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Flipping the Classroom for Pharmacokinetics

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Abstract A flipped classroom approach was implemented in a pharmacokinetics course to encourage active student learning and enable the development of higher level learning skills. Students viewed written and/or audio-visual recordings of content materials prior to active face-to-face engagement where they then applied their learning through the evaluation and analysis of different clinical scenarios, calculation of dosing regimens, and synthesis of information to create resources. Student outcomes for the flipped pharmacokinetics course in 2013 were compared with student outcomes for the traditionally taught pharmacokinetics course in 2012 which acted as control. Student evaluations of the course showed significantly stronger satisfaction with their learning experience by students in the innovative 2013 course compared to students in the traditional 2012 control (P=0.01).Although students in the 2013 cohort strongly agreed that flipping the classroom enabled them to apply their learning and that it had a positive effect on their learning, there was no significant difference in the major assessment results between the 2013 and 2012 cohorts.

Keywords: *flipped classroom, student-centred learning, higher level learning skills*

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1. Introduction

Pharmacokinetics involves the application of mathematical principles to describe drug behaviour within the body. The most important competencies for students to acquire in this field are the ability to calculate dosing regimens, recover patient specific parameters and apply pharmacokinetics concepts in lieu of, or in support of, mathematical calculations [1]. To reinforce the development of these competencies students need immediate experience applying course content to strengthen their learning and give relevance and value to the information received.

Traditionally, the delivery of pharmacokinetics education in pharmacy programs has followed a didactic, lecture-based teaching format, a teacher-centred approach in which information is defined, controlled and directed by the lecturer. It would appear that this limits higher levels of student learning [2] as students are not encouraged to learn how to gather, analyse or synthesise information and do not develop the skills to analyse the logic of questions and problems [3]. It has also been suggested that because of its mathematical focus, pharmacy students find it difficult to apply pharmacokinetics to patient care in the clinical setting [4]. Students and pharmacists alike need to be able to transfer learned processes from one context to another. This application of knowledge is a key component of deep learning and in the more basic science side of the pharmacy curriculum, such as in pharmacokinetics, this is sometimes overlooked [5]. Thus the intake of knowledge and its reproduction, delivered via traditional models of didactic teaching, is no longer adequate for pharmacy students [6].

The converse of the teacher-centred approach to learning goes beyond the simple acquisition of knowledge and comprehension and involves active participation by students in the learning process. Student-centred learning facilitates higher levels of learning, including critical thinking and increased retention of information [3, 7], and the analysis, synthesis and evaluation of information [5]. It is now well known that students who actively participate in the learning process learn more than those who do not [8-10] and they experience increased retention of information and learning [7].

The concept of re-arranging face-to-face contact time with students from a teacher centred to a student focussed experience progressed in 2007 with the idea of flipping the classroom [11]. In this model students are directed to view pre-recorded material in their own time, and class time is used for active student engagement, discussion and application of concepts with real life examples. Advances in technology have meant that lecture materials can be prepared and presented in different ways to meet the needs of students with different learning styles. The students of today have grown up using computers, video games and other tools of the digital age and respond to learning using technology. According to Prensky (2001) 'digital natives', as he calls them, think and process information fundamentally differently from their predecessors and are used to receiving information really fast [12]. When students are provided with the tools in advance of class

sessions they can work through the materials at their own pace and be active constructors of their own knowledge, not passive recipients.

To encourage students to become responsible for their own learning and to begin developing higher level learning skills for life-long learning weflipped the classroom to developa pharmacokinetics course with a student centred approach to learning using pre-recorded material and actively engaging students in problem solving, critical thinking and the application of pharmacokinetics knowledge in a clinical setting. This paper describes the changes to the course and investigates student satisfaction with this changed approach to learning pharmacokinetics compared to student satisfaction with the teacher centred, didactic teaching of pharmacokinetics the previous year.

2. Materials and Methods

The Master of Pharmacy at the University of Newcastle, Australia, is an intensive program with 240 units of study, offered in six trimesters over two years. The pharmacokinetics course is offered over 12 weeks in the first trimester of Year 1. Traditionally, the teacher centred, face-to-face component of the course comprised of 2 x 1 hour lectures each week for all students, followed by 1 x 2 hour tutorials each week for groups of 17-20 students. In 2013, changes were introduced and a student-centred approach to teaching and learning was developed using the flipped classroom model, with new content material given to students outside of class time followed by the assimilation of knowledge in-class through problem solving and discussions. Thus, lecture materials were pre-recorded as weekly modules and made available on-line through the learning management system, Blackboard, for out of class independent student learning. The materials were prepared to accommodate individual differences in learning styles. For visual learners, audio-visual presentations were created using Adobe Captivate®. To support the audio-visual materials and for students who prefer to learn by reading, written materials were produced using SoftChalk®, and also uploaded onto Blackboard. Thus students were able to view written and/or audio visual materials. To encourage students to study these materials, a short quiz on the content was attached to each weekly module and the quizzes had to be completed and submitted on-line at least 1-hour prior to face-to-face in-class discussion sessions.

Following the out of class independent student learning, students met in the former lecture periods for class sessions to discuss and to review the work. For these sessions, the students were given work sheets that identified their learning objectives for the session and set out a number of short-answer questions and multiple choice questions (MCQs) which enabled students to identify any problematic areas to be addressed. The work sheets also included scenarios that involved the calculation of dosing regimens and pharmacokinetic parameters as well as applying learning to simple case studies. The 1 x 2hr tutorial that followed enabled students to apply their learning to clinical issues related to pharmacokinetics either through case studies or writing newsletters, and to discuss this work with the other students. The tutorial commenced with a ten minute overview which summarised the work covered that week, linking key points and focussing student attention on the main concepts and confirming that students understood the more complex concepts. Thepresented case studies gave students the opportunity to apply their knowledge to calculate dosing for patients with different medical conditions, including calculations of drug parameters such as elimination rate constants, clearance and volume of distribution, and the plotting of graphs to illustrate the processes The 1-2 page newsletters required students to synthesise and apply course content to further reinforce their learning. The newsletters were to be user-friendly, written for the medical, nursing and allied health professionals, and included topics such as therapeutic drug monitoring (TDM), Digoxin and TDM, and bioequivalence.

Progressive assessment was implemented witha weekly on-line quiz with questions that focussed on the work that was being covered that week. The quiz was uploaded on to Blackboard and accessible for students to complete until 1 hour prior to the face-to-face review session. These quizzes and the newsletters completed in the tutorial sessions made up the minor assessment items, comprising 10% of the total marks for the course. There were three major assessment items; two written exams, one mid-course for 20%, and one at the end of the course for 50% of the total marks, also one individual written assignment for the final 20% of the total marks. The written assignment was a common case study but with a different fictitious drug and set of data for each student. They were required to determine the pharmacokinetics of the new drug for product information to write a monograph for a drug compendium such as the Australian drug compendium, MIMS Australia [13].

To determine student satisfaction with this different approach to learning an independent academic, not involved in the teaching of the 2013 pharmacokinetics course, observed student activities in the review and discussion periods as well as in tutorials and asked students to comment on their experiences with this changed way of learning. Then, at the completion of the course, students provided feedback completing an evaluation of the course using a university managed on-line course evaluation survey. The survey comprised 15 questions each with a 5-point Likert-scale response option from “strongly agree” to “strongly disagree”.

3. Results

Observations reported by the independent academic were that there was very good to excellent group dynamics with students helping each other with calculations and discussing approaches to problem solving. Some students made comments about the difficulty of memorising all of the equations but reported no difficulties with the calculations as students were given plenty of opportunity, with support, to practise these. Students made very positive comments about the topic summary given in the weekly tutorial with some students claiming that the summaries were the best part of the tutorial because it consolidated their learning.

The evaluation of the course through a university managed course evaluation survey by the 2013 student

cohort was compared with the responses from the 2012 cohortin which no innovations to learning were introduced and which was used as a control. Significantly more students in 2013 recorded "strong agreement" to the positive statements about the course compared to students in 2012 (P=0.01) while significantly more students in the 2012 cohort recorded "agreement" to the statements (P=0.001). The questions asked and the percentage responses are shown in Table 1.

Table 1. Comparison of pharmacy students' evaluation of course in 2013 and 2012

	2013 %		2012 %	
	Strongly agree*	**Agree**	**Strongly agree***	**Agree**
Expectations: I was clearly informed about the learning objectives of this course	20/87	2/8.7	11/78.6	3/21.4
Support: The teaching staff were available to help me with my learning	21/91.3	2/8.7	11/78.6	3/21.4
Learning activities: The activities of this course motivated me to learn	21/91.3	2/8.7	9/64.3	5/35.7
Teaching: The quality of teaching in this course helped me achieve the learning objectives	23/91.3	2/8.7	11/78.6	3/21.4
Structure: The various components of this course were linked in ways that supported my learning.	18/78.3	5/21.7	10/71.4	4/28.6
Organisation: Overall the course was well organised	21/91.3	2/8.7	11/78.6	3/21.4
Resources: The resources for this course helped me achieve the learning objectives.	21/91.3	2/8.7	12/85.7	2/14.3
Outcomes: My knowledge and skills have developed as a result of studying this course	16/69.6	7/30.4	11/78.6	3/21.4
Challenge: This course challenged me in ways that extended my learning	16/69.6	4/17.4	7/50	7/50
Assessment: The assessment items were clearly related to the learning objectives	20/87.0	3/13.0	12/85.7	2/14.3
Criteria: The criteria for all assessment items were made clear	21/91.3	2/8.7	11/78.6	3/21.4
Feedback: I received feedback that was helpful to my learning	21/91.3	2/8.7	11/78.6	3/21.4
Relevance:: I am able to apply my learning from this course to my wider goals	17/73.9	6/26.1	9/64.3	5/35.7
Satisfaction: Overall, I am satisfied with the quality of this course	17/73.9	6/26.1	10/71.4	4/28.6
Self evaluation: I made a consistent effort to succeed in this course	16/69.6	7/30.4	9/64.3	5/35.7

P = 0.01

Assessment results for the pharmacokinetics course in 2013 were compared with those for the students who had studied this course in 2012. Student numbers in the course in the two different years were very similar, with 64 students completing this course in 2013 and 67 students completing the course in 2012. The value of the major assessments was the same for both years and the written assignment in 2013 was similar to that of 2012. Although the results for the major assessment items are slightly higher for the 2012 cohort, there is no significant difference in the results for the two groups (Table 2). However, the results for the minor assessment items are significantly higher for the 2013 cohort compared to the 2012 cohort (P=0.002) (Table 2).

Table 2. Comparison of assessment results in 2013 and 2012

	2013 n=64	**2012** n=67	**P**
Minor assessments (10%)	64/9.48	67/8.76	0.002
Assignment (20%)	64/18.21	67/18.80	ns
Exam 1 (20%)	64/13.78	67/15.06	ns
Exam 2 (50%)	60/30.17	66/31.48	ns
Total (100%)	71.54	72.57	ns

4. Discussion

By flipping the classroom in this pharmacokinetics course, new material traditionally presented in face-to-face didactic lectures was moved outside of class to online access using technology to present the material for independent student learning. Face-to-face class time was then used to encourage deep learning through discussions, problem solving, the application of learning in different contexts and the opportunity to personalise the learning of the students. Thus by flipping the classroom we also flipped Bloom's Taxonomy of Learning, a pyramid of learning domains in a hierarchical framework from simple to complex. Traditionally, the emphasis is on 'remembering' which is represented at the base of the pyramid then progressing with less emphasis to the more complex levels of learning at the peak. It is understanding and application of knowledge that are the most important goals of education [14], thus by inverting Bloom's pyramid, there is less emphasis on 'remembering' and increasing emphasis is placed on the higher level learning skills of applying, evaluating and analysing [15].

Our model of the inverted pyramid for the progressive development and application of learning in the pharmacokinetics course is shown in Figure 1. The out of class, online, passive learning, comprised the reading of materials, watching recorded lectures, remembering definitions and equations and confirming the understanding of content and recall of information. This progressed to in-class, active learning, with quizzes to assess understanding and the calculation of dosing regimens. As students progressed to higher levels of learning they applied their knowledge to evaluate and analyse different clinical

scenarios and were involved in the discussion of concepts. Students then demonstrated higher order thinking skills as they synthesised technical and medical information to create easy-to-read resources for the benefit of general health professionals. While these learning domains are presented as distinct and separate, there is overlap as they flow from one to the other.

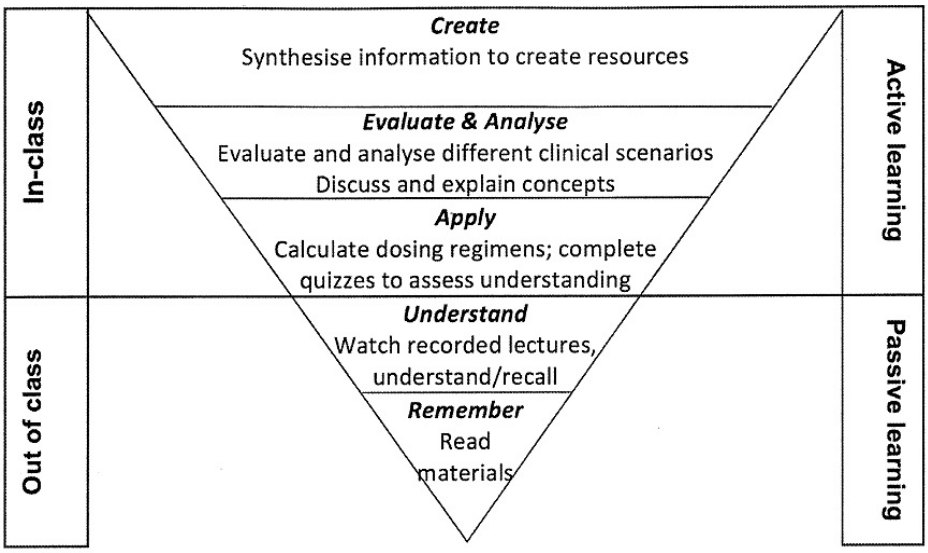

Figure 1. Our model of the flipped classroom

Flipping the classroom created an environment in tutorials where students worked together on case studies, problem solving to apply their newly acquired knowledge to calculate dosing for patients with different medical conditions. These case studies provided students with experiences they would encounter with patients in their future work environment and added to the relevance of their work. Students interacted with their peers, developing their communication skills while also learning from each other. This active learning experience encouraged the development of skills required in the future work environment. When the students in the 2012 control cohort had studied this pharmacokinetics course they had worked on calculations from individual, structured workbooks in their tutorials. As thesestudents worked independently, the need for collaboration did not occur and many of these students did not attend the tutorials but chose to work from home.

As this course was taught in the first trimester of the Master's program it was the first experience for these students working in the Flipped Classroom model. Student satisfaction with the course was significantly greater for the 2013 cohort compared with the 2012 control cohort and there was stronger agreement on the positive effects of teaching and learning from students in the 2013 innovation group compared to students in 2012. In particular, a greater proportion of students in the 2013 cohort strongly believed that their learning was motivated by the activities in the course, that the resources helped them to achieve the learning objectives, and that the various components of the course were linked in ways that supported their learning compared to the 2012 students. Also, a greater proportion of students in the 2013 cohort strongly believed that the course challenged them in ways that extended their learning and that they were able to apply their learning from the course to their wider goals compared to the 2012 students.

Although the majority of the 2013 student cohort indicated that the course supported their learning which was motivated by the activities in the course, there was no significant difference in their assessment results apart from the minor assessment tasks.. In fact, the results for thethree major assessment tasks were slightly higher for the 2012 control cohort. A possible reason for the lower results for the 2013 cohort could be partly attributed to the lower marks for these students at the lower end of the range. Four students in the 2013 innovation group failed the course and their lower marks were recorded in the final results for the cohort, while the three students in the 2012 cohort who were failing the course withdrew from the course to avoid recording a 'fail' result and their marks were not included in the final assessment results. It is possible that the significantly higher minor assessment results for the 2013 cohort could be attributed to greater student involvement and active learning that occurred in the tutorials compared to the 2012 students who chose to work on their own, at home.

Previous studies have compared student satisfaction and student performance where the same course has been delivered to two groups of students in two different ways, as in a traditional classroom settingor by distance education, where distance education includes online courses, interactive videoconferencing, videotaped and audio-taped lectures. Reported student satisfaction with the different methods of delivery does vary. Significantly greater student satisfaction was reported for online compared to traditional delivery in a course in Clinical Pharmacokinetics [16] which is similar to our findings. Lower satisfaction was reported among students for online videoconferencing compared to traditional delivery in Pharmacotherapy and Pharmacokinetics courses [17]. Chisholm et al. suggest that the student dissatisfaction was confined to some instructors in the videoconferencing group [17]. However, in a Business course, no differences in student satisfaction were reported between online and traditional delivery [18].Student performance in these studies was also compared. No differences in performance were observed between online and traditional delivery in

two of the studies [17,18] but there were significantly better results observed in the traditional classroom group compared to online in one of the studies [16]. Other studies that compared student performance only when using two different modes of delivery for the same course reported no differences in student performance. These include traditional versus online videoconferencing in Pharmacy courses [19], Pharmacokinetics [20] and Pharmaceutics [21]. These results are more consistent with our findings.

5. Conclusion

The Pharmacokinetics students in the 2013 flipped classroom indicated strong satisfaction with their learning environment where they were provided with multiple opportunities to apply their learning in 'real life' cases, and strongly agreed that it had a positive effect on their learning. However, there was no significant difference in overall assessment outcomes compared to the 2012 control. Ideally, a larger sample size would strengthen the findings in this study but numbers are controlled by student enrolment in the course.Further research is needed using assessment tasks that will measure critical thinking, communication, problem solving and the application of learning in clinical settings to determine the effectiveness of this model of learning

Statement of Competing Interests

The authors declare that they have no competing interests

List of Abbreviations

MCQs: Multiple choice questions
TDM: Therapeutic drug monitoring.

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