Chapter 3

Learning and teaching of basic sciences in the health related professions in the 21st Century

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Previous research in pure sciences reported a link between students' approaches to study and their perceptions of both the learning environment (Trigwell & Prosser, 1991) and their conceptions of learning (Van Rossum & Schenk, 1984). As far as perceptions of the learning environment are concerned, it was found that aspects such as the nature of the objectives and self-directed learning capabilities of students are associated with deep approaches to learning, whereas assessment emphasising rote learning and heavy workloads favours students resorting to surface approaches (Entwistle & Ramsden, 1983; Kember, 1996). Conceptions of learning on the other hand, refers to the way students view learning (Van Rossum & Schenk, 1984; Prosser & Trigwell, 1999). These authors found that those who see learning as a method of achieving greater meaning or understanding were more likely to follow deep approaches to learning, as compared to those whose view of the purpose of learning is more limited. This latter group were suggested to be more likely to follow surface approaches to learning. More specifically, research into the learning of physics (Prosser, Walker & Millar, 1996) and mathematics (Crawford, Gordon, Nicholas & Prosser, 1998), established a greater likelihood of obtaining a higher quality learning outcome when students pursue a deep approach to learning. As these findings were obtained with students studying familiar, non-compulsory subjects, in non professional degrees (e.g., science), the question arose whether these same relationships could be extended to applied science students studying unfamiliar, compulsory subjects, in professional degrees.

The Faculty of Health Sciences at the University of Sydney provides courses in over ten different allied health professions (e.g., communication sciences and disorders, medical radiation sciences), all of which involve the study of some basic science. The Discipline of Biomedical Science caters for all the biomedical foundation teaching in the faculty, a role commonly known as service teaching. The required standard of entry (University Admissions Index (UAI)), varies widely among the courses, and in general, there are no topic pre-requisites for entry into any of the courses. Students studying basic sciences therefore exhibit different backgrounds in prior topic knowledge and have different professional goals and thus interest profiles. There is even a wide range of understanding of what their chosen profession really involves, resulting in many students showing ambivalence about engaging with apparently 'irrelevant' material in a compulsory subject. In the past, highly tailored subjects were offered to students in different professional degree programmes. This minimised, but did not eliminate, the effect of many of these issues. For example, topic background knowledge was more uniform within a single professional group. Decreases in funding have led to commonality of basic science instruction in large multidisciplinary classes. In addition, students are pursuing unfamiliar topics (e.g., biochemistry), that are compulsory parts of a professional degree, where the emphasis is on practice rather than foundation studies. The challenge therefore has been not only to pitch content at an appropriate level, but also to put it in a context that has meaning for the students. Hence, it seemed crucial to obtain information about the views of incoming students, so that the learning environment of the different student groups at the Faculty of Health Sciences could be enhanced. For this purpose an analysis of students' pre-semester conceptions of biochemistry and approaches to study was undertaken (Minasian-Batmanian, Lingatd & Prosser, 2005).

Students' experiences of learning and the relation between these experiences and learning outcomes have been reported both from qualitative (e.g., phenomenographic) and quantitative (e.g., factor and cluster analysis) perspectives (Marton, Hounsell & Entwistle, 1997; Prosser & Trigwell, 1999; Ramsden, 2003). Phenomenography involves investigating the variation in students' experiences of a particular phenomenon and describing these experiences in terms of structurally related categories of description which are not pre-determined, but are constituted in relationship to the data **(**Marton et al., 1997**)**. Historically this technique used in-depth interviews with a small number of individuals thought to represent the variation in the selected population. An alternative approach has been reported to make use of short open ended written statements from a large number of individuals (Prosser, 2002). The latter qualitative phenomenographic approach was particularly applicable to our large student group and was therefore chosen to analyse students' views and experiences in the present study. It enabled students to describe their views in their own words, rather than choosing a best alternative from a prepared list, thereby allowing a greater spectrum of experience to be expressed and captured.

Initially it was intended to survey the students solely at the beginning of their first year university course. However, the results proved to be so surprisingly unexpected (Minasian-Batmanian, Lingard & Prosser, 2005), that it was decided to repeat the survey using the same methodology after the topic material was delivered and they had completed their semester of learning. This post-semester study was recently finalised and reported (Minasian-Batmanian, Lingard & Prosser, 2006). This chapter compares these pre- and post-semester results. It describes how students' perceptions changed after a semester of studying biochemistry and the changes made to teaching to improve conceptions and approaches to study.

Method

First year students (203 pre-semester and 151 end-semester, of 250) at the University's Faculty of Health Sciences completed surveys on their experiences of learning biochemistry**.** The cohort comprised 150 Physiotherapy and 100 exercise and sports science students studying biochemistry in a multidisciplinary class. The mean age of 19.1 ± 2.5 SD years (n=149) and range of 17-36 reflects the fact that 24% were not immediate school-leavers. The University entry score (UAI) was high (94.5 ± 3.7; n=125; Range 83.9 - 99.9) and two-thirds were female. Only half of the students had studied chemistry to year 12 and 20% had not even studied it to year 10. A similar distribution was evident in the study of biology. Fifteen percent of students had completed both chemistry and biology to year 12; 11% had studied neither of these beyond year 10.

In addition to some demographic data, both surveys consisted of a half-page open written response to the questions shown below in Table 3.1. The wording of the questions was such that they could easily be understood and students could provide answers in their own words.

Table 3.1. Survey design

	Open-ended questions
Approaches to learning	Pre-semester 1) What do you think you need to do to learn biochemistry? End-semester 2) How did you approach the study of biochemistry in Semester 1? What sort of things did you do and why did you do them?
Conceptions of subject	Pre-semester 1) What do you think biochemistry is about? End-semester 2) Having now completed Semester 1, what do you think biochemistry is about?

A phenomenographic methodology originally described by Marton and Saljo (1976) and further refined by Marton et al. (1997) was used to sort student responses into broad categories of description for each question. A detailed description of this process as applied to our study has already been published (Minasian-Batmanian et al., 2006).

The analyses were carried out in the framework of deep or surface approaches to learning and fragmented and cohesive conceptions. They resulted in a similar set of categories for both pre-semester and end-semester surveys. However, the questions in the end-semester survey elicited a few responses of a totally different nature that remained 'unclassified'.

Results

How did students approach the learning of biochemistry?

An analysis of the students' responses to the survey questions in Table 3.1, revealed a set of 4 qualitatively different, but logically related categories (A to D) describing their approaches to learning biochemistry, upon entry to university. On the other hand, it can be seen that two of these categories (A and C) were obtained for students reporting their first semester experience. Table 3.2 presents descriptions of these categories and the associated representative quotes from the student surveys. Some end-semester survey responses (~6%) could not be categorised into the groups described above, or any other group.

Table 3.2. Categories of responses (pre- and end-semester) for students' approaches to learning biochemistry

Category	Pre-semester representative quotes	End-semester representative quotes
A. Learning by meeting class requirements with the intention to reproduce - process driven	'Listen to lecturers, take notes, summarise, be studious' 'Read textbook, attend all lectures, pracs. Keep up to speed (organisation)'	'Studied to pass' 'Read through lecture notes, learnt it' 'I went over lecture notes to review and study for the exam' 'I left everything to last minute, then crammed'
B. Learning by studying chemistry and/ or biology with the intention to reproduce chemistry and biology - content driven	'Have a basic chemistry knowledge (e.g., element, moles, reactions etc) and have a basic knowledge of biology' 'Know about some types of proteins in the body, some hydrocarbon compounds, lipids and the role of water in the body' 'I need to have background knowledge on chemistry and biology. Therefore I am going to have to do some study in biology'	None in this category
C. Learning by relating chemistry and/or biology to the body with the intention to understand how biology and chemistry relate to body function	'Have an understanding of biology and how chemistry plays a vital role within it' 'Study the relationship between chemistry and biology, through how chemistry principles work in the human body'	'Attend all lectures. Drew on previous knowledge in HSC chemistry and biology. In general, revised and asked questions until I understood' 'Read textbook for greater understanding, did practice exams to see what needed review
D. Learning by conceptualising the body in terms of chemical and biological processes with the intention to understand the whole body in biological and chemical terms	'Understand both the basics of the biological structures and functions and the basic chemical principles, and then understand how it comes together as whole body functions'	None in this category

The categories were analysed in terms of the students' intentions for their studies and their strategies for achieving their intentions. The relationships between these two factors (intentions and strategies) have been explained in detail in a previous publication (Minasian-Batmanian et al., 2006).

The approaches identified by these categories are inclusive and form a logical hierarchy, progressing from an intention to reproduce knowledge (Categories A and B) to an intention to seek relationships between items of new information and to apply it to understanding a greater whole (Categories C and D). The approach to reproduction (surface approach) is reflected in comments emphasising learning content and following processes such as printing notes and attending lectures. In contrast, those who expressed an intention to understand (deeper approach) were focusing on how chemistry and biology related to the body.

Many students who sought understanding also intended to use some surface techniques, so these latter approaches were included in their overall strategy. However, students whose approach was categorised as A reported using process only. This overall situation was the same in both pre- and end-semester surveys. The difference, however, lay in the fact that in the end-semester survey, no responses were found in either categories B or D. The absence of any responses in category D may simply reflect the very small numbers involved (2 in the pre- and 0 in the end-semester survey). However, the absence of responses in category B indicates that students have narrowed their focus, such that a pre-semester intention to focus on content had been abandoned and the sole focus of the surface strategy was on process.

What were the students' conceptions of biochemistry?

In the pre-semester survey, the students were asked what they thought biochemistry was about. Then at the end of the semester, they were asked to reflect on what they now thought it was about (Table 3.1). An analysis of the students' responses revealed a set of four categories of students' conceptions of biochemistry, which were the same for the pre- and end-semester surveys. Table 3.3 summarises a brief description of these categories and representative quotes.

Categories A and B represent simple or fragmented ideas with chemistry and biology not integrated with the overall functioning of the body, whereas categories C and D represent higher-level cohesive conceptions of biochemistry with chemistry and biology being the basis for complex function. (See Minasian-Batmanian et al. (2006) for the logical relationship among these categories.)

As for the categories of approaches to learning, these categories of conception are also logically inclusive, with the responses of students who viewed the topic as a coherent whole also recognising the component parts. A student who sees a larger picture and conceives the body as a functioning whole that is reliant on chemistry and/or biology is apparently much more able to relate small items of information than a student who only conceives that biochemistry is simply chemistry and/or biology related to the body.

Table 3.3. Categories of the responses (pre- and end-semester) for students' conceptions of biochemistry

Category	Pre-semester representative quotes	End-semester representative quotes
A. Biochemistry is the study of chemistry or biology only	'Chemical processes within the body' 'Chemistry based on living things' 'The chemical reactions that occur in the body'	'The study of organic and inorganic compounds' 'Chemistry involved with the body' 'Chemistry reactions in the body'
B. Biochemistry is the study of chemistry and biology	'Biology and Chemistry combined into one subject' 'Biology mixed with chemistry'	'Biology and chemistry' 'Chemistry and biology combined' 'Processes in the body, both biological and chemical'
C. Biochemistry is the study of biology and/or chemistry related to the body	' The chemical reactions which take place within all living things to maintain homeostasis and keep them alive' 'A combination of biology and chemistry that explains the structure and function of living organisms'	'How reactions in the body take place, why, and the consequences of each to provide what we need to survive' 'Understanding at the microscopic level how our body works so that we may have a more complete understanding of the entire human anatomy'
D. Biochemistry is the study of body structure and function and how they relate to chemistry and/or biology	'About what makes us tick – what enables us to move our limbs and bodies. Our digestive, reproductive, respiratory and homeostatic mechanisms are run by chemical reactions'	'Study of the chemical basis of life. Pretty well explains how the body operates on a molecular level to arrive at something greater.'

Distribution of responses and the link between approach and conception

The distribution of responses across categories for both pre- and end-semester approaches and conceptions is presented in Table 3.4.

Table 3.4. Distribution of pre- and end-semester approaches and conceptions

Approach/Conceptions	Pre-semester % (n)	End-semester % (n)
Approach		
Surface		
A. Process driven	54.1 (98)	82.6 (100)
B. Content driven	32.6 (59)	0 (0)
Deep		
C. Understanding how chemistry and/or biology relate to the body	12.2 (22)	17.4 (21)
D. The body: its foundation in chemical and biological processes	1.1 (2)	0 (0)
Missing data (no response)	(22)	(30)
Total	(203)	(151)
Conception		
Fragmented		
A. Chemistry or biology	51.5 (86)	45.7 (48)
B. Chemistry and biology	31.7 (53)	25.7 (27)
Cohesive		
C. Biology and/or chemistry related to the body	13.8 (23)	27.6 (29)
D. Body structure and function: its dependence on chemistry and/or biology	3.0 (5)	1.0 (1)
Missing Data (no response)	(36)	(46)
Total	(203)	(151)

Table 3.4 indicates that the percentage of students who at the end of semester reported using surface learning approaches did not change from their earlier pre-semester expressed intentions (82.6% v. 86.7%). However, the breakdown of the

surface category has changed markedly, with no responses whatsoever being obtained in category B at the end of semester.

There is a decrease in the number of students who reported a 'fragmented' conception of the topic (prior 83.2% cf. post 71.4%). A correspondingly larger group of the students (post 28.6% cf. prior 16.8%) focused on the topics as being constituent parts related to a greater whole (in this case the function of the body).

With student conceptions of biochemistry and their approach to learning defined independently by the above categorisations, it was then possible to explore any potential relationship between the two. Table 3.5 shows an analysis of the relationship between topic conceptions and learning approaches in both the pre- and end-semester surveys.

Table 3.5. Relationship between approaches to learning biochemistry and conceptions of biochemistry as determined at pre- and end-semester times

Approach	Conception column %			
	Fragmented		Cohesive	
	Pre-semester (A+B)	End-semester (A+B)	Pre-semester (C+D)	End-semester (C+D)
Surface				
• Pre (A+B)	91%		63%	
• End (A+B)*		88%		66%
Deep				
• Pre (C+D)	9%		37%	
• End (C+D)*		12%		34%

Chi-square = 14.5, p < 0.001, for pre-semester results.
Chi-square = 10.4, p = 0.014 (exact significance), for end-semester results.
* There were no responses in categories B or D in the end-semester survey.

In both pre- and end-semester cases there is a statistically significant relationship between approaches and conceptions. (Chi-square = 14.5, p<0.001; Chi-square = 10.4, p = 0.014, respectively). Moreover, the relationship shows that in both pre- and end-semester surveys, students with fragmented conceptions, compared to those with a cohesive conception, are much more likely to adopt surface rather than deep approaches to study (91% cf. 9%; 88% cf. 12%, respectively). On the other hand, students with a more comprehensive understanding of what biochemistry is about approached their learning with more meaningful, deep learning practices (63% cf. 37% (pre); 66% cf. 34% (end), respectively). These latter data also indicate that among those who exhibited cohesive conceptions, twice as many still chose to use surface approaches to learning.

Most of the students who responded to the end-semester survey had also completed the pre-semester survey and thus represent a sub-group of the pre-semester responses. A small group (7% of group), were new respondees. Any possible biasing influence has been assessed by undertaking statistical analyses with and without this group. The significance of this relationship was unaffected.

No relationship was observed between either student conceptions or approaches and any of the demographic variables (age, sex, time since leaving school, level of prior study in chemistry or biology or parental tertiary study).

Discussion

The teaching and learning of compulsory basic science in professionally oriented undergraduate degree programmes present many challenges for both staff and students. These challenges include in particular the different levels of background knowledge in the topic and the students' lack of appreciation of its importance in the profession. In choosing how the content is presented, staff have to balance the risk of 'losing' the students with less topic background against 'boring' those with greater prior knowledge.

Earlier research in the study of basic sciences had reported a linkage between students' prior conceptions and how they approached their learning, e.g., physics (Prosser et al., 1996, Stewart et al., 2001), or mathematics (Crawford et al., 1998). However, in these cases the students were choosing to study these topics as part of their interest stream in a non-professional degree (e.g., science). Our research sought to examine student conceptions of, and approaches to learning, in a health sciences service subject (biochemistry), where the topic is both compulsory and studied early in the students' degree programme, before they have any experience of the dimensions of professional practice.

Before study of the topic, most students (83%) were found to have only a fragmented conception of the topic to be studied and its potential place in their overall professional studies. A similar percentage (87%) expressed an intention to use surface approaches to learning. However, it was surprising and alarming to find that of those with cohesive conceptions, where a deep approach to learning might have been predicted, roughly twice as many intended to use surface approaches as well (Minasian-Batmanian et al., 2005). This impelled us to re-examine their views at the end of the semester.

The comparison of their expressed views at the beginning and end of their studies reveals an increase in the percentage of students with a cohesive conception of the topic (17% to 29%), without any concomitant change in the reported use of deeper approaches to learning. Thus, despite a third of the students having achieved cohesive conceptions by the end of the semester, this did not translate into their deeper approaches to learning.

Hence, the ability of more students to view topics as being constituent parts of a greater whole (in this case the function of the body) did not result in their altering their approaches to learning from 'surface' approaches. The surface approaches adopted were characterised by answering objectives, reading the recommended textbook and re-reading lecture notes, with the apparent intention just to reproduce.

Even though a semester of study increased the proportion of students with cohesive conceptions, about 70% still had a fragmented view of the topic. There are many potential explanations for the low number of students exhibiting deep approaches to learning. Examples would be time constraints driven by overall workload (including employment), prior exam success using only surface strategies at school and difficulty in seeing where the basic knowledge fits or has relevance to their profession. Some students may have intended to achieve a deeper understanding but did not know how to go about it, i.e., they might have thought that 'going through objectives' was indeed a deep approach to learning. In relation to assessment, it is widely acknowledged that the nature of assessment drives the type of learning. It is not known how the students perceive the assessment in biochemistry, but it contained 20% of questions requiring a higher level of understanding. Obviously, there is a need to explore the students' perception of assessment; something that has recently been addressed.

Our findings broadly re-enforce the importance of the relationship between topic conceptions and approaches to learning (Prosser et al., 1996; Donald, 1997) and extend this link to a situation where learning occurs in both a foundation subject (i.e., non-major) and a subject which is part of a professional degree (e.g., physiotherapy) (Minasian-Batmanian et al., 2005 & 2006). However, the higher percentage of student learners with cohesive conceptions who indicated that they used surface approaches may prove to be a characteristic of foundation subjects in professional degrees. It is therefore necessary to better understand its basis, and find innovative solutions. Some insight into the students' thinking was obtained from the 'unclassified' responses mentioned earlier. An example of the potential effect of prior topic knowledge is the following student's response, 'I had studied chemistry and biology before, so I didn't spend much time on it at the end of the semester. I just did the sample questions before the actual exam'. This student was apparently making a strategic decision to apply time to other areas. This concept of strategic learning may reduce attempts to achieve deeper learning as a student concentrates more on another topic. Although cultural differences in learning approaches have been reported with Chinese students in Hong Kong having an approach that required a third categorisation more in line with 'strategic' learning (Marton, Watkins & Tang, 1997), this is unlikely to have had a big impact as most students in the present study were locally educated.

Curriculum review and experience over several years had led to certain changes that were already incorporated into the subject undertaken by the students surveyed for this research e.g. worksheets (with later release of detailed answers), review sessions, practice questions, online discussion forum etc. Clearly these aspects have assisted the students gaining a cohesive conception of the material, because the proportion had nearly doubled (from 17% to 29%). However, it is still only about one-third of students and new strategies must be investigated and implemented to increase this figure further.

Research findings implemented into teaching and learning

This biochemistry unit of study was designed to encourage deeper learning by incorporating at least 20% distinction level questions. In order to inform students of what it is they are expected to do to achieve deeper approaches, grade descriptors were recently developed and applied to practice questions. This has enabled students to gain experience in what constitutes higher level conceptions, including the ability to inter-relate information and apply it to a larger whole. Thus the students have seen examples of how and why they need to pursue deeper learning. Their views on the level of difficulty have been collected for comparison with those of staff and also with the students' marks. It is hoped that this strategy will better prepare students to learn and study more effectively. In fact, many of the students who participated in this exercise remarked that the process helped them understand what relating information is about. A further approach to encourage more students to embrace deeper learning was achieved by increasing the degree of student participation in class by asking them to role play situations, like protein synthesis, which has been introduced in lectures to emphasise the overall process. It would be an interesting future investigation to find out if this personal involvement with the material translates into better understanding and retention and therefore academic performance.

Academics teaching this subject have varied their teaching method to include only minimal necessary factual information so that the students are not overwhelmed by content which in turn would lead them to adopt a surface approach to learning. Examples of how material applies to professional scenarios are now regularly incorporated into the teaching, to highlight the overall implications of the conceptual and theoretical course material.

The problem of some students having no prior chemistry background has been addressed by introducing a quiz covering basic chemical concepts. If the students are able to successfully complete this formative assessment, they are not required to attend the initial segment of the subject. This initiative has been well received by the students and has resulted in a dual benefit. Firstly, the anxiety felt by the students with no background was lessened, as the threat of being left behind or embarrassed to participate was removed. Secondly, it prevented students with a better background losing interest in the subject.

Given the predominantly large group learning situation, students' individual needs were taken into account, by introducing review tutorials. These tutorials were set up to resolve any problems still persisting following the release of model answers to worksheets. In this way, individual barriers to deep learning could be removed. These tutorials were also useful in identifying specific skills (such as mathematical) that were lacking in students.

Further studies are intended to find out if student academic performance may be linked to a) their conceptions of and approaches to learning and b) improvements in teaching and learning. The present research suggests that many students may need to be taught exactly what constitutes deep learning and to value it not only for their immediate learning but as a lifelong learning tool. It may also be that there are students who do understand the nature of deep learning and do value it, but are still making strategic decisions about their learning approach for reasons that may be beyond our control. This could be especially important for students from different backgrounds undertaking studies in multidisciplinary classes in their initial year at university.

A crucial practical point to stress is the importance of having sufficient authority to ensure broad application of any change in order to ensure resultant modification of student behaviour.

Acknowledgements

This project was financially supported by the Faculty of Health Sciences Teaching Research Small Grant Scheme. We also acknowledge the invaluable input into our research study of Associate Professor Michael Prosser.