Pharmacy Education, 2017; 17 (1) 159 - 166

Student pharmacists' perceptions of the difficulty of topics and preferences for learning tools for incorporation in a mobile application for reinforcement of the Pharmaceutical Biochemistry course content

MELANY P. PUGLISI[1*], MICHAEL NOLAN[1], TATJANA PETROVA[2], TAUSEEF SALIM[1], ANNA RATKA[1]

[1]*Department of Pharmaceutical Sciences, College of Pharmacy, Chicago State University, Chicago, Illinois 60628, USA*

[2]*Department of Pharmacy Practice, College of Pharmacy, Chicago State University, Chicago, Illinois 60628, USA*

Abstract

There is interest in implementing new technology in the pharmacy professional curriculum. The objectives of this study were to: (1) assess the perceived level of difficulty of topics in Pharmaceutical Biochemistry in the Pharm.D programme; and (2) assess the student perceptions of what learning methods can be used to reinforce the course material. A 32 item questionnaire using a five-point Likert scale (least to most difficult) was administered to 240 professional students. Section A asked respondents to rate the level of difficulty of the topics taught in the course. Section B asked respondents to choose learning methods for reinforcing lectures. Protein structure and non-covalent bonding were rated easier while carbohydrates, glycolysis, cell signaling, RNA, DNA and biotechnology were rated as more difficult. Students chose practice quizzes for all topics. The results demonstrate that respondents perceive practice quizzes, animation, flash cards and 3D models as useful tools.

Keywords: *Pharmacy Education, Student Perceptions, M-Learning, Biochemistry*

Introduction

Blended learning is a hybrid form of learning that combines a traditional classroom atmosphere with an electronic learning (e-learning) or mobile learning (m-learning) component. Mobile learning, where students access course materials via cell phones, tablets, or laptop computers, has become an important tool from pre-kindergarten to graduate level education (Ruth *et al.*, 2013). The use of mobile devices allows students easy access and more exposure to course information at their convenience. This is usually an independent process that occurs without significant guidance from the instructors (Martin *et al*., 2011). The purpose of blended learning is to supplement and reinforce the information that is conveyed in class. Blended learning, when properly used in the curriculum, can aid student learning and success in many academic settings (Williams, 2002). Pereira and colleagues reported that the use of blended learning increased the pass rate from 71.4% to 81.9% for students in human anatomy classes (Pereira *et al*., 2007). Interactive digital images and online quizzes have been used to successfully help students with pharmaceutical calculations (Fox *et al*., 2007).

According to Capretz & Alrasheedi (2013) the critical factors for success with mobile applications in blended learning include: user friendly design, technical competence, learner community development, learner perceptions, content, and ownership. Several studies have addressed the interest of students in the adoption of a mobile learning platform (Al-Fahad, 2009; Chuttur, 2009; Alzaza & Yaakub, 2011; Capretz & Alrasheedi, 2013; Chen & Denoyelles, 2013; Ruth *et al*., 2013). Student perceptions of mobile learning are varied, complex and multifactorial. Seventy-four percent of students at the United States (US) Naval Academy and 61% of students at the US post-naval graduate school said that they would use mobile learning opportunities if offered (Chen & Denoyelles, 2013). Alzaza & Yaakub (2011) reported that over 50% of students stated that mobile learning services improved students' ability to study. Most students believe that mobile learning can give them instant feedback and provide the ability to study anytime or anywhere (Capretz & Alrasheedi, 2013). The technology acceptance model states that for actual system use several conditions must be met including perceived usefulness and perceived ease of use (Al-Fahad, 2009). Student perceptions are not always taken into consideration during the development of a mobile learning tool. This can lead to the lack of acceptance by the students (Chuttur, 2009). Developing a learning tool that reflects the course curriculum can direct and guide students, promoting better adaptation of the platform.

[*]Correspondence: Melany P. Puglisi, *Department of Pharmaceutical Sciences, College of Pharmacy, Chicago State University, Douglas Hall 206, 9501 South King Drive, Chicago, IL 60628, USA. Phone: +1 773 821 2163; Fax: +1 773 821 2595. Email: mpuglisi@csu.edu*

ISSN 1447-2701 online

The use of blended learning in biochemistry is not novel. The use of molecular visualisation techniques in the classroom varies by instructor. Of those that use them, 75% of biochemistry teachers have reported that they create their own materials for use in class (Craig *et al.*, 2013). Use of other electronic resources is based on need and vary from simple visualisation of molecules and protein structures to demonstrating laboratory (lab) analytical techniques such as polymerase chain reaction (PCR). The use of computer aided learning in PCR increased both the confidence of participants in the lab and quiz scores (Gibbins *et al*., 2003). Students at the University of Massachusetts used 3-dimensional (3D) structures to answer more challenging questions based on protein folding (White *et al*., 2010). Recognising that the majority of students usually carry a cell phone, "cell-phone" flash cards have been introduced to students to replace traditional flash cards for concepts in organic chemistry (Pursell, 2009). This integrated blended learning method is well accepted by the students because it provides a valuable supplementation to the lectures (De Fatima Wardenski, *et al*., 2012; Varhese *et al*., 2012).

Biochemistry is an important component of pre-pharmacy or pharmacy education (Prescott *et al.*, 2014). The development of additional blended learning and incorporation of e-learning platforms can enhance learning of biochemistry concepts (Craig *et al*., 2013). An application developed for use with mobile phones and personal digital assistants for an undergraduate biochemistry class at University of Guelph, Canada, was reported as beneficial by 54.4% of the students who accessed the resource (Teri *et al*., 2014). Karaksha *et al*. (2013) suggest that making an electronic study aid known to the student body is an important first step in its adoption by course participants. In addition, Crawford *et al*. (2012) stated that faculty should be aware of the different learning styles of students and make an effort to incorporate a variety of techniques to accommodate all participants in the course.

At Chicago State University-College of Pharmacy (CSU-COP) Pharmaceutical Biochemistry I and II are core components in the pharmacy professional curriculum. Students attend 45 hours of didactic instruction during which the course material is presented using PowerPoint slides with spontaneous notes on a tablet. In addition, they attend two workshops with active learning assignments that are completed in groups and each group presents a topic at the end of the semester. Online tools are made available to all students to disseminate course materials and manage their grades. Moodle™, an online tool used to manage the course and provide feedback, is used universally throughout the curriculum while, LiveText is a secondary programme mainly used to manage portfolios. These flexible e-learning platforms are key components of blended learning in the curriculum (Gonzalez-Banales & Monarrez-Armendariz, 2014).

The objectives of this study were to: (1) assess the perceived level of difficulty of topics taught to students enrolled in the Pharm.D programme; and (2) assess the student perceptions of what methods can be used to reinforce course material. These results will be used to guide the development of a study application for mobile platforms (*i.e.* IPad or Google Tablet) for course participants.

Methods

Study Participants

The questionnaire was administered to student pharmacists in the second, third and fourth professional years (graduating classes of 2015, 2016, and 2017) who completed the Pharmaceutical Biochemistry I and II course sequence (PHAR 6113 and 6114; three credits each) in the pharmacy curriculum by May 2014. A total of 240 student pharmacists had the opportunity to complete the questionnaire. Out of the 240 students, 133 (54.5%) were females and 107 (44.5%) were males. The questionnaire was administered in August and September 2014. Participation in the study was voluntary and all the participants completed a waiver consent prior to their participation. The study was approved by the CSU's Institutional Review Board (IRB protocol #037-05-14).

Questionnaire Development

In order to address the objectives of this study a questionnaire was developed and its validity was examined. Based on recommendations from the literature on questionnaire development, the following steps were followed: questions development; selecting a scaling technique; selecting a response format; preparing drafts of the questionnaire and conducting a review of items; preparing the final draft of the questionnaire; and assuring validity of the developed questionnaire (Gable & Wolf, 1993). The items in the questionnaire were formatted as confirmatory statements. Each item in the questionnaire described a particular biochemistry concept covered in the syllabus. The language in the questionnaire was carefully constructed to reflect the language used by the instructors and the textbook in the course. Within the course animation was incorporated into the lectures to demonstrate important concepts, examples of flash cards are provided to encourage students to prepare their own, 3D computer models are used to demonstrate stereochemistry, quizzes were used as assessments and key words were provided for each topic. Face and content validity of the questionnaire were assured by extensive literature review and formal feedback from two biochemistry professors (Gable & Wolf, 1993; De Fatima Wardenski *et al*., 2012; Varghese et al., 2012; Craig *et al*., 2013; Karaksha *et al*., 2013; Petrova *et al*., 2014). After the questions were developed, two biochemistry professors with significant knowledge and teaching experience in the area reviewed the questions providing feedback. Based on the provided feedback the items were modified.

The Questionnaire

A 32 item questionnaire was developed using the Likert scale: one to five, where one was the least difficult, three was neutral and five was the most difficult. Questions were organized in two sections, A and B. The content of the questions in Section A was related to the difficulty of topics taught in the course. The questions in Section B were related to the methods for reinforcing concepts presented in the didactic portion of the course. Each section had 16 questions. The first set of 16 questions in Section A asked students to indicate the level of difficulty for the course topics (Table I). These questions were derived from the course topics. The second set of 16 questions in Section B asked the students to identify learning methods that would be most effective for reinforcing the material. Choices included 3D models, flash animation, flash cards, practice quizzes, and key definitions. For each topic, students were instructed to select up to five methods that could be useful study tools.

Table I: Biochemistry topics used in questionnaire given to 1st year student pharmacists. Students were asked to assess the level of difficulty of each topic.

QUESTION	TOPIC IN PHARMACY BIOCHEMISTRY
DIRECTIONS:	**Rate the difficulty of the following topics 1-16 covered in the PHAR 6113-6114 Pharmaceutical Biochemistry Sequence, on the scale from 1-5 where 1 = least difficult, 3=neutral and 5= most difficult.**
1	Amino acid structure, stereochemistry and chemical properties
2	Understanding the differences of primary, secondary, tertiary and quaternary protein structures
3	Non-covalently bonding between molecules
4	Enzymatic kinetics, mechanisms of inhibition
5	Carbohydrate structures and stereochemistry
6	Glycolysis including the anaerobic and aerobic fates of pyruvate
7	Role of gluconeogenesis and glycolysis in feed/ fast cycles
8	Oxidation/reduction reactions
9	Differentiating among the different classes of enzymes:
10	Gene expression
11	DNA replication and repair
12	Transmembrane signaling proteins and their interaction at specific receptors on the surface of the cell
13	RNA synthesis, processing and regulation
14	The role of the ribosome and tRNA in protein synthesis
15	DNA cloning
16	Electrophoresis, chromatography and polymerase chain reaction

Student Baseline Performance

To determine the baseline performance of the students in the classes of 2015-2017, the assessment results from the cumulative final exams the Pharmaceutical Biochemistry sequence were tabulated. Questions from the assessments were grouped into the 16 course topics used in the survey (Table I) and the percentage of students who chose the correct answers in that area was calculated. The number reported represents the percentage of students in all three classes.

Statistical Analysis

Data collected from the questionnaire Sections A and B were analysed as two separate data sets because they asked different research questions and yielded unrelated types of data. Questions in data set A (Section A) employed a Likert scale to measure the difficulty of each major topic in the course while questions in data set B provided five choices of possible study tools for each major topic in the course. Descriptive statistics from the data set A were obtained using PASW (Predictive Analytic Software) version 18.0. A two-tailed *t*-test at a 95% ($p<0.05$) confidence level was used to compare the student response to a neutral rating of three. Topics were considered as difficult if the average rank was significantly higher than three and easy if the average was significantly lower. Statistics were calculated for the pooled data from the classes of 2015 – 2017 as well as data from the individual class cohorts. Primary component analysis was also performed on data set A.

In Section B, students were asked to choose all of the possible study tools, *i.e.* 3D models, flash animation, flash cards, practice quizzes, and key definitions that would be useful in reinforcing the major topics in the course. The data collected in Section B (data set B) was nominal, and frequency and percentage were calculated to determine the preferred methods for each of the 16 course topics.

Results

The questionnaire was administered to 66, 93, and 81 (N=240) student pharmacists from the class of 2015, 2016, and 2017, respectively. The overall response rate was 78.3% (N=188), with individual class response rates of 80.0% (53), 80.0% (74) and 76.0% (62) for the class of 2015, 2016, and 2017, respectively.

Student Baseline Performance

In the final exam results for participants in the study, less than 70% of the students answered the questions correctly for the following topics (Table II): 7) role of gluconeogenesis and glycolysis in feed/fast cycle; 10) gene expression; 11) DNA replication and repair; 14) the role of the ribosome and tRNA in protein synthesis; 15) DNA cloning; and 16) electrophoresis, chromatography

and polymerase chain reaction. Four additional topics (Table II), 2) understanding the differences of primary, secondary, tertiary and quaternary protein sequence; 4) enzymatic kinetics, mechanisms of inhibition; 12) transmembrane signaling proteins and their interaction at specific receptors on the surface of the cell; and 13) RNA synthesis, processing and regulation, proved challenging to the survey cohorts. For these four topics, only 75 – 78% of students were able to answer the questions correctly. The majority of the students (≥ 80%) performed well on the six remaining topics.

Level of Difficulty of Course Topics

In data set A, nine out of the 16 course topics were rated as statistically different from neutral, with two of the topics being rated as easier than neutral and seven being rated as more difficult. Topics identified as easy included questions: (2) understanding the difference between types of protein structures ($p<0.001$) and (3) non-covalent bonding between molecules ($p<0.001$) (Figures 1a and 1b). The topics identified as more difficult more advanced topics included questions: (6) glycolysis ($p<0.001$), (7) feed/fast cycle ($p<0.001$), (12) transmembrane signalling proteins ($p<0.001$), (13) RNA synthesis, processing and regulation ($p<0.001$), (14) the role of the ribosome and tRNA in protein synthesis ($p=0.02$), (15) DNA cloning ($p<0.001$), and (16) electrophoresis, chromatography, and polymerase chain reaction ($p<0.001$) (Figures 1a and 1b). The results for each question were similar across the three student cohorts, however, the class of 2016 found the course as a whole more difficult (overall difficulty rating 3.20). The class of 2015 found the course as a whole less difficult (overall difficulty rating 2.98).

Table II: Student overall baseline performance on assessment questions in each topic area

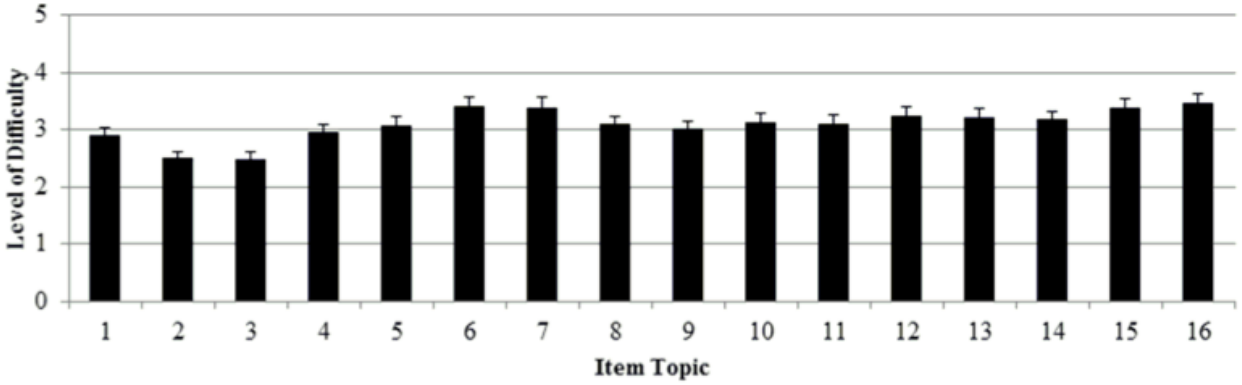
TOPIC	STUDENTS OVERALL PERFORMANCE ON CUMULATIVE FINAL EXAM (%)
Amino acid structure, stereochemistry and chemical properties	80
Understanding the differences of primary, secondary, tertiary and quaternary protein structures	78
Non-covalently bonding between molecules	90
Enzymatic kinetics, mechanisms of inhibition	77
Carbohydrate structures and stereochemistry	83
Glycolysis including the anaerobic and aerobic fates of pyruvate	80
Role of gluconeogenesis and glycolysis in feed/fast cycles	65
Oxidation/reduction reactions	86
Differentiating among the different classes of enzymes	84
Gene expression	60
DNA replication and repair	61
Transmembrane signaling proteins and their interaction at specific receptors on the surface of the cell	76
RNA synthesis, processing and regulation	74
The role of the ribosome and tRNA in protein synthesis	58
DNA cloning	57
Electrophoresis, chromatography and polymerase chain reaction	60

Table III: Student preferences for reviewing specific topics in the pharmacy biochemistry sequence

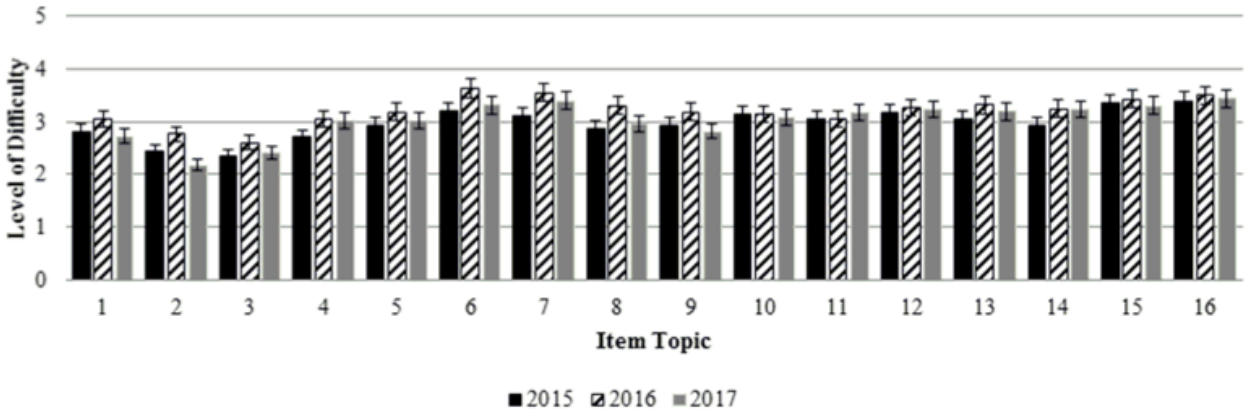
Topic	Animation	Flash Cards	3D Model	Quizzes	Key Words
Amino acid structure, stereochemistry and chemical properties	66 (35.1%)	82 (43.6%)	86 (45.8%)	83 (44.2%)	26 (13.9%)
Understanding the differences of primary, secondary, tertiary and quaternary protein structures	61 (32.5%)	43 (22.9%)	83 (44.2%)	75 (40.0%)	32 (17.0%)
Non-covalently bonding between molecules	68 (36.2%)	40 (21.3%)	59 (31.4%)	71 (37.8%)	28 (14.9%)
Enzymatic kinetics, mechanisms of inhibition	68 (36.2%)	53 (28.2%)	41 (21.8%)	85 (45.2%)	43 (22.9%)
Carbohydrate structures and stereochemistry	59 (31.4%)	56 (29.8%)	78 (41.5%)	77 (41.0%)	22 (11.7%)
Glycolysis including the anaerobic and aerobic fates of pyruvate	64 (34.1%)	62 (33.0%)	38 (20.2%)	94 (50.0%)	43 (22.9%)
Role of gluconeogenesis and glycolysis in feed/fast cycles	53 (28.2%)	58 (30.1%)	37 (19.7%)	90 (47.9%)	40 (21.3%)
Oxidation/reduction reactions	57 (30.3%)	68 (36.2%)	44 (23.4%)	95 (50.5%)	36 (19.2%)
Differentiating among the different classes of enzymes:	41 (21.8%)	81 (43.1%)	33 (17.6%)	85 (45.2%)	59 (31.4%)
Gene expression	78 (41.5%)	50 (26.6%)	35 (18.6%)	90 (47.9%)	45 (30.0%)
DNA replication and repair	81 (43.1%)	48 (25.5%)	44 (23.4%)	91 (48.4%)	37 (19.7%)
Transmembrane signaling proteins and their interaction at specific receptors on the surface of the cell	76 (40.4%)	49 (26.1%)	37 (19.7%)	89 (47.3%)	30 (16.0%)
RNA synthesis, processing and regulation	76 (40.4%)	49 (26.1%)	36 (19.2%)	86 (45.8%)	41 (21.8%)
The role of the ribosome and tRNA in protein synthesis	69 (36.7%)	43 (22.9%)	32 (17.0%)	90 (47.9%)	37 (19.7%)
DNA cloning	76 (40.4%)	50 (26.6%)	33 (17.6%)	88 (46.8%)	47 (25.0%)
Electrophoresis, chromatography and polymerase chain reaction	68 (36.2%)	50 (26.6%)	30 (16.0%)	88 (46.8%)	63 (33.5%)

Figure 1: Reported difficulty level of each of the 16 topics (Table I) taught in the Pharmacy Biochemistry sequence

(a) Data set A for all classes 2015-2017



(b) Data set A for the individual classes 2015-2017



Methods for Reinforcing Topics in the Course

Response rates for the different study tools proposed in the study ranged from 11.7% to 50.5% of the participants. In the pooled responses from all classes for data set B, students requested practice quizzes for all of the major topics (<40%) in the PHAR 6113-6114 course sequence except for non-covalent bonding between molecules (Table III). Students in the survey requested animation as a study tool to demonstrate the topics such as the role of gene expression (41.5%), DNA replication and repair (43.1%), transmembrane signaling proteins and their interaction at specific receptors on the surface of the cell (40.4%), RNA synthesis, processing and regulation (40.4%), and DNA cloning (40.4%) (Table III). Students chose flash cards as a study tool to reinforce amino acid structure, stereochemistry and chemical properties (43.1%) and differentiation among the different classes of enzymes and the differences of primary, secondary, tertiary and quaternary protein structures (43.1%) (Table III). The 3D-model was most frequently chosen by students to better demonstrate the following topics: amino acid structure, stereochemistry and chemical properties (45.8%), understanding the differences of primary, secondary, tertiary and quaternary protein structures (44.2%), and carbohydrate structures and stereochemistry (41.5%) (Table III). Students did not indicate that key words are helpful tools for any of the topics (<40%) (Table III).

Discussion

Student baseline performance and student responses indicate that student pharmacists in the class of 2015, 2016, and 2017 consider many of the major course topics in the Pharmaceutical Biochemistry course sequence challenging. Many of the topics identified by students in this survey as challenging fall into five threshold concepts identified as essential for the understanding of biochemistry (Loertscher *et al*., 2014). Students also reported that they desire quiz questions for almost all the topics, and animation, flash cards and 3D models for select topics. These results suggest that students perceive value in supplemental study material beyond access to e-resources such as electronic notes or presentations to reinforce difficult topics for student success within the course.

With a few exceptions, the student overall baseline performance on questions on the cumulative final exam in each topic was in agreement with the students' perception of the difficulty of topics. Poor performance (*i.e.* less than 70% success on questions in a topic) was observed for topics that were identified as challenging by the survey participants: the feed/fast cycle, RNA synthesis, processing and regulation, the role of the ribosome and tRNA in protein synthesis, DNA cloning, and electrophoresis, chromatography, and polymerase chain reaction. Students performed well on questions related to understanding the difference between types of protein structures and non-covalent bonding between molecules; both topics identified as less challenging. For glycolysis including the anaerobic and aerobic fates of pyruvate and transmembrane signaling proteins, students performed well on the exam questions suggesting that they had a better understanding of the material despite the level of difficulty.

When interpreting these results, it is important to consider when the specific topics were delivered within the academic school year. Topics rated most difficult including transmembrane signalling proteins, RNA synthesis, processing and regulation, the role of the ribosome and tRNA in protein synthesis, DNA cloning and electrophoresis, chromatography, and polymerase chain reaction are included in the second semester of the biochemistry course sequence. In the pharmacy curriculum at CSU, the second semester of the first professional year has a heavier course load. In the Autumn semester, students take five didactic courses, while in the Spring, students take five didactic courses and one experiential course requiring them to spend time at a practice site. The heavy academic workload for the student may influence the perceived difficulty of the topics in the second semester (Reid *et al*., 2006). The perceived difference in the overall difficulty of the course topics among the classes of 2015, 2016, and 2017 may be due to differences in the background or preparation of the students who enrolled in this course. Furthermore, students from the class of 2015 could have experienced potential recall bias.

Student pharmacists indicated that four of the proposed methods, 3D models, flash animation, flash cards, and practice quizzes, for reinforcing the didactic material would be useful for at least two of the major course topics. Respondents favored practice quizzes over all the other tools in the questionnaire. This study aide may be most popular because it can provide instant feedback to students, an attribute identified as useful to students in similar studies (Alzaza & Yaakub, 2011). Practice quizzes may also be favoured because the questions may be seen by students as potentially similar to questions asked on an exam.

Flash cards were requested for two topics: amino acids and enzyme kinetics. It is recognised that students commonly use flash cards to commit concepts in organic chemistry to memory (Pursell, 2009). These could include cards that can be purchased from publishers or cards prepared by the individual students. The adoption of flash cards to an electronic platform such as a cell phone has been shown to engage students in learning beyond the classroom (Pursell, 2009).

Computer-aided drawing or learning tools are commonly used in undergraduate and graduate chemistry courses to illustrate the 3D structure of molecules and their mechanisms of action in chemical and biological reactions (Gibbins *et al*., 2003; White *et al.* 2010; De Fatima Wardenski *et al*., 2012; Varghese *et al*., 2012; Craig *et al*., 2013). It was therefore not surprising to find that students chose visual learning aids, *e.g*. animation and 3D models, for concepts to reinforce topics that involve structures, stereochemistry and pathways: amino acids, protein structure and carbohydrates. Students often find it challenging to visualise the 3D structure and stereochemistry of a molecule and traditionally have used ball and stick sets to build a model. Using a mobile application, students can be given access to software that allows them to see 3D models of molecules to compare different structures at one time and visualize how a molecule can sit into a receptor site of an enzyme. A further extension of this is to add animation that shows how a molecule, such as glucose, moves through a pathway to yield energy into the system or how a gene is translated into a protein. The student pharmacists recognised this as a potential tool for understanding gene expression, DNA and RNA synthesis, transmembrane signalling proteins and their interaction at specific receptors on the surface of the cell and DNA cloning in the lab.

The effectiveness of mobile applications in blended learning is dependent upon many factors, most importantly the willingness of the student to use the application (Ruth *et a*l., 2013). The creators of an application for an undergraduate biochemistry and nutrition course at the University of Guelph reported that although the content of the application corresponded directly to the course materials, most students used the application infrequently or not at all (Karaksha *et al*., 2013). They suggested that the low adoption rate of the application was correlated with the individual student's comfort level with technology, programming errors and in some cases, too much broad information provided on a given topic. In this study, student input was collected to guide the development of an application for student pharmacists that reflected the different learning styles of the participants (Karaksha *et al*., 2013). Using this student feedback to develop an application to support the Pharmaceutical Biochemistry sequence will more likely result in a study tool that will be adopted by students (Albarrak, 2011; Lee *et al*., 2012).

Conclusion

This study demonstrates that student pharmacists perceive many of the topics of the Pharmaceutical Biochemistry course sequence as challenging. Students' performance on cumulative exams agree with their perceptions for nearly all topics. Based on student preferences, the following

tools will be developed for a mobile application: practice quizzes for the topics (only one topic fell below the 40% cut-off at 37.8%); animation for five of the topics that centre mainly on DNA, RNA and transmembrane signalling proteins; flash cards for amino acids and enzyme kinetics; and 3D structures for amino acid, protein and carbohydrate structures. With this in mind, the mobile application to be developed will have some components dedicated to all of the topics included in the questionnaire, however more content will be devoted to the more difficult topics.

Conflict of Interest

The authors have no conflicts of interest to declare for the research presented in this manuscript.

Acknowledgements

The authors thank Mr. Donald Brower for his assistance with administering the questionnaire to the class of 2015. Thank you to Ms. Tracie Williams for administrative support and the student pharmacists from the class of 2015, 2016, and 2017 for their participation in the survey.

References

Al-Fahad, F.N. (2009). Students' attitudes and perceptions towards the effectiveness of mobile learning in King Saud University, Saudi Arabia. *Turkish Online Journal of Educational Technology*, **8**, 111–119.

Albarrak A.I. (2011). E-learning in medical education and blended learning approach. In *Education in a Technological World.* (ed. A. Mendez-Vilas). Badajoz, Spain: Formatex., pp.147-153.

Alzaza, N.S. & Yaakub, A.R. (2011). Students' awareness and requirements of mobile learning services in the higher education environment. *American Journal of Economics and Business Administration*, **3**, 95–100.

Capretz, L.F. & Alrasheedi, M. (2013). A meta-analysis of critical success factors affecting mobile learning. *Electrical and Computer Engineering*, **Paper 18**.

Chen, B. & Denoyelles, A. (2013). Exploring students' mobile learning practices in higher education. *Educause Review Online*. Available at: http://www.educause.edu/ero/. Accessed 15th May, 2016.

Chuttur, M.Y. (2009). Overview of the Technology Acceptance Model: Origins, developments and future directions. *Sprouts: Working Papers on Information Systems*, **9**(37).

Craig, P.A., Michel, LV. & Bateman, R.C. (2013). A survey of educational uses of molecular visualization freeware. *Biochemistry and Molecular Biology Education*, **41**, 193-205.

Crawford, S.Y., Alhreish, S.K. & Popovich, N.G. (2012). Comparison of learning styles of pharmacy students and faculty members. *American Journal of Pharmaceutical Education*, **76**, 192.

De Fátima Wardenski, R., De Espíndola, M.B., Struchiner, M. & Giannella, T.R. (2012). Blended learning in biochemistry education: analysis of medical students' perceptions. *Biochemistry and Molecular Biology Education*, **40**, 222-228.

Fox, L.M., Pham, K.H. & Dollar, M. (2007). Using interactive digital images of products to teach pharmaceutics. *American Journal of Pharmaceutical Education*, **71**(3), 58.

Gable, R.K. & Wolf, M.B. (1993). Instrument development in the affective domain: Measuring attitudes and values in corporate and school settings. Massachusetts: Kluwer Academic Publisher.

Gibbins, S., Sosabowski, M.H. & Cunningham, J. (2003). Evaluation of a web-based resource to support a molecular biology practical class - does computer-aided learning really work? *Biochemistry and Molecular Biology Education*, **31**, 352-355

Gonzalez-Banales, D.L. & Monarrez-Armendariz, C. (2014). Incorporation of social networking and application of responsive design for Moodle. *Innovation and Research in Engineering Magazine*, **11**, 50-61.

Karaksha, A., Grant, G., Anoopkumar-Dukie, S., Nirthanan, S.N. & Davey A.K. (2013). Student engagement in pharmacology courses using online learning tools. *American Journal of Pharmaceutical Education*, **77**, 125.

Lee, H.S., Kim, T.G. & Choi, J.Y. (2012). A study on the factors affect smart phone application acceptance. In 3rd International conference on e-Education, e-Business, e-Management and e-Learning. *International Proceedings of Economics Development and Research*, **27**, 27-34. Singapore: IACSIT Press.

Loertscher, J., Green, D., Lewis, J.E., Lin, S. & Minderhout, V. (2014) Identification of threshold concepts for biochemistry. *CBE-Life Sciences Education,* **13**, 516 – 528.

Martín, S., Díaz, G., Cristóbal, E.S., Gil, R., Castro, M. & Peire, J. (2011). New technology trends in education: Seven years of forecasts and convergence. *Computers and Education*, **57**, 1893-1906.

Pereira, J.A., Pleguezuelos, E., Merí, A., Molina-ros, A., Molina-tomás, M.C. & Masdeu, C. (2007). Effectiveness of using blended learning strategies for teaching and learning human anatomy. *Medical Education*, **41**, 189-95.

Petrova, T., Kavookjian, J., Madison, M.B., Dagley, J., Shannon, D. & McDonough, S. (2014). Motivational Interviewing Skills in Health Care Encounters (MISHCE): Development and psychometric testing of assessment tool. *Research and Social Administrative Pharmacy*. doi:10.1016/j.sapharm.2014.12.001

Prescott, J., Ellen, S., Wilson, E. & Wan, K. (2014). Pharmacy students' perceptions of natural science and mathematics subjects. *American Journal of Pharmaceutical Education*, **78**, 118.

Pursell, D.P. (2009). Adapting to student learning styles: Engaging students with cell technology in organic chemistry instruction. *Journal of Chemical Education*, **86**(10), 1219-1222.

Reid, L.D., Motycka, C., Mobley, C. & Meldrum, M. (2006). Comparing self-reported burnout of pharmacy students on the founding campus with those at distance campuses. *American Journal of Pharmaceutical Education*, **70**(5), 114.

Ruth, D. M., Mastre, T. M. & Fricker, R. (2013). A study of mobile learning trends at the U.S. Naval Academy and the Naval Postgraduate School. *Educause Review Online*. Available at : http://www.educause.edu/. Accessed 15th May, 2016.

Teri, S., Acai, A., Griffith, D., Mahmoud, Q., Ma, D.W. & Newton, G. (2014). Student use and pedagogical impact of a mobile learning application. *Biochemistry and Moleculary Biology Education*, **42**, 121-35.

Varghese, J., Faith, M. & Jacob, M. (2012). Impact of e-resources on learning in biochemistry: first-year medical students' perceptions. *BioMed Central Medical Education*, **12**, 21.

White, B., Kahriman A., Luberice L. & Idleh F. (2010). Evaluation of software for introducing protein structure. *Biochemistry and Molecular Biology Education*, **38**, 284-289.

Williams, C. (2002). Learning On-line: A review of recent literature in a rapidly expanding field. *Journal of Further and Higher Education*, **26**, 263-272.

Yilmaz, O. & Sanalan, V.A. (2011). M-Learning: M-learning applications, students input for M-Learning in science instruction. *World Journal of Education*, **1**(2), 172-180.