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Learning About Clinical Pharmacokinetics: A Case Study

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Changes in the nature of pharmacy education are often discussed in terms of differences in teaching method rather than a concern for student learning. A case study of a clinical pharmacokinetics course (CPKC) illustrates some issues. In 2000, the course was reviewed against a backdrop of research on teaching and learning. It showed that students' experiences tended to be reproductive, focusing on the acquisition of more knowledge, especially for examination purposes. In 2001, changes were made, emphasising a constructive alignment of all aspects of the curriculum, aimed at encouraging, understanding, and the development of critical thinking skills. Subsequent review showed a significant shift: students were more interested in their learning experiences and how the course encouraged these. The case study illustrates how small curriculum changes can make a significant differences to students' experiences of learning pharmacokinetics if the changes are made at a philosophical and strategic level rather than focusing on teaching methods.

Keywords: Constructive alignment; Curriculum change; Learning; Pharmaceutical reasoning

INTRODUCTION

In recent decades, particularly in North America, the United Kingdom and Australasia, there have been observable changes in the nature of pharmacy education (Serajuddin, 1998; Shaw, 2000). The changes include a greater emphasis on clinical pharmacy and an increasing "professionalisation" of the discipline. They are accompanied by debates about the relative merits of the traditional pharmaceutical science curriculum and the new, more professionally oriented courses. On the one hand, there are those who argue that the sciences seem to be struggling to establish their continuing relevance. In contrast, others suggest that the move towards clinical pharmacy has eroded the scientific foundations within pharmacy degrees (Serajuddin, 1998; Shaw, 2000) and pharmacy graduates are the poorer for that. Moreover, clinical/practice areas are often suspected of lacking substance or of simply producing graduates who have received a second-rate medical training.

At a more concrete level, changes in teaching method are evident in the move away from didactic lectures to the use of more interactive teaching methods such as workshops, tutorials, and computer aided learning packages (CAL). While some traditional pharmaceutical science courses within degree programmes have been successfully modified to take advantage of these new approaches to teaching (Alsharif *et al.*, 1999; Brazeau *et al.*, 1999), it is in the curricula of the relatively new discipline of clinical pharmacy/pharmacy practice that these changes are readily observed. Proponents of both teaching approaches claim the advantages of their position. For example, those who have adopted more contemporary approaches to teaching suggest that they have greater educational merit. However, the traditionalists argue that these approaches have yet to stand the test of time within a pharmacy curriculum. This kind of polarisation is furthered by reports that some students enjoy small group teaching (Shaw, 2000) or that methods such as CAL have been overplayed and students are unhappy (Nicholls, 2000).

These political tensions, and the more technical concerns about teaching method, are not limited to pharmacy education. With the move to "mass" higher education, universities worldwide are taking

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note of wider social concerns. Throughout the professions, curricula are being redesigned to address calls for critical skills associated with ethical dilemmas, social judgements, and informed application (Barnett, 1997). Often such changes are made with little thought of educational rationales, the beliefs and values associated with teaching and learning, and the nature of the knowledge that is being taught. The result is an uneasy alignment of the old and the new and the kind of debate that is outlined above. Such debate may be advanced if its focus shifts from a concern with teaching method to a concern with the quality of student learning.

A Clinical Pharmacokinetics Course (CPKC) in a New Zealand University provides a classic example of a contemporary clinically based subject that has been added to a traditional science curriculum. We use the CPKC as a case study to explore some of the issues and show how small changes in teaching and curriculum can have significant effects in the way that students go about learning clinical pharmacokinetics.

A FRAMEWORK FOR REVIEW

Trigwell's (2001) model of university teaching (Fig. 1) intended as a framework for "judging university teaching" provides a useful organising device for the description and discussion of the case study.

According to Trigwell, Fig. 1 comprises a section through a series of concentric spheres (e.g. the layers of an onion) that represent the teaching/learning situation. The student, who is located at the core, is most affected by the immediate teaching practices or teachers' strategies. The next layers are associated with planning and thinking, and the outermost layer consists of the immediate teaching/learning environment. Teachers' thinking should be interpreted broadly to include knowledge of the subject, knowledge and beliefs about teaching, and reflections on teaching and learning. All the layers are logically aligned so that the substance of each informs decisions in the others (Biggs, 1999). We start at the outermost layer.

The Teaching Learning Context

The CPKC was introduced into the pharmacy degree five years ago. It was run in parallel with other fourth-year clinical courses that focused on different aspects of professional practice in pharmacy. All the courses were taught through the use of case studies, workshops, and tutorials. In contrast, the previous three years of the degree programme were concerned predominantly with teaching scientific theory of pharmacy through lectures and labs.

Students' progression to the CPKC assumed a good grasp of pharmacokinetics, which was studied extensively in the previous year. The CPKC curriculum was based on the study of a small group of drugs that are subject to therapeutic drug monitoring (TDM). In addition, students were required to start to think about the use of pharmacokinetics in real patients and to realise the limitations of standard textbook pharmacokinetic equations and data. Teaching in the CPKC comprised the following:

- six lectures (whole class of approximately 100–120 students) focusing on hepatic disease, cardiac disease, renal disease, drug interactions, and computer applications;
- five workshops (four streams of approximately 25–30 students) based on case studies which involved prior reading and the completion of self-assessment questions;
- five tutorials (whole class) in which a case study was discussed and students were given the opportunity to clarify outstanding issues deriving from the workshop.

Assessment in the CPKC was divided into two components: an internal assessment (worth 20%) that consisted of a large multiple choice test towards the end of the course; and a final exam (80%) comprising three sections involving case studies,

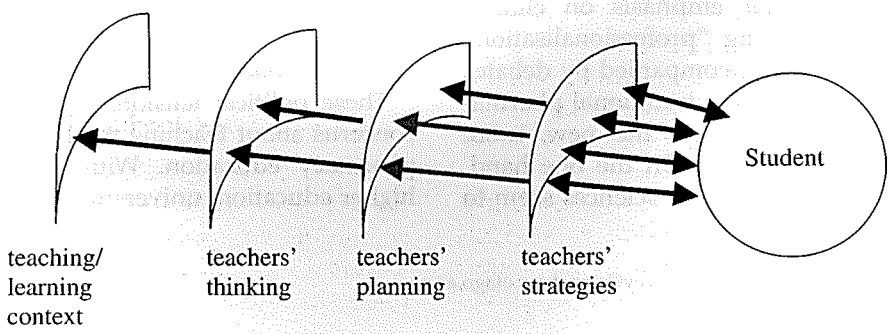

FIGURE 1 A model of University teaching (reproduced from Trigwell, 2001, p. 67).

short answer questions, and multiple choice questions.

In 2000, the CPKC was reviewed with an intention to implement changes to the course in 2001. In line with Trigwell's (2001) framework, the review took account of the context of the course including: recent international trends in pharmacy education (as outlined previously); the local institutional context; the relation of the course to the degree programme; and the intended graduate profile. It also drew upon research on teaching and learning in higher education, and students' views of the course. The students' views provided useful insights into the teaching/learning context.

Students' Views of the CPKC in 2000

Students' views of the CPKC were evaluated by a questionnaire that was distributed to students in the final lecture of the CPKC in 2000 ($n = 106$ enrolled students). A total of 71 (67%) students responded. The questionnaire comprised two parts. The first part included 21 closed questions (see Appendix A) that were concerned with students' perceptions of the quality of their learning, the teaching materials and methods, their workload, and the teachers' attitude towards them. These questions were selected from a pool of well tested questions used for the standard evaluation of courses within the University. Responses were given on a Likert scale of 1–5 where (with the exception of questions 16–18) 1 was most positive. In questions 16–18, 3 was the ideal response. The second part of the questionnaire consisted of the following open-ended questions: (1) For me, the best aspect of the course was (2) The change I would most like to see in the course is (3) Any other comments?

The data generated by each of the standard questions were subjected to statistical analysis. In view of the fact that the use of a mean in association with a Likert scale tends to assume that each item on the scale is of equal value, and that the mean can be unduly affected by a small number of responses on either end of the scale, the "interpolated" median (Webb, 1994, p.136) was adopted as an indication of central tendency. Responses to the open-ended questions were transcribed and subjected to a simple qualitative analysis that sought common themes and patterns. Of the 71 students who responded to the questionnaire, 46 (64.7%) made one or more written comments.

In general, the quantitative data suggested that students rated the lecturers' attitude to students (median 1.4) and their contribution to the course (median 1.9) very highly. These data were supported by students' comments. The workload, level of content and relation between reading materials and lectures was perceived to be well balanced. Students also indicated that they prepared before coming to class (median 1.6). Close to 50% of the comments relating to the "best aspect" of the course were associated with the workshops. Students focused on the usefulness of the case studies, the discussion of the case studies, and the self-assessment questions. For example:

> "The workshops really helped my learning" (43/2000).[†]

> "The group discussion in the workshops is invaluable. It gives each student the chance to clear up any misconceptions they may have as well as interact with other students and help them with difficulties" (21/2000).

> "Working through case studies in small groups. We pooled our knowledge and nutted [out] the answers all together. Much more interesting than doing it on your own" (16/2000).

Students' ratings of the worth of the self-assessment questions (median 1.5) supported these findings. However, of concern were the relatively lower ratings for: increase in interest in the subject matter (median 2.4); enjoyment of learning the subject matter (median 2.7), the effort that students put into the course (median 2.4), challenge and motivation to learn (median 2.5), the value of class discussion (median 2.2), and selection of teaching methods (median 2.3). In response to the question about the changes that students wanted to see, nearly 50% of the comments focused on more practice of exam questions and on the need for more lectures. They were particularly concerned with what they were required to know, and what they needed to know for assessment. For example:

> "Guidelines on important information needed to know... highlight main points—what we need *to know*" (10/2000, student's emphasis).

> "More exam-like questions would be good to practice with" (6/2000).

> "Model answers for case studies would be helpful for exam revision" (17/2000).

> "More focus on what to expect in exam questions" (44/2000).

In addition, the tutorials were not well received. Despite a few comments about their clinical relevance, they were perceived to be unnecessary and to lack structure.

Perceptions of the Teaching Team

In general, the evaluation showed that the course worked reasonably well. However, students' views confirmed the perceptions of the teaching team. Despite the adoption of teaching methods that were understood to be "student-centred", the course was

[†]Responses are identified by student number and year of evaluation.

falling short of its potential. The following sections will discuss the revision of the CPKC, against a backdrop of relevant research on teaching and learning.

Teachers' Thinking and its Relation to the Teaching Learning Context

In line with Trigwell's model, revision of the CPKC required some exploration of the *thinking behind the teaching*, or the (from school-based research) *pedagogical content knowledge* (Wilson *et al.*, 1987). In explanation, Wilson *et al.*, indicate that as teachers develop their expertise, they make decisions that draw on a particular form of knowledge. This comprises an integration of knowledge of the learner, knowledge of the curriculum, knowledge of the context, and knowledge of teaching.

A brief, but somewhat polarised, summary of research on a similar area in higher education provides a background. In a review of 13 studies of academics' conceptions of teaching, Kember (1997) reports a range of views of teaching from those that were "teacher-centred" and "content-oriented", to those that were "student-centred" and "learning-oriented" (see also Prosser and Trigwell, 1999; Samuelowicz and Bain, 1992). Knowledge of the variation in views is important. There is accumulating evidence to suggest that the way in which university teachers think about teaching and learning, directly relates to their approach to teaching and to students' approaches to learning (Entwistle and Walker, 2000). In general, teacher-centred and content-oriented ways of thinking about teaching are more often associated with traditional or didactic practices in which the key activity is the transmission of knowledge. The teacher is seen to be responsible for providing the information and the student learns it. In contrast, student focused ways of thinking about teaching are more concerned with the facilitation of learning. This approach to teaching is aimed at helping students to make relations with the knowledge in ways that bring about understanding and conceptual change. Logically, these two views of teaching can be associated with particular views of the nature of knowledge, learning and assessment. In the former, knowledge tends to be treated as a transmittable entity that can be learned and reproduced, and assessment is likely to require its reproduction, e.g. multiple choice and short answer tests. In the latter, knowledge is seen as dynamic and changing, learning involves constructing one's own understanding, and assessment provides guidance and structure (e.g. analytic tasks involving inquiry and synthesis).

A similar relation exists between students' understanding of learning and the way they go about it (for a broad overview see Prosser and Trigwell, 1999). More specifically, Bond (2000) identified four broad categories of ways in which students understand learning. These categories are: (1) Learning as a reproductive act; (2) Learning that is concerned with making a relation with knowledge (e.g. practising and applying it in given or new situations); (3) Learning that involves constructing knowledge (a network or body of knowledge); (4) Learning that is concerned with change and transformation (as in seeing something differently, and changing one's view of the subject or world). Students' views of knowledge, teaching, and assessment are coherently related to these experiences. For example, students who believe that learning is reproducing, experience knowledge as a static entity that is given and that can be reproduced for a test situation, and see teachers as the providers of that information. In contrast, students who understand learning in terms of constructing or transforming, think of knowledge as something that can be seen in different ways, can be manipulated and used to develop other understandings, and they understand that teaching facilitates this development (Bond, 2000). Students who think about learning in these ways are more likely to use approaches to learning that are critically reflective, and develop desirable learning outcomes.

The research outlined above focuses on how teachers and students understand the activities of teaching and learning. Given these findings, it is unsurprising that "there is one way of conceiving university teaching that is more likely to result in higher quality student learning than other ways of thinking" (Trigwell, 2001). Trigwell's claim is backed up by the large amount of research that looks at the nature of "good" teaching (e.g. Ramsden *et al.*, 1995). The following characteristic is one of seven that are considered essential for good teaching:

> "Good teachers demonstrate an ability to transform and extend knowledge, rather than merely transmitting it; they draw on their knowledge of their subject, their knowledge of their learners, and their general pedagogical knowledge to transform the concepts of their discipline into terms that are understandable to their students" (Ramsden *et al.*, 1995, p. 24).

It will be evident that this characteristic is described in terms of teaching that is "student-centred" and "learning-oriented", but it is also concerned with the use of "pedagogical content knowledge" (Ramsden *et al.*, 1995, p. 24). Intentions, knowledge, beliefs and values are integrally linked in this way of thinking about teaching. In addition, a teacher's intention is strongly affected by the supports and/or constraints inherent in the teaching/learning context. Thus, teaching practices are influenced by the university traditions and cultural norms in which a curriculum is located (e.g. Barnett, 1997). So the intention to adopt

student-focused teaching strategies may inadvertently be undermined by other factors.

This kind of undermining is implied in the outline of the CPKC and in the data that derives from students' views of the course. Students' concerns with assessment issues, their need for more knowledge, and their requests for guidance about what they need to know (either in lectures, or as model answers) suggests an emphasis on reproductive approaches to learning. The description of the assessment in the CPKC (as outlined earlier) indicates that despite differences in teaching method, the basic philosophy of teaching and learning associated with the fourth-year resembles that of the previous three. For example, only 20% of the assessment is internal to the course, and a large proportion of the total assessment marks derive from multiple choice or short answer tests.

Usually, these kinds of assessment practices are associated with a curriculum that focuses on knowledge acquisition and the encouragement of reproduction. So small group teaching and the use of case studies are not indicators of student-focused teaching. Neither are lectures an indicator of teacher-focused teaching. Rather, the important concept that derives from our analysis of the CPKC and the research outlined above is the idea of the intention that underpins the teaching or learning activity (Trigwell, 2001). When the thinking behind the teaching is made explicit, it is the coherence of the alignment between the context, planning, teaching strategies and assessment tasks (Biggs, 1999) that becomes the dominating concern rather than a focus on the teaching technique.

The Relation Between Teachers' Thinking and Teachers' Planning

We illustrate this relation between teachers' thinking and teachers' planning (Trigwell, 2001) by exploring some of the thinking behind the changes that were eventually made to the CPKC.

A fairly standard definition of pharmacokinetics is:

> ...the study of the absorption, distribution, metabolism and elimination of drugs so that a mathematical basis for the description and prediction of the time-course of drugs (and their metabolites) can be provided.

Not only does this definition derive from a knowledge-centred curriculum, but it also represents pharmacokinetics as a study of facts and equations; a view of knowledge that tends to be static and unchanging, and one that lends itself to reproduction. However, the rate of development of new pharmaceuticals is exponential so a curriculum that focuses on knowledge of drugs *per se* is likely to be obsolete for the practising graduate.

Instead, what is needed is an identification of the requisite graduate capacities and skills.

For the teaching team, the key word in the definition was prediction. Their aim was to produce graduates who have a critical understanding of the application of principles of pharmacokinetics and who can predict how a specific drug will behave in any individual. That is, graduates must be able to deal with as yet unrecognised situations. This aim was unlikely to be achieved by a curriculum that focused on the transmission of information. What was required was an approach that changed the way in which students experienced pharmacokinetics (Laurillard, 1993). The revised CPKC required students to develop a critical approach to pharmacokinetics and produce graduates who could use the associated skills in new and challenging situations. Accordingly, "clinical pharmacokinetics" was redefined as a study of "the dynamic interrelationship between the patient, the disease, the treatment, pharmacodynamics, and pharmacokinetics." The new definition brought the person into the "equation"; something that is often ignored by the "apprentice" clinical pharmacist. It also suggested a curriculum in which the different parts constituted a related whole so that students would be encouraged to draw on and apply knowledge obtained from almost everywhere else within the pharmacy degree, rather than simply focusing on learning new facts.

Thus, the intention of the new curriculum is to encourage learning for understanding, to develop students' critical thinking, problem solving skills, and problem approach behaviours (i.e. Ramsden *et al.*, 1995). More specifically, when a graduate is confronted with a pharmacokinetic problem involving a patient, who may have multiple disease states, and is taking several medications, they must first be able to identify that (a) a problem exists, and (b) the nature of the problem. It is important for them to be able to prioritise their actions. They must be able to use their knowledge of physiology, pharmacology, and pathology to identify which aspects of the disease are important to the pharmacokinetic problem. They can then use their knowledge of pharmacokinetics and drug therapy to offer solutions. Their solutions should be based on good evidence and they should be able to justify their decisions, using a logical and reasoned argument, where no direct evidence exists.

Teachers' Strategies

Based on the arguments outlined above, a number of modifications were made to the CPKC from within its original framework. They were aimed at changing and/or enhancing the learning experience of the students so that they were more likely to meet the desired learning outcomes.

Clear Goals

Research indicates that the communication of clear goals and the identification of learning outcomes is one of the essential characteristics of good teaching (Ramsden, 1992; Ramsden *et al.*, 1995). Students' views of the CPKC suggested that this area required attention. Thus, one of the first planning activities was the design of appropriate learning outcomes; in this case graduate outcomes which could become a guide for the way in which the subject was to be taught (Biggs, 1999). Accordingly, one of the first changes to the CPKC was the design of an introductory lecture in which students were provided with an explanation of the course objectives, the relevance of the objectives to the course and to graduate outcomes, and the way in which teaching, learning and assessment were aligned with the objectives.

A graduate profile that requires students to demonstrate problem-recognition and problem-solving capabilities means that they must understand what these skills involve. Explaining the course objectives was integral to initiating this process. The next task was to encourage students to engage in learning activities that were likely to result in the desired learning outcomes (Biggs, 1999; Ramsden, 1992). In 2000, it was evident that students understood teaching and learning in terms of passing exams and gaining necessary qualifications; they were output oriented. In contrast, the teaching team wanted students to be personally involved in the learning process and to be interested in, and excited by, the course content. This too was an aim of the introductory lecture. Ramsden *et al.* (1995) argue that "good teachers show an enthusiasm for their subject, and a desire to share it with their students." The lecture was used to ignite the flame.

Learning Activities

In 2000, the workshops in the CPKC were structured around case studies that required a problem-based learning (PBL) approach, and the review suggested that they worked reasonably well. However, the case studies were revised to encourage students to adopt a more holistic approach to solving the problems; a strategy that has proved successful in other pharmacy degrees (Alsharif *et al.*, 1999; Brazeau *et al.*, 1999; Tebbett *et al.*, 1997). In 2000, evaluation of the CPKC indicated that the group dynamics within the workshops were sometimes detrimental to the learning process. Students commented that their peers were "under-prepared", "over-prepared" (having already completed the case studies that were within the manuals), or "unwilling to share ideas". To address these issues the cases were taken out of the workshop pre-reading material and provided in each workshop. A system of peer assessment (worth 5% of the course marks) was introduced in order to stimulate students into preparing for, and contributing to, the workshops.

In contrast to the workshops, little was achieved in the tutorials. These sessions tended to repeat workshop material and students who were unsure about the subject were reluctant to speak out in front of over 100 classmates. Furthermore, to be effective, the workshops needed to be adequately supported by well-structured lectures (Brazeau *et al.*, 1999). But, the existing lectures were not aligned with the workshop material. Therefore the tutorials were removed and the number of lectures was increased. However, rather than focusing only on knowledge transmission, the lectures used case studies to make decisions on drug therapy, and explore the scientific rationale (with an emphasis on pharmacokinetic aspects) behind those decisions. Thus, like the workshops, the lectures modelled the thinking skills identified above and provided an integration of apparently disparate areas of knowledge. This approach helped students to take a holistic and integrated approach to the case studies. The focus on case studies also aligned the teaching with the assessment activities.

Assessment

Another characteristic of good teaching is the "use [of] valid and appropriate assessment methods, and [the provision of] high quality feedback to... students" (Ramsden *et al.*, 1995). In the CPKC "valid" was interpreted as alignment between the intended graduate outcomes and the nature and requirements of the assessment tasks (Biggs, 1999).

The existing multiple-choice tests not only encouraged a surface approach to learning (Ramsden, 1992) but they failed to meet the validity criterion. The internally assessed, multiple-choice test was replaced with a research project, based on a fictitious drug, which was conducted in small groups. The students were given a set of pharmacokinetic data for the drug, which they were told had been obtained from young, healthy volunteers. They were given a profile of a patient of a certain age, body type and with a specific disease. Their task was to research the difference between their patient's body composition, metabolism and biochemistry, and that of the young, healthy volunteer. They were then asked to predict how the pharmacokinetics of the drug for the patient would differ from the healthy volunteer, and make recommendations regarding therapy for the patient. The assignment focused on the use of basic principles of pharmacokinetics. The aim was to encourage the development of the skills in the use of any drug that the graduate may

encounter during their career, including drugs that are not yet developed.

The final exam was also altered substantially. Multiple-choice and short answer questions are often associated with a reproductive approach to learning. These sections were removed, leaving room to expand the case study section. Instead of increasing the amount of content within this section, more emphasis was placed on the requirement to think critically while using an integrated knowledge base. Traditionally, equations required to answer questions were supplied on a separate equation sheet. This practice was continued so that students could concentrate on the interpretation and analysis of the results of the calculations rather than the rote learning of lists of equations.

Students' Views of the CPKC in 2001—A Comparative Analysis

The new CPKC was delivered in 2001. Students' views were evaluated through the same questionnaire, methods and analytical procedures that were used in 2000. In 2001, 72 students (72% of enrolment) completed the questionnaire (67% in 2000). Of these, 56 (77.7%) made one or more written comments (64.7% in 2000). Changes in students' views were established by comparing the data for 2000 and 2001 through the use of a Mann–Whitney *U* test in which a p of <0.05 was considered significant. In the following sections, the results of the two evaluations are compared.

Students' Views: An Evaluation of the Changes

In 2000, students' responses to the open ended questions were predominantly *concerns* regarding the course structure, the acquisition of *more* knowledge, and the technical requirements for assessment. In contrast, in 2001 there was a qualitative change in the nature of the responses to the same questions. For instance, in 2000 students' typically commented:

> "...keep the overheads on for longer please... should give us more time to copy" (30/2000).

And:

> "could we put more focus on exam questions especially MCQ test" (1/2000).

In light of the research outlined previously, these data suggest that students' approach to the course was essentially reproductive. Specifically, they were relying on an external source for much of their learning. Moreover, comments were concerned predominantly with observations about issues with the course, demonstrating an external focus. In contrast, in 2001, almost all the students' comments were concerned with their own learning experiences. For example, in response to the question regarding the best aspect of the course, responses included:

> "The chance in workshops to apply what we had learnt" (25/2001).

And:

> "The workshops were excellent because we got to work on case scenarios and it gave a good understanding of the clinical bits" (44/2001).

Of the 56 students who gave written responses in 2001, approximately 85% of the comments could be interpreted as a positive appreciation of the course. As in 2000, the students continued to focus on workshops, lectures, and assessment but the nature of the responses differed considerably. In 2001, they were concerned with the actual benefits of different aspects of teaching and assessment. For instance, a total of 30 (54%) comments related to understanding, application or some other aspect of learning. To illustrate this, students who perceived one of the best aspects of the course to be the workshops, made the following comments:

> "...working and discussion in a group-exchanging ideas is a good way to learn" (6/2001).

> "...they made understanding of the calculations better and assisted in the general understanding of the course material" (30/2001).

> "...able to interact and get a better understanding of concepts" (24/2001).

It was also evident that students' comments had shifted away from a concern about the requirements for assessment to interest in what they were learning and how it was assessed. They were also aware of the direct relation between learning and assessment:

> "The assignment was a good learning process" (23/2001).

There were numerous statements to the effect that the best aspect of the course was the positive relation between lectures, workshops, assessment, and other subjects. Moreover, students indicated that the course could be improved further by having more of the same.

> "The assignment was directly related to the course and increased our understanding of the concepts we learn" (15/2001).

> "The assignment helped bring together things learnt in workshops and theory and apply them to a specific situation" (16/2001).

There was also a significant increase in comments that the course was relevant to pharmacy practice. Specifically, the assignment using the fictitious drug was seen as particularly relevant to the real world:

> "The assignment—it brought all the pharmacokinetic information together and made it relevant to the 'real world'. It increased my understanding of the course greatly" (19/2001).

"The pharmacokinetic assignment—put knowledge into practice" (22/2001).

"I thought the assignment was good—actually made you think about how to apply pharmacokinetic concepts" (38/2001).

As with the comments above, there was a focus on more relational aspects of learning—the integration of knowledge and its application:

"Better incorporated knowledge—became 'common sense knowledge'..." (2/2001).

The quantitative results provide strong support for the qualitative data. For instance, all the Z scores on the Mann Whitney *U* were negative, indicating that, between 2000 and 2001, there was a shift towards the lower, more positive, end of the Likert scale. This was evident either as an actual numerical change on the scale, or as a shift in distribution. In particular, questions related to students' interest in the subject matter, enjoyment of learning, and challenge and motivation to learn yielded responses that were significantly different ($p < 0.05$) in 2001 (see Table I).

In addition, there was a significant difference in perceptions of the appropriateness of the teaching method ($p < 0.02$) and the relation between lectures and reading materials ($p < 0.001$).

DISCUSSION AND CONCLUSIONS

The changes to the CPKC were made without significant changes to the teaching settings or the staff/student workload. Therefore, this case study illustrates how small changes to an existing curriculum can make a qualitative difference in students' experiences of learning. Our main argument is that such changes to teaching and curriculum must be made at both the philosophical and strategic levels. In 2000, the CPKC was basically a study of the TDM drugs using clinical examples. Its focus suggested teaching and curriculum practices that were "teacher-centred" and "content-oriented" (Kember, 1997). In 2001, it became a study of the clinical application of pharmacokinetic principles, using the TDM drugs to emphasise and illustrate these principles. This decision to change the thinking about the taught content rather than increase it was one of the most crucial to the course. For example, in response to the question of the best aspect of the course, one student commented:

"That we did a few drugs really well rather than many drugs and examples badly" (29/2001).

This apparently simple change in focus comprises more than a concern with the content of the course. It involves the way in which pharmacokinetic knowledge "works" and the thinking behind professional practice; the clinical or pharmaceutical reasoning. It also involves an integration of this kind of professional knowledge with a knowledge of teaching and learning, which Wilson *et al.* (1987) described as "pedagogical content knowledge". The changes in teaching and curriculum were the practical realisation of this concept.

This notion of pharmaceutical reasoning was integral to the new curriculum. In general, the data suggest that this concept made a crucial contribution to the change in students' thinking. In the curriculum it was supported structurally, by the constructive alignment (Biggs, 1999) of different aspects of the course with each other. One of the main features was the replacement of tutorials with a new style of lecture that was essentially based around a case study. The case, which followed the life of a patient and explored the scientific and clinical rationale behind decisions on drug therapy, required vertical and horizontal integration of knowledge from almost everywhere within the pharmacy degree. The use of the case study also required students to work with the course material in a different way; a problem to be solved rather than information to be reproduced. Thus, they required a critical understanding of the material.

Considerable effort was made to relate the content of the lectures to readings, workshops and assessment. Students' comments suggest that the reenforcement of key ideas and principles was one of the most important aspects of the course. Indeed, one of the main requests relating to improvement was for more of the same. Many of the changes that were made focused on engaging students in the learning activities. These included making the course more personalised and explaining in detail the relationship between course objectives, learning

TABLE I Data relating to students' experiences of learning

Question	Median 2000	Median 2001	Z^*	p
Did this course increase your interest in the subject matter? Yes greatly...No, not all	2.4	2.1	−2.47	0.01
I enjoyed learning about the subject matter Very much...Not at all	2.7	2.2	−2.47	0.002
In this course I felt challenged and motivated to learn Almost always...Almost never	2.5	2.1	−2.44	0.02

*Mann–Whitney *U test*.

activities, and assessment. Probably of most significance in bringing about changes in students' thinking, were the changes to the assessment. The introduction of a problem solving assignment using a fictitious drug and the use of case studies in the examination eliminated the possibility of success in reproductive approaches to assessment tasks. Thus, pharmaceutical reasoning was modelled in teaching through a problem solving approach and the extensive use of case studies, and it was affirmed through the validity of the assessment.

There were no preconceptions regarding the kinds of changes that showed up in the evaluation data. In 2001, the questionnaire did not capture the full extent of the change, and the qualitative detail of the shift could have been captured using a more thorough evaluation tool. In fact, as we conducted this study we became aware that the design of the questionnaire itself reflected a "teacher-centred" and "content-oriented" (Kember, 1997) focus. This issue was exemplified in the way in which the students' responses in 2001 continued to focus on teaching method despite differences in meaning. So we failed to extend the idea of constructive alignment to the evaluation of teaching and learning. We also realise that any claim to significant changes in students' understandings should be accompanied by more extensive research into the "thinking behind their learning". However, what we observed in the data is well supported in educational research and a strong indication that it is possible to significantly enhance student learning with existing resources.

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APPENDIX A

The questionnaire

1.	How much do you feel you have learned or accomplished in the course?	A great deal	1	2	3	4	5	Very little
2.	Did this course increase your interest in the subject matter?	Yes, greatly	1	2	3	4	5	No, not at all
3.	I enjoyed learning about this subject matter:	Very much	1	2	3	4	5	Not at all
4.	How much effort did you put into this course?	A great deal	1	2	3	4	5	Very little
5.	I prepared before coming to class	Always	1	2	3	4	5	Never
6.	Rate the contribution of the lecturer to this course:	Excellent	1	2	3	4	5	Poor
7.	How would you characterize the lecturer's ability to explain?	Excellent	1	2	3	4	5	Very poor
8.	I could clearly hear what the lecturer was saying:	Almost always	1	2	3	4	5	Almost never
9.	In this course, I felt challenged and motivated to learn:	Almost always	1	2	3	4	5	Almost never
10.	Was class discussion a valuable part of this course?	Yes, very valuable	1	2	3	4	5	No, of little value
11.	Class discussion had clear direction and purpose:	Almost always	1	2	3	4	5	Almost never
12.	How would you describe the lecturer's attitude toward students in the course?	Very helpful	1	2	3	4	5	Indifferent
13.	Did the lecturer seem genuinely concerned about each student's progress?	Yes, very much so	1	2	3	4	5	No, not at all
14.	The course seemed:	Very well organized	1	2	3	4	5	Very disorganized
15.	Teaching methods used in this course seemed:	Very well chosen	1	2	3	4	5	Poorly chosen
16.	How did lectures relate to material in textbooks and other readings?	Too much overlap	1	2	3	4	5	Too unrelated
17.	How do you view the level of course content?	Too advanced	1	2	3	4	5	Too elementary
18.	How much work did this course require?	Much too much	1	2	3	4	5	Much too little
19.	How worthwhile did you find the self assessment	Very worthwhile	1	2	3	4	5	Worthless questions
20.	Overall, rate the course reading materials (texts, assigned readings, handouts, etc.):	Excellent	1	2	3	4	5	Very poor
21.	Did tutorials/workshops contribute to your understanding of this subject?	Yes, greatly	1	2	3	4	5	No, not at all