning tools at their preferred times, which help them have active learning experiences and engages them in the learning process (Maxwell 2012). Moreover, some studies have found that e-learning tools help students undertake a deep learning approach and progress into independent life-long learners (Buckridge et al. 2010; Pahinis et al. 2007; Hughes 2002; Hughes 2003). Further, a large body of research suggest that this progression is essential for successful teaching (Martin et al. 2002; Ramsden 2003; Biggs and Tang 2007b).

Yet, while e-learning tools offer a number of inherent features such as flexibility in place and time for learning, adaptability to diverse learning styles and paces of the students, or scalability to rising student numbers, their use remains limited (MacLean et al. 2011). This may be due to miscommunication between e-learning tool developers and the educators who make decisions about their use, economic factors such as high costs and
time requirements for the development of e-learning tool content, the paucity of knowledge regarding how to effectively integrate e-learning tools into higher education curricula and, perhaps most importantly, a lack of consensus in the scholarly literature on e-learning tool effectiveness (Berman et al. 2008; Masters and Ellaway 2008; Yelland et al. 2008). Assessment of student level of understanding is possible using taxonomic classification of exam answers; however, to the best of our knowledge, no study has employed this approach to evaluate the effect of e-learning tools within higher education sector thus far. Therefore, it would appear that no higher education study has followed a holistic approach to evaluate the impact of technology on student learning, which might have contributed to the overly cautious implementation of e-learning tools in higher education settings (Berman et al. 2008). Hence, there is a need for further scholarly research to overcome these challenges and maximise the potential of e-learning tools.

Our team has aimed to address some of these issues by designing a series of e-learning tools to complement the delivery of pharmacology content within the framework of a defined pedagogy and to evaluate the impact of our e-learning tools on student level of understanding through taxonomic classification of student final exam answers. We chose to analyse student level of understanding in a summative assessment that contributed significantly to the course grade. The Human Pharmacology I and II final exams contained multiple choice questions (MCQs), short answer questions (SAQs) and long answer questions (LAQs); however, because the examination questions were not identical in each course, Bloom’s revised taxonomy was used to classify the SAQs and LAQs according to appropriate knowledge and cognitive dimensions and to ensure that the assessments were of comparable standard. Bloom’s revised taxonomy has been used by educators to provide similarity to the purpose of the activities and assessments that reveal whether the objectives of the course have been achieved by students (Chyung and Stepich 2003; Halawi et al. 2009).

Further, we aimed to assess student level of understanding in each question, instead of quantifying their performance by exam scores. The Structure of the Observed Learning Outcome (SOLO) taxonomy was therefore chosen as an evaluation rubric to qualitatively analyse student level of understanding for the short and long answer exam questions. SOLO provides a consistent framework through which to evaluate student responses and has been widely used in educational research as a means of determining the complexity
and depth of student learning outcomes (Chan et al. 2002). SOLO is a hierarchical model that is suitable for measuring learning outcomes of different kinds of subjects, among different levels of students and for all lengths of questions (Chan et al. 2002). Several researchers who have applied SOLO into their studies value both the comprehensiveness and the objectivity of the criteria provided for measuring students’ cognitive attainment and the degree of deep learning that has occurred throughout a course (Taylor et al. 2007; Taylor and Cope 2007; Holmes 2005).

This study also intended to evaluate the educational benefits of in-house designed e-learning tools that were embedded as supplements to the standard pharmacology curricula. The e-learning tools were implemented during semesters one and two of 2012 and student performance in terms of level of understanding (scored using SOLO taxonomy) was compared to the previous academic year (2011) where students received their pharmacology content solely through the standard curriculum. Our overarching goal of this research is to apply SoLT principles to improve the pharmacology courses we teach, and the study has the potential to achieve this by providing a framework for standardising the evaluation of student performance, determining student level of understanding, and improving students’ learning experiences.
**Methodology:**

This study was conducted at the School of Pharmacy, Griffith University, Gold Coast campus, Australia. A suite of 83 e-learning tools (first set) was designed for the third year Human Pharmacology I course in semester one - 2012 and 65 e-learning tools (second set) for the Human Pharmacology II course in semester two - 2012. These are both 13 week courses normally delivered by means of three hours of didactic teaching per week and weekly tutorials and laboratories totalling 2 to 4 hours. The e-learning tools covered the mechanisms of action for the majority of drug classes in the 3rd year pharmacology curriculum and supplemented the usual delivery of this content.

To evaluate the educational benefits of the e-learning tools, our team conducted a comparative study that consisted of two academic cohorts as well as two phases. The two academic cohorts were as per the following: third year pharmacy students who studied the standard Human Pharmacology I and II curricula in 2011 (control group) and those who studied the standard curricula, and in addition received supplemented e-learning tools in 2012 (intervention group). The first phase of the study was to invite students, from both groups, to participate in a survey while the second phase was to evaluate and compare student level of understanding (based on SOLO taxonomy) during the final exams between the two groups. Ethical approval was granted by the Griffith University Human Ethics Committee (protocol PHM/05/10/HREC).

**Survey design and pilot testing:**

To evaluate baseline student attributes in semester one, a paper-based survey was designed according to previous studies that examined student preference towards technology (Taplin et al. 2011; MacLean et al. 2011; Euzent et al. 2011; Chen et al. 2010) and obtained demographic data including gender, the Grade Point Average (GPA), frequency of attending lectures, and difficulty of understanding topics that cover drug mechanisms of action.

As students from the control group in 2011 did not use the customised e-learning tools designed and implemented specifically for the purpose of this study, the survey examined student preference for technology, using a general term namely: online-learning tools, by way of a five-point Likert scale (strongly agree, agree, no comment, disagree and strongly disagree). Student learning style was assessed by asking students whether they remember
E-learning tool design and implementation:
Custom animations were sequenced in Microsoft PowerPoint 2010 and narration was added using iSpring Pro 6.1.0 to both produce the embedded animation and to convert the animations into a Flash format for ease of delivery through Blackboard (Karaksha et al. 2011). Participants could easily control the speed of the final e-learning tools, skip content, and move forward and backward as needed to revisit specific concepts. The first and second sets of e-learning tools were made available to students who enrolled in the Human Pharmacology I and II courses in 2012 via the course websites in Griffith University’s Blackboard interface. We made the e-learning tools available to students before the first major assessment item (mid-semester exam).

Student recruitment:
The control group (2011)
The course convenor approached students who enrolled in the Human Pharmacology I course (semester one – 2011) to explain the study aims and objectives. The students were then invited to participate in the first phase of the study and undertake the survey. Students who expressed interest to continue to the second phase of the study were instructed to tick a designated box that appeared on their exam paper. This box indicated their consent for the research team to evaluate their exam answer booklets for both Human Pharmacology...
courses I and II in 2011. The exam booklets were de-identified and coded to keep student participation anonymous. In each phase, students were advised that their participation was completely voluntary and would not affect their academic standing or course grades.

The intervention group (2012)
The course convenor approached students who enrolled in the Human Pharmacology I course (semester one – 2012) in the introductory lecture to explain the study aims and objectives. The students were also informed about the e-learning tools and the method to access them through the Blackboard. Student engagement with the e-learning tools during semester one and two was reported previously (Karaksha et al. 2013a); the study demonstrated significant difference in student usage of e-learning tools between both semesters. The students accessed the e-learning tools more often in semester two after receiving multiple reminders through emails and announcements.

The students were then invited to participate in the first phase of the study and undertake the survey to obtain their demographic data and attitude towards online-learning tools. As in the control group, students who expressed interest to continue in the second phase of the study were instructed to tick the designated box that appeared on their exam paper, which indicated their consent for the research team to evaluate their exam answer booklets for both Human Pharmacology courses I and II in 2012. The exam booklets were de-identified and coded to keep student participation anonymous. As in the control group, students were reminded in each phase that their participation was completely voluntary and would not affect their academic standings.

Demographic data.
Demographic data were obtained from participants through two resources. Students who participated in phase one of the study self-reported their demographic information via the survey. Demographic data were also consensually obtained from university records for the students who chose to participate in the second phase of the study.

Exam questions classification and scoring procedure
To evaluate the educational benefit of the e-learning tools, student level of understanding in the final exams was evaluated using the SOLO taxonomy and compared between the control and the intervention groups. As the e-learning tools were designed to explain drug
mechanisms of action, we only evaluated the questions that concerned drug mechanisms of action. A reference question which covered drug mechanisms of action but for which no e-learning tool was designed was also evaluated as a negative control. To compare the short and long answer questions between the two groups in the semester one and semester two final exams, our team used Bloom’s revised taxonomy to classify the questions according the appropriate knowledge and cognitive dimensions (Anderson et al. 2001). Then we grouped the questions that examined for the same level of knowledge and cognitive dimensions to ensure valid comparisons between different exam questions. Bloom’s revised taxonomy can be used to classify the questions in categories according to what they examine. This can be the knowledge dimension (four levels): factual, conceptual, procedural, and metacognitive knowledge; and the cognitive dimension (six levels): remember, understand, apply, analyse, evaluate and create (Anderson et al. 2001). However, the highest levels of the taxonomy namely: metacognitive knowledge, evaluate, and create are not usually examined within the undergraduate level (Amer 2006).

To evaluate student level of understanding in the short and long answer questions, SOLO taxonomy was used to classify each student’s exam responses. This taxonomy consists of five levels of increasing structural complexity: pre-structural, uni-structural, multi-structural, relational and extended abstract (Biggs and Tang 2007a). SOLO taxonomy has been used successfully by other researchers to measure cognitive learning outcomes and qualitatively evaluate student performance in different courses among different levels of students (Bhattacharyya et al. 2012; Shea et al. 2011; Taylor et al. 2007; Biggs and Tang 2007a). Description of the scoring system is available in Table 1.

This process was pilot tested by our team (Karaksha et al. 2013b) and a validation process was followed to ensure consistency in evaluating student responses. Student answers were checked against the SOLO taxonomy criteria by the main investigator and two senior pharmacology lecturers with post-graduate educational qualifications. A meeting was set up to reach a consensus for student answers that were given inconsistent SOLO levels between the markers.
Data analysis:

To evaluate the survey results, a number of quantitative analyses were undertaken. Demographic data including gender, GPA, and English as first language, as well as student preference for technology and learning style, were compared between the students from the control and intervention groups using t-tests and chi-squared tests. Participant attitudes towards the technology were assessed by way of a 5-point Likert scale (strongly agree, agree, no comment, disagree, and strongly disagree); however to improve sample size per group, these categories were collapsed into three types of response: “positive,” “neutral,” and “negative” responses. Student level of understanding in short and long answer questions was scored according to SOLO taxonomy and SOLO scores were compared between the two groups using t-tests. Backward linear regression analysis was performed to model student level of understanding, using the demographic data variables (age, gender GPA, domestic/international and group) and control/intervention group. The effect of e-learning tools usage on student level of understanding for the intervention group was assessed by correlation analysis. Power analysis using Russ Lenth’ power applet showed that we had at least 80% power to detect one standard deviation difference in the means for all t-test analyses. However, we had only 76% power to detect a difference of 15% in proportions between groups for the chi-squared analyses for student preference (Lenth 2006). All statistical analyses were performed using IBM SPSS software (v 20). Probability (p) values of less than 0.05 were considered statistically significant.
Results
A total of 118 students were enrolled in Human Pharmacology I course in the year 2011 compared to 82 in 2012. Fifty five (47%) students participated in the survey from the year 2011 compared to 43 (53%) from the 2012 cohort. There was no significant difference between the two groups in the demographic data (Table 2; p > 0.05). Students were also asked to indicate their studying habits for the Human Pharmacology courses (Table 2). No significant difference was seen in the number of students who read through the lecture notes before attending lectures ($\chi^2 = 1.2, p > 0.05$). The level of difficulty in understanding course content responses were divided between easy, neutral or difficult, with no significant difference between the groups. Finally, participants were asked to indicate their attendance behaviour at Human Pharmacology lectures. There was no significant difference between the groups; only a small percentage (12%) of students rarely attended lectures with the majority (88%) either frequently or always attending.

Student attitudes towards online-learning tools were also analysed and compared between the groups (Table 3). The results demonstrated, in general, positive preference for the online-learning tools. Significantly more students from the intervention group were positive towards the benefit of the online learning tools for understanding the mechanism of action concepts and for changing their learning style, compared to the control group (p < 0.05). However, the majority (79%) of students from both groups were either negative or neutral regarding the substitution of traditional didactic lectures with online-learning tools.

A total of 78 students consented to participate in the second phase of the study, with 53 (45%) students from the control cohort (2011) and 25 (31%) from the intervention cohort (2012). The demographic data of those participants were obtained from the university records to ensure accuracy (Table 4). Statistical analysis for demographic data showed no significant difference between the two groups in any of the comparisons. However, the difference in the gender variable approached significance (p = 0.07), as more females participated in the control group.

Student level of understanding for the semester one exam (Human Pharmacology I) was scored according to SOLO taxonomy and compared between the e-learning tool and control groups. Table 5 shows SOLO scoring for both overall performance and for
individual questions classified by Bloom’s revised taxonomy. Students from the intervention group significantly outperformed their peers from the control group in question one, which examined the factual and procedural knowledge domain in addition to recall and understanding from the cognitive domain. One question was repeated in both years’ exams (digoxin) and students from the intervention group outperformed the students from the control group, with the difference approaching significance \( p = 0.059 \). On the other hand, there was no significant difference between the control and intervention group when answering the reference exam question (no e-learning tool was designed to cover this question).

One student from the control group and two students from the intervention group failed in the Human Pharmacology I course and were not able to proceed to study the Human Pharmacology II course in second semester. Table 6 shows SOLO scoring of student level of understanding for the semester two exam (Human Pharmacology II), again for both, overall performance and for individual questions classified by Bloom’s revised taxonomy. Students from the intervention group performed better than the control group when comparing the overall level of understanding, with the difference approaching significance \( p = 0.08 \). Moreover, four questions on specific drugs were repeated in both years’ exams; participants from the intervention cohort outperformed the control group, with a significant difference \( p = 0.02 \) and \( p = 0.04 \) for two out of the four questions. Finally, students from the control group performed significantly better \( p = 0.002 \) in the reference exam question for which there was no e-learning tool (question 8), which examined the factual and procedural knowledge domain in addition to understanding and analyses from the cognitive domain.

There was no significant decrease in level of understanding in the intervention group while there was a significant decrease in the control group (Table 7). Figure 1 demonstrates that the decrease in the level of understanding for the intervention group was significantly less than the control cohort.

To model the level of student understanding while controlling for possible confounding variables, we performed backward linear regression analysis, separately, for each semester. For semester one, four models were generated with the most significant model \( p = 1.67 \times 10^{-8} \) containing the variables intervention group (control vs intervention) and
GPA, with the variables domestic/international, age, gender removed from the model. This model explained approximately 38.4% of the variance in semester one level of understanding ($R^2 = 0.384$), with $GPA$ as the most significant predictor of level of understanding ($\beta = 0.39; p = 3.79 \times 10^{-9}$) and intervention group approaching significance as a predictor of level of understanding ($\beta = 0.17; p = 0.09$). Student status (domestic or international), age, and gender were not shown to be significant predictors ($p > 0.2$). For semester two, again, the model containing the variables intervention group and $GPA$ was the most significant of the four models generated ($p = 1.52 \times 10^{-6}$). This model explained approximately 31.1% of the variance in semester two level of understanding ($R^2 = 0.311$). Again, $GPA$ was the most significant predictor of level of understanding ($\beta = 0.39; p = 1.18 \times 10^{-6}$); however, intervention group was also shown to be a highly significant predictor for semester two ($\beta = 0.344; p = 0.009$). Students who used the e-learning tools had an increase of about 0.35 in their total level of understanding SOLO score. This may be because student uptake of the e-learning tools was significantly higher in semester two than semester one, showing the significant effect of the e-learning tools on student level of understanding in semester two. This was supported by correlation analysis of student level of understanding in the intervention group and e-learning tools usage (Figure 2). In both semesters, a strong positive correlation was observed; however in semester one the correlation was 77% compared to 88% in semester two.
Discussion
Our team was able to successfully develop and embed 148 e-learning tools designed to meet our pharmacology curriculum’s learning objectives and underpinned by relevant teaching theories, using commercially available software packages such as iSpring Pro and PowerPoint. The advantage of these e-learning tools designed and developed in-house is that, in addition to the explicit alignment in their content and context with our curriculum, educators can easily update content to match evolving course learning objectives or changed practices, unlike commercially available tools developed by trained programmers using complex software packages.

Student preference towards the application of technology into their learning and teaching experience were uniformly positive among the majority of students from both groups (67%). Although students from the control group did not have the opportunity to use our e-learning tools, the majority were positive that technology would be useful for learning and understanding the difficult concept of drug mechanisms of action based on the limited experiences in accessing material available on the internet. A similar trend was found from a pilot e-learning tools study that examined nursing students preference within Griffith University (Karaksha et al. 2013b). These findings corroborate evidence that university students have positive preference towards technology and high expectations for technology to be part of their learning experiences (Berman et al. 2008; Yelland et al. 2008; Prensky 2009). However, while our students had positive preference for technology, the majority (79%) were either neutral or not in favour of the substitution of didactic lectures entirely with online-learning tools. Thirunarayanan et al (2011) confirmed this finding in their report by stating that 70% of participants in their study preferred to attend traditional face-to-face lectures (Thirunarayanan et al. 2011). Others have found that students still consider face-to-face discussions with lecturers and peer interaction in the classroom as critical to their learning success (Lohnes and Kinzer 2007; Garcia and Qin 2007). Thus, e-learning tools may be most successful when implemented as supplement to face-to-face teaching.

To analyse the benefit of e-learning tools, we used Bloom’s revised taxonomy to classify the questions according the knowledge and cognitive dimensions they examine for and then scored student level of understanding using SOLO taxonomy when attempting the questions. Overall, it appeared that the e-learning tools had a significant effect improving
Demographic variables such as gender, GPA, age and background have been shown to influence exam performance/level of understanding. Previous research suggested that males usually have positive experience with technology while females do not like to learn from computers and prefer person-to-person learning (Ausburn et al. 2009; Johnson 2011). Other research has suggested that age could impact student performance and interaction with technology (Willey et al. 2008). Thus, we analysed demographic variables in our participants to ensure that there were similar characteristics of students in all groups and found that there were no significant differences in the distribution of the key demographic variables between groups. We also modelled the level of student understanding while controlling for these possible confounding variables by performing backward linear regression analysis for each semester. This analysis demonstrated that age, gender, and background did not have a significant effect on level of understanding. However, the analysis confirmed that GPA did significantly affect student level of understanding, conforming to the widely accepted conclusion that GPA is a strong
indicator of academic performance (Willey et al. 2008; Sonnert and Fox 2012). However, in our study, GPA alone did not account for the improvement in students’ level of understanding, as the e-learning tools were also found to be a significant predictor for student level of understanding. Thus, the benefit of e-learning tools still remained even when student GPA was taken into account.

E-learning tools also appeared to mitigate the effect of a decrease in understanding as students move on from a less complex course (Human Pharmacology I, semester one) to a more complex course (Human Pharmacology II, semester two). It is commonly acknowledged that academics should not challenge students with difficult concepts at the start of their courses (Norton 2009); and instead, the focus should be to introduce them to the environment of the course and then include the difficult content in the final stages of the course (Norton 2009). Therefore, the Human Pharmacology curriculum has been structured to start from simple modules in Human Pharmacology I, in order to build student knowledge, and then proceed to more complicated and complex modules involving processes and mechanisms in Human Pharmacology II. A typical example of a more complex module is the mechanism of cancer drugs in the semester two Human Pharmacology II course, where students usually struggle to digest the mechanism of action. Thus, we expected to observe an overall drop in the student level of understanding of content from semester one as compared to content from semester two, given that semester two was a more complex course. Although, in general, a decrease in understanding was observed for both groups only the decrease in level of understanding among the control cohort was found to be statistically significant. Further, students from the control group achieved only a uni-structural level of understanding when answering questions related to cancer drugs in semester two, while students from the intervention group scored a higher level of understanding. This further supports the benefit of e-learning tools on student level of understanding when students move from introductory courses to more complex courses in the same field.

However, the significant impact of the e-learning tools was only observed when student engagement with the e-tools was at high levels. For instance, in semester one, the total level of understanding was not significantly different between the groups; however, analysis of student engagement with the e-learning tools revealed low level of usage and engagement. This was because students either forgot or did not have time to access the
tools (Karaksha et al. 2013a). This was addressed in semester two, by constantly reminding the students about the e-tools throughout the semester, which led to a significantly higher engagement with the e-learning tools in semester two (Karaksha et al. 2013a). The increase in student engagement with the e-learning tools was reflected in their level of understanding; students from the intervention group outperformed their peers from the control group in every short answer question reinforced by e-learning tools. This was also confirmed by further analysis which showed strong positive correlation between e-learning tool usage and student level of understanding in the exam. A previous study reported a similar conclusion by showing a strong relationship between study materials usage and exam performance (Nieder et al. 2011).

To conclude, this study evaluated the effects of a set of in-house designed e-learning tools, embedded as supplements to standard pharmacology curricula in semester one and two, and found a number of significant benefits for student learning. E-learning tools appeared to significantly improve student level of understanding as scored by the SOLO taxonomy when there was substantial engagement of students with the e-tools. We also found that e-learning tools appeared to mitigate the decrease in student understanding observed when students progress into more complex courses. E-learning tools also showed the capacity to cater for different learning styles and to improve retention. The study also demonstrated that a holistic approach underpinned by educational pedagogy could be employed to objectively evaluate the impact of technology on student learning, effectively comparing different student cohorts using Bloom’s revised taxonomy to classify exam questions into common learning dimensions, and using SOLO taxonomy scoring to evaluate student level of understanding instead of simply exam grades. Our approach and findings contribute to the scholarship of learning and teaching (SoLT) in relation to e-learning tools, and may potentially enhance both pharmacology and other courses by providing a framework on standardising the evaluation of the impact of online learning strategies on student performance and learning experiences.

**Acknowledgements**
The authors would like to acknowledge the role of third year pharmacy students – 2011 cohort for undertaking the study survey and 2012 cohort for using the e-learning tools and participating in the study survey. The authors would like to thank the faculty of
Griffith Health at Griffith University for providing the blended learning grant that funded this work.

Reference


Table 1: SOLO scoring system.

<table>
<thead>
<tr>
<th>SOLO score</th>
<th>SOLO level descriptor</th>
</tr>
</thead>
<tbody>
<tr>
<td>0. No answer</td>
<td>No answer, or there are written words, but not relevant to the question.</td>
</tr>
<tr>
<td>1. Pre-structural</td>
<td>Here students do not have any kind of understanding but use irrelevant information and/or miss the point altogether. Scattered pieces of information may have been acquired, but they are unorganized, unstructured, and essentially void of actual content or relation to a topic or problem</td>
</tr>
<tr>
<td>2. Uni-structural</td>
<td>Students can deal with one single aspect and make obvious connections. Students can use terminology, recite (remember things), identify names, etc.</td>
</tr>
<tr>
<td>3. Multi-structural</td>
<td>At this level students can deal with several aspects but these are considered independently and not in connection. Metaphorically speaking, the students see the many trees, but not the forest. They are able to enumerate, describe, classify, combine, apply methods, structure, execute procedures, etc.</td>
</tr>
<tr>
<td>4. Relational</td>
<td>At level four, students may understand relations between several aspects and how they might fit together to form a whole. The understanding forms a structure. They may thus have the competence to compare, relate, analyze, apply theory, explain in terms of cause and effect, etc.</td>
</tr>
<tr>
<td>5. Extended abstract</td>
<td>At this level, which is the highest, students may generalize structure beyond what was given, may perceive structure from many different perspectives, and transfer ideas to new areas. They may have the competence to generalize, hypothesize, criticize, theorize, etc.</td>
</tr>
</tbody>
</table>

SOLO: Structure of the observed learning outcomes.
Table 2: Student demographic data and behaviour in the Human Pharmacology courses.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Control n = 55 (%)</th>
<th>Intervention n = 43 (%)</th>
<th>Statistic, p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gender</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female (n = 62)</td>
<td>37 (67)</td>
<td>25 (58)</td>
<td>$\chi^2 = 0.9$, $p = 0.35$</td>
</tr>
<tr>
<td>Male (n = 36)</td>
<td>18 (33)</td>
<td>18 (42)</td>
<td></td>
</tr>
<tr>
<td><strong>GPA</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Mean, SD)</td>
<td>5.4 ± 0.58</td>
<td>5.3 ± 0.62</td>
<td>$t = 0.8$, $p = 0.41$</td>
</tr>
<tr>
<td><strong>English as first language</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes (n = 70)</td>
<td>39 (71)</td>
<td>31 (72)</td>
<td>$\chi^2 = 0.01$, $p = 0.9$</td>
</tr>
<tr>
<td>No (n = 28)</td>
<td>16 (29)</td>
<td>12 (28)</td>
<td></td>
</tr>
<tr>
<td><strong>Prior lecture study</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes (n = 14)</td>
<td>6 (13)</td>
<td>8 (18)</td>
<td>$\chi^2 = 1.1$, $p = 0.3$</td>
</tr>
<tr>
<td>No (n = 83)</td>
<td>48 (87)</td>
<td>35 (82)</td>
<td></td>
</tr>
<tr>
<td><strong>Difficulty to follow topics that cover drug MOA</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Easy (n = 32)</td>
<td>17 (31)</td>
<td>15 (35)</td>
<td>$\chi^2 = 0.2$, $p = 0.9$</td>
</tr>
<tr>
<td>Neutral (n = 36)</td>
<td>21 (39)</td>
<td>15 (35)</td>
<td></td>
</tr>
<tr>
<td>Difficult (n = 29)</td>
<td>16 (30)</td>
<td>13 (30)</td>
<td></td>
</tr>
<tr>
<td><strong>Attend Pharmacology lectures</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rarely (n = 12)</td>
<td>9 (17)</td>
<td>3 (7)</td>
<td>$\chi^2 = 3.1$, $p = 0.21$</td>
</tr>
<tr>
<td>Frequently (n = 33)</td>
<td>20 (36)</td>
<td>13 (30)</td>
<td></td>
</tr>
<tr>
<td>Always (n = 53)</td>
<td>26 (47)</td>
<td>27 (63)</td>
<td></td>
</tr>
</tbody>
</table>

This table includes statistical comparisons of demographic data and student behaviour towards Human Pharmacology courses. No statistical significant difference was observed in any comparison. #: mechanism of action
Table 3: Student attitude towards online-learning tools.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Control n = 55 (%)</th>
<th>Intervention n = 43 (%)</th>
<th>Statistic, p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preference towards online-learning tools application in L&amp;T #</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Positive (n = 62)</td>
<td>31 (57)</td>
<td>31 (72)</td>
<td>$\chi^2 = 2.8, p = 0.25$</td>
</tr>
<tr>
<td>Neutral (n = 25)</td>
<td>16 (29)</td>
<td>9 (21)</td>
<td></td>
</tr>
<tr>
<td>Negative (n = 11 )</td>
<td>8 (14)</td>
<td>3 (7)</td>
<td></td>
</tr>
<tr>
<td>Online-learning tools are useful for learning MOA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Positive (n = 81)</td>
<td>46 (84)</td>
<td>35 (82)</td>
<td>$\chi^2 = 0.1, p = 0.95$</td>
</tr>
<tr>
<td>Neutral (n = 15)</td>
<td>8 (14)</td>
<td>7 (16)</td>
<td></td>
</tr>
<tr>
<td>Negative (n = 2)</td>
<td>1 (2)</td>
<td>1 (2)</td>
<td></td>
</tr>
<tr>
<td>Online-learning tools assist in understanding MOA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Positive (n = 77)</td>
<td>41 (74)</td>
<td>36 (84)</td>
<td>$\chi^2 = 7.0, p = 0.03$</td>
</tr>
<tr>
<td>Neutral (n = 16)</td>
<td>13 (24)</td>
<td>3 (7)</td>
<td></td>
</tr>
<tr>
<td>Negative (n = 2)</td>
<td>1 (2)</td>
<td>4 (9)</td>
<td></td>
</tr>
<tr>
<td>Online-learning tools change the learning style</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Positive (n = 49)</td>
<td>20 (37)</td>
<td>29 (67)</td>
<td>$\chi^2 = 9.3, p = 0.009$</td>
</tr>
<tr>
<td>Neutral (n = 38)</td>
<td>27 (49)</td>
<td>11 (26)</td>
<td></td>
</tr>
<tr>
<td>Negative (n = 11 )</td>
<td>8 (14)</td>
<td>3 (7)</td>
<td></td>
</tr>
<tr>
<td>Preference to replace traditional lectures with online-learning tools</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Positive (n = 21)</td>
<td>12 (22)</td>
<td>9 (21)</td>
<td>$\chi^2 = 0.14, p = 0.93$</td>
</tr>
<tr>
<td>Neutral (n = 22)</td>
<td>13 (24)</td>
<td>9 (21)</td>
<td></td>
</tr>
<tr>
<td>Negative (n = 55 )</td>
<td>30 (54)</td>
<td>25 (58)</td>
<td></td>
</tr>
<tr>
<td>Preference towards studying MOA format</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Animation (n = 15)</td>
<td>7 (13)</td>
<td>8 (19)</td>
<td>$\chi^2 = 5.5, p = 0.065$</td>
</tr>
<tr>
<td>Text (n = 11)</td>
<td>3 (5)</td>
<td>8 (19)</td>
<td></td>
</tr>
<tr>
<td>Both (n = 72)</td>
<td>45 (82)</td>
<td>27 (62)</td>
<td></td>
</tr>
</tbody>
</table>

This table includes statistical comparisons of preference towards online-learning tools between two groups: students who studied the standard pharmacology curricula (control) and those who studied the standard curricula + e-learning tools (intervention). #L&T: learning and teaching.
Table 4: Demographic data of the participants from the second phase.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Control n = 53</th>
<th>Intervention n = 25</th>
<th>Statistic, p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (Mean, SD)</td>
<td>24.2 ± 4.36</td>
<td>23.3 ± 6.24</td>
<td>t = 0.73, p = 0.43</td>
</tr>
<tr>
<td>GPA (Mean, SD)</td>
<td>5.2 ± 0.83</td>
<td>5.1 ± 0.80</td>
<td>t = 0.64, p = 0.52</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female (n = 48)</td>
<td>36 (68)</td>
<td>12 (48)</td>
<td>χ² = 3.2, p = 0.07</td>
</tr>
<tr>
<td>Male (n = 29)</td>
<td>16 (32)</td>
<td>13 (52)</td>
<td></td>
</tr>
<tr>
<td>Background</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Domestic (n = 69)</td>
<td>47 (89)</td>
<td>22 (88)</td>
<td>χ² = 0.1, p = 0.75</td>
</tr>
<tr>
<td>International (n =8)</td>
<td>5 (11)</td>
<td>3 (12)</td>
<td></td>
</tr>
</tbody>
</table>

This table includes statistical comparisons of demographic data between the two groups for the second phase participants.
Table 5: Student level of understanding in semester one exams.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Control n = 53</th>
<th>Intervention n = 25</th>
<th>Statistic, p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Factual + procedural knowledge and remember + understand</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q1 (2011) vs (2012)</td>
<td>2.6 ± 0.63</td>
<td>3.0 ± 0.64</td>
<td>t = - 2.1, p = 0.03</td>
</tr>
<tr>
<td><strong>Factual knowledge and understand + analyse</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q3 (2011) vs Q8 (2012)</td>
<td>3.2 ± 0.85</td>
<td>3.0 ± 0.79</td>
<td>t = 1.1, p = 0.26</td>
</tr>
<tr>
<td><strong>Factual + conceptual knowledge and understand</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q4 (2011) vs Q7 (2012)</td>
<td>1.9 ± 1.13</td>
<td>2.1 ± 0.83</td>
<td>t = - 0.9, p = 0.36</td>
</tr>
<tr>
<td><strong>Factual + conceptual knowledge and understand + analyse (Reference question - no e-tool)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q5 (2011) vs Q10 (2012)</td>
<td>3.2 ± 0.67</td>
<td>2.9 ± 0.64</td>
<td>t = 1.9, p = 0.06</td>
</tr>
<tr>
<td><strong>Factual + procedural knowledge and understand + analyse</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Digoxin 2011 vs 2012</td>
<td>3.5 ± 0.61</td>
<td>3.8 ± 0.72</td>
<td>t = 1.9, p = 0.059</td>
</tr>
<tr>
<td>Q12 (2011) vs Q5 (2012)</td>
<td>2.4 ± 1.15</td>
<td>2.8 ± 1.05</td>
<td>t = - 1.3, p = 0.21</td>
</tr>
<tr>
<td>LAQ⁰ (2011) vs (2012)</td>
<td>3.9 ± 1.11</td>
<td>4.0 ± 0.88</td>
<td>t = - 0.07, p = 0.95</td>
</tr>
<tr>
<td><strong>Total performance</strong></td>
<td>2.9 ± 0.52</td>
<td>3.0 ± 0.5</td>
<td>t = - 1.0, p = 0.32</td>
</tr>
</tbody>
</table>

This table includes statistical comparisons of student level of understanding in Human Pharmacology I course between the control and intervention groups as measured by SOLO taxonomy. Scoring ranges between 2 (uni-structural level) and 4 (relational level). #LAQ: long answer questions.
Table 6: Student level of understanding in semester two exams.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Control n = 52</th>
<th>Intervention n = 23</th>
<th>Statistic, p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Factual + procedural knowledge and remember + understand</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cytarabine 2011 vs 2012</td>
<td>2.2 ± 1.1</td>
<td>3.0 ± 1.4</td>
<td>t = -2.32, p = 0.02</td>
</tr>
<tr>
<td>Mitomycin C 2011 vs 2012</td>
<td>2.0 ± 1.1</td>
<td>2.4 ± 1.5</td>
<td>t = -0.98, p = 0.33</td>
</tr>
<tr>
<td>Trastuzumab 2011 vs 2012</td>
<td>2.1 ± 1.0</td>
<td>2.7 ± 1.3</td>
<td>t = -2.1, p = 0.04</td>
</tr>
<tr>
<td>Nitromidazole 2011 vs 2012</td>
<td>1.9 ± 1.1</td>
<td>2.3 ± 1.0</td>
<td>t = -1.2, p = 0.23</td>
</tr>
<tr>
<td><strong>Factual knowledge and understand + analyse</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q4 (2011) vs Q2 (2012)</td>
<td>2.3 ± 0.7</td>
<td>2.4 ± 0.8</td>
<td>t = -0.5, p = 0.62</td>
</tr>
<tr>
<td><strong>Factual + procedural knowledge and understand + analyse (Reference question - no e-tool)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q8 (2011) vs (2012)</td>
<td>3.3 ± 1.2</td>
<td>2.5 ± 0.6</td>
<td>t = 3.3, p = 0.002</td>
</tr>
<tr>
<td><strong>Factual + procedural knowledge and understand + analyse</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q7 (2011) vs Q6 (2012)</td>
<td>2.3 ± 0.7</td>
<td>2.7 ± 1.1</td>
<td>t = -1.7, p = 0.08</td>
</tr>
<tr>
<td>LAQ⁶ (2011) vs (2012)</td>
<td>3.7 ± 1.3</td>
<td>3.7 ± 1.1</td>
<td>t = -0.05, p = 0.96</td>
</tr>
<tr>
<td><strong>Total performance</strong></td>
<td>2.4 ± 0.6</td>
<td>2.7 ± 0.7</td>
<td>t = -1.8, p = 0.08</td>
</tr>
</tbody>
</table>

This table includes statistical comparisons of student level of understanding in Human Pharmacology II course between the control and intervention groups as measured by SOLO taxonomy. Scoring ranges between 2 (uni-structural level) and 4 (relational level). #LAQ: long answer questions.
Table 7: Student level of understanding (Total performance) between semesters.

<table>
<thead>
<tr>
<th>Group</th>
<th>Semester one</th>
<th>Semester two</th>
<th>Statistic, p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control (2011; n = 53 vs 52)</td>
<td>2.9 ± 0.52</td>
<td>2.4 ± 0.6</td>
<td>t = 4.6, p = 0.001</td>
</tr>
<tr>
<td>Intervention (2012; n = 25 vs 23)</td>
<td>3.0 ± 0.5</td>
<td>2.7 ± 0.7</td>
<td>t = 1.7, p = 0.09</td>
</tr>
</tbody>
</table>

This table includes statistical comparisons of the decrease in student level of understanding.
Figure 1: Decrease in student level of understanding between the semester one course (3024PHM) and semester two course (3028PHM). Error bars represent the standard error of mean.
Figure 2: Scatterplots showing the number of hits on e-learning tools and student level of understanding in the related questions. (A) for the course 3024PHM (semester one – 2012). (B) for the course 3028PHM (semester two – 2012). Student level of understanding is categorised according to SOLO taxonomy into five levels: 1. pre-structural, 2. uni-structural, 3. multi-structural, 4. relational, 5. extended abstract.
Appendix E
USB Flash Drive

The USB contains examples of the following:

- 3rd generation e-learning tools,
- Feedback forms that allowed students to send anonymous comments
- Short-term retention quizzes